THE WEST BANK, PALESTINE
PALESTINIAN WATER AUTHORITY
JENIN MUNICIPALITY

PROJECT FOR STRENGTHENING THE CAPACITY OF WATER SERVICE MANAGEMENT IN JENIN MUNICIPALITY

PROJECT COMPLETION REPORT (ANNEX)

OCTOBER 2022

JAPAN INTERNATIONAL COOPERATION AGENCY

TEC INTERNATIONAL CO., LTD. (TECI)
PADECO CO., LTD. (PADECO)

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ANNEX 1

MANUALS, GUIDELINES AND PLANS - NRW

Annex 1.1

NRW Management Manual (Comprehensive Version) – English Version

PALESTINIAN WATER AUTHORITY

THE PROJECT FOR STRENGTHENING THE CAPACITY OF WATER SERVICE MANAGEMENT IN JENIN MUNICIPALITY

NON-REVENUE WATER MANAGEMENT MANUAL

Oct 2021

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

TEC INTERNATIONAL CO., LTD.

PADECO CO., LTD.

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List of Abbreviation / Acronym

AL:	Apparent Losses
ALC:	Active Leakage Control
AZP:	Average Zonal Point
CDS:	Customer Database Survey
DBD:	Demand Based Discharge
DN:	Nominal Diameter
DMA:	District Metered Area
GIS:	Geographic Information System
GPS:	Global Positioning System
IWA:	International Water Association
JET:	JICA Expert Team
JICA:	Japan International Cooperation Agency
JM:	Jenin Municipality
KPI:	Key Performance Indicator
LPCD:	Liter Per Capita Per Day
MCM:	Million Cubic Meter
NRW:	Non-Revenue Water
PA:	Pilot Area
PDD:	Pressure Dependent Discharge
PPWM:	Pre-Paid Water Meter
RL:	Real Losses
SDG:	Sustainable Development Goal
SIV:	System Input Volume
UFM:	Ultrasonic Flowmeter
WBWD:	West Bank Water Department

1 PREFACE

Providing safe and reliable drinking water to all by 2030 is SDG No. 6 set by UN. While the water resources are limited, the water demand is increasing due to various factors including population growth and increased life standards of people. On the other hand, huge quantity of treated water is being lost in transmission and distribution system due to leakage and other reasons. The difference between supplied water volume and billed volume is known as non-revenue water (NRW). The problem of high NRW is especially severe in low and middle-income countries.

Jenin municipality (JM), as most other parts of the State of Palestine, depends on precious groundwater as its water source. JM produces about one-third of its current daily supply volume by the wells owned by it and purchases the rest from bulk water providers from within and outside the municipality by paying a premium price. Every drop of this water is precious, costing money to JM. Despite such a situation, more than half of the supplied water in Jenin is lost somewhere in the distribution system and does not generate any revenue. As per project records, Jenin lost 1.879 MCM in 2018, and 2.037 MCM in 2019 as NRW, resulting in NRW ratio of 59.6% and 60.1% respectively, in those years. The 2.037 MCM lost in 2019 could have supplied water to 42,940 people throughout the year at 130 LPCD.

The reasons for such a high NRW in Jenin are many, but the most important are: lack of technical and managerial capacity to deal with NRW, lack of awareness about the seriousness and consequences of high NRW, and weak financial position of JM.

In the above context, through this technical cooperation project, JICA provided support to JM to strengthen its capacity of water service management. The most important objectives of this project are to improve technical and managerial capacity of JM to manage NRW and increase revenue collection.

This manual is prepared with the aim to help JM and other Palestinian water utilities in planning and implementing NRW management activities. It follows the principles of international best practices on NRW management, but it has been prepared mainly based on the lessons learned from the field works conducted in Jenin. This manual is intended for senior level staff such as water engineers and managers. A simplified version of the manual has also been prepared for the use of general technical staff involved in NRW management.

2 INTRODUCTION TO WATER BALANCE AND NRW

Understanding water balance is the first crucial step in NRW Management. In simple terms, water balance shows how much water was produced, how much was supplied, how much reached the customers, and where the rest went. This also indicates where the major problems lie.

2.1 IWA Standard Water Balance and its Components

The IWA Standard Water Balance (Table 2-1) shows the international best practice of water balance. It lists and defines various components of water balance including non-revenue water (NRW).

Table 2-1: IWA Standard Water Balance

<table>
<tr><td rowspan="9">(1)
System Input Volume (SIV)
حجم المياه الداخله للشبكة</td><td rowspan="4">(2)
Authorized Consumption
الاستهلاك القانوني</td><td rowspan="2">(2-1)
Billed Authorized Consumption
الاستهلاك القانوني المُفوتر</td><td>(2-1-1) Billed Metered Consumption
الاستهلاك المفوتر المُقاس</td><td rowspan="2">Revenue Water
ايراد المياه</td></tr>
<tr><td>(2-1-2) Billed Unmetered Consumption
الاستهلاك المُفوتر غير المُقاس</td></tr>
<tr><td rowspan="2">(2-2)
Unbilled Authorized Consumption
الاستهلاك القانوني و غير المَفوتر</td><td>(2-2-1) Unbilled Metered Consumption
الاستهلاك غير المفوتر المُقاس</td><td rowspan="7">Non-Revenue Water (NRW)
الفاقد من المياه</td></tr>
<tr><td>(2-2-2) Unbilled Unmetered Consumption
الاستهلاك غيرالمُفوتر و غير المُقاس</td></tr>
<tr><td rowspan="5">(3)
Water Losses
فاقد المياه</td><td rowspan="2">(3-1)
Apparent (Commercial) Losses
الفواقد التجاريه</td><td>(3-1-1) Unauthorized Consumption
الاستهلاك غير القانوني</td></tr>
<tr><td>(3-1-2) Customer Metering Inaccuracies
عدم دقة عداد المشترك</td></tr>
<tr><td rowspan="3">(3-2)
Real (Physical) Losses
الفاقد الحقيقي</td><td>(3-2-1) Leakage on Transmission and/or Distribution Mains
التسرب في خطوط النقل والتوزيع الرئيسية</td></tr>
<tr><td>(3-2-2) Leakage and Overflows at Utility's Storage Tanks
تسرب وفيضان خزانات مرافق المياه</td></tr>
<tr><td>(3-2-3) Leakage on Service Connections up to point of Customer Metering
التسرب في الوصلات المنزلية الممتدة الى عداد المشترك</td></tr>
</table>

2.2 Definition of NRW

NRW is defined as the difference between system input volume and billed authorized consumption. In other words, NRW is the difference between volume of water supplied and volume of water billed.

NON-REVENUE WATER (NRW)	=	*WATER SUPPLIED (System input Volume)*	-	*REVENUE WATER (Billed Consumed Water)*

NRW includes any water which is authorized to use (such as firefighting) but not billed. This component is known as ‘Unbilled Authorized Consumption’ in Standard IWA Water Balance.

2.3 Examples of IWA Standard Water Balance components from Jenin

The following is an example of water balance (for Pilot Area 1, Nov 2018) components in IWA water balance format. In this table all components of water balance have been identified individually except the leakage on mains and service connections (components 3-2-1 and 3-2-3 respectively) which are grouped together.

Table 2-2: Pilot Area 1 Water Balance for Dec. 2018 as an example

<table>
<tr><td rowspan="5">(1) System Input Volume (SIV)
كمية المياه المدخلة في النظام المائي</td><td rowspan="4">(2) Authorized Consumption (AC)
الاستهلاك المصرح به
=
11,193 m³
39.7%</td><td rowspan="2">(2-1) Billed Author.Cons. (BAC)
الاستهلاك المصرح به المفوتر
11,193 m³
39.74%</td><td>(2-1-1) Billed Metered (BMC)
11,193 m³ 39.7%</td><td rowspan="2">Revenue Water (RW)
المياه المحاسب عليها
11,193 m³
39.7%</td></tr>
<tr><td>(2-1-2) Billed Unmetered (BUC)
0 m³ 0.00%</td></tr>
<tr><td rowspan="2">(2-2) Unbilled Author.Cons. (UAC)
الاستهلاك المصرح به غير المفوتر
0 m³
0.00%</td><td>(2-2-1) Unbilled Metered (UMC)
0 m³ 0.00%</td><td rowspan="3">Non-Revenue Water (NRW)
المياه غير المحاسب عليها</td></tr>
<tr><td>(2-2-2) Unbilled Unmetered (UUC)
0 m³ 0.00%</td></tr>
<tr><td></td><td>(3-1) Apparent Losses (AL)
Or Commercial Losses</td><td>(3-1-1) Unauthorized Consumption (UC)
6,469 m³ 22.97%</td></tr>
</table>

= 28,165 m³	**(3) Water Losses (WL)** الفاقد الكلي	الفاقد التجاري (الظاهري) 7,488 m³ 26.59%	**(3-1-2) Metering Inaccuracies (MI)** 1,019 m³ 3.62%	= 16,972 m³
	= 16,972 m³ **60.3%**	**(3-2) Real Losses (RL) Or Physical Losses** الفاقد الحقيقي (تسرب) 9,484 m³ 33.67%	**(3-2-1) Leakage on Transmission and/or Distribution Mains** 9,470 m³ 33.62%	**60.3%**
			(3-2-2) Leakage and Overflows at Utility's Storage Tanks 14 m³ 0.05%	
			(3-2-3) Leakage on Service Connections up to Point of Customer Metering (Combined with 3-2-1 above)	

Identifying all components of water balance accurately is very important but it needs considerable efforts. The methods of their calculation have been explained in detail in the coming sections.

2.4 Definition of Terms Related to Standard IWA Water Balance

System Input Volume

The system input volume is the total volume of treated water, from all sources of water including municipality's own wells, private wells contracted by the municipality, and imported from outside the municipality.

Authorised Consumption

The volume of metered and/or unmetered water taken by registered customers or organizations authorized to use water. Authorised consumption may include items such as water taken for firefighting, fire training exercises, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, amongst others. These may be billed or unbilled, metered or unmetered.

Water Losses

The difference between system input volume and authorised consumption.

Billed Metered Consumption

All metered consumption which is also billed.

Billed Unmetered Consumption

All billed consumption which is calculated based on estimates or norms but is not metered.

Revenue Water
The volume of water for which income is obtained. This is the sum of billed metered and billed unmetered consumption.

Unbilled Authorised Consumption
Unbilled authorised consumption are those components of authorised consumption which comprise legitimate usage, but which are not billed and therefore do not produce revenue.

Unbilled Metered Consumption
Unbilled metered consumption is metered consumption which is, for any reason, unbilled. This may, for example, include metered consumption by the utility itself or water provided to institutions free of charge.

Unbilled Unmetered Consumption
Unbilled unmetered consumption is any kind of authorised consumption which is neither billed nor metered. This component typically includes items such as firefighting, flushing of mains and sewers, street cleaning, amongst others.

Non-Revenue Water (NRW)
Non-revenue water are those components of system input volume which are not billed and do not produce revenue, i.e. not revenue water. It is equal to unbilled authorised consumption plus Real Losses and Apparent Losses.

Apparent Losses (AL)
Apparent Losses include all types of inaccuracies associated with customer metering as well as data handling errors, such as meter reading and billing, plus unauthorised consumption from theft or illegal use.

Unauthorised Consumption
Unauthorised consumption is any unauthorised use of water. This may include water illegally withdrawn from hydrants, for example, for unauthorised construction purposes, illegal connections, bypasses to consumption meters or meter tampering.

Illegal Connection
A connection which has been installed onto a main or another service pipe without the permission or authority of the municipality.

Data Handling and Billing Errors

The volume of true consumption which is not recorded on the billing system due to billing or data handling errors. These could include transcription errors, consumption on premises that have not been registered on the billing system due to internal procedural errors, premises incorrectly flagged on the billing system (e.g. flagged as demolished but still live), etc.

Customer Metering Inaccuracies
The volume by which meters under-record the true volume consumed by customers.

Real Losses (RL)
Real Losses are water volumes lost through all types of leaks, bursts and overflows.

Leakage and Overflows from Utility Storage Tanks
Water lost from leaking storage tank structures (service reservoirs) or overflows from such tanks caused by operational or technical problems, for example, a failed level control mechanism or leaking tank joints.

Leakage on Service Connections up to the Point of Customer Metering
Water lost from leaks and breaks of service pipes from and including the tapping point up to the customer meter.

Leakage on Transmission and/or Distribution Mains
Water lost from leaks and breaks on transmission and distribution pipelines and appurtenances.

3 STANDARD NRW COUNTERMEASURES

Managing NRW involves addressing underlying causes. Preparing an accurate water balance is the starting point. It shows where the major problem is. Then suitable strategy should be applied to address the cause of the problem.

As NRW consists of Real and Apparent Losses, management of NRW includes managing these components. Reducing Apparent Losses is nearly always cost-effective and offers fast payback. The activities are technically easy to carry out, but politically difficult, because it often requires taking a strong stance against fraudulent practices of utility staff and the (small) portion of the population benefiting from the status quo.

On the other side, reduction of Real Losses through leakage control can be expensive, requires significant technical know-how, and must be carried out extensively to bring results. Economic balance between the costs of leakage control and the benefits that leakage control generates should always be considered.

3.1 Real Loss Reduction

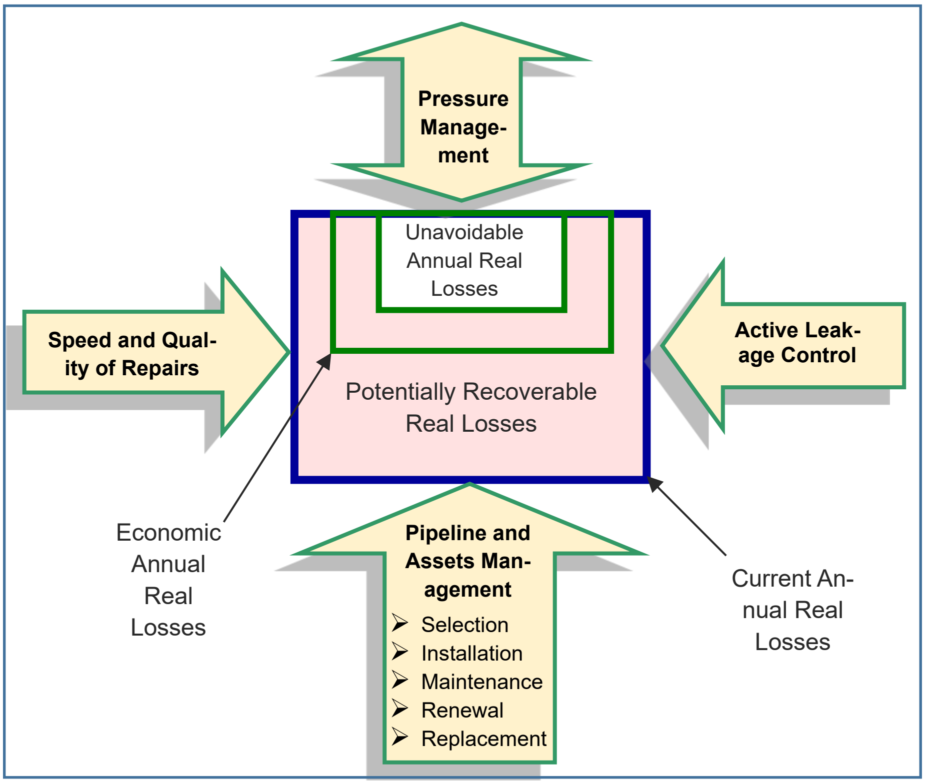


Figure 3-1: The four basic methods of managing Real Losses (IWA)

As shown in Figure 3-1 the methods of managing Real Losses can be lumped into 4 groups; (i) speed and quality of repairs, (ii) pipe line and asset management, (iii) active leakage control, and (iv) pressure management. They are briefly outlined hereafter.

Speed and quality of repairs. Repairing leaks in a timely and efficient manner following a set work standard and using quality materials is essential in order to reduce NRW. A bad quality repair invites more leaks either from the same place or in its vicinity because of the disturbance to the surrounding ground and bedding caused by both the initial failure and its subsequent repair.

Pipeline and assets management. Proper selection, installation, maintenance, renewal, and replacement of pipe and other assets come under this component. The main goal of this component is to manage network rehabilitation in an economical manner to reduce the need for corrective maintenance.

Active leakage control. The frequency at which new bursts and leaks occur depends upon the overall condition of the infrastructure and how well the pressure is managed. Dependent upon the specific ground type, there will always be some proportion of leaks and bursts that do not appear on the surface, i.e. non-visible leaks, and these need to be detected. Active Leakage Control (ALC) is a proactive strategy to reduce water loss by the detection of non-visible leaks using trained engineers and technicians using specialized equipment followed by the prompt repair of leaks. Alternatively, we can say that active leakage control is practiced when competent persons (company staff or hired) are deployed to find leaks, which have not been reported, by customers or other means. The main methods of ALC are regular survey and leakage monitoring.

Regular survey – This is a method of starting at one of the distribution systems and proceeding to the other using one of the following techniques:

- ✧ Listening for leaks on pipe work and fittings
- ✧ Reading metered flows into temporarily-zoned areas to identify high-volume night flows
- ✧ Using clusters of noise loggers (leak localizing)

Leakage monitoring – This is flow monitoring into zones or districts metered areas (DMAs) to measure leakage and to prioritize leak detection activities.

Pressure management. Pressure management for leakage control is the practice of managing system pressures to the optimum levels of service ensuring sufficient and efficient supply to legitimate uses and customers, while reducing unnecessary or excess pressures and eliminating transients, which cause the distribution system leak unnecessarily. Pressure management reduces the frequency of new breaks as well as the flow rates from all breaks and background losses.

3.2 Apparent Loss Reduction

Figure 3-2 shows four components of an active apparent loss management program.

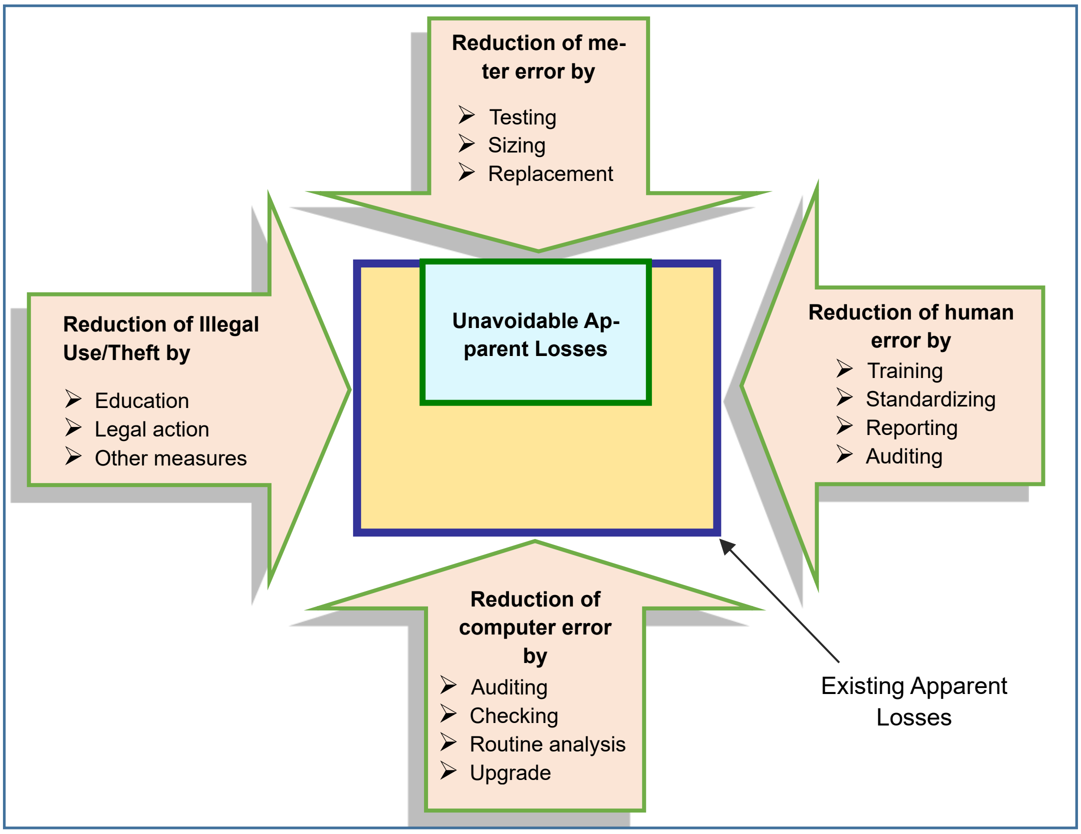


Figure 3-2: The four components of an active Apparent Loss management program (IWA)

Reduction of meter error. Both production and customer meters should be in proper working condition with their errors within defined tolerance margin. For this, the meters should be of good quality, and be installed and maintained properly. The meter accuracy should be checked from time to time and calibrated when necessary. The meters should be replaced after a certain age or throughput.

Improving meter reading and billing. A significant portion of Apparent losses comes from mistakes in the meter reading and billing chains, not only because of poor technology, outdated customer database, and data-handling errors in the office but also because of fraudulent practices on the part of water utility staff.

Illegal and unknown connections. Illegal connections/unregistered connections pose the biggest problem to water utilities in the developing world and perhaps contribute to the biggest loss of revenue (consumption not paid) and production cost (due to wastage) incurred by the utility. Contrary to common belief, a large portion of water stolen from public utilities does not come from poor, marginal urban areas, but rather from large industrial customers and those with political clout and enough resources to bribe utility staff and management. Allowing illegal connections and such fraudulent behaviour is unfair for those in the population who do pay their bills, especially the poor, and works against promoting a culture of good governance.

Illegal and unknown connection issues need focused efforts. The main ingredients required for addressing and controlling this problem, are the following:

- An independent property database with a link between the connections database and the property database,
- An effective debt management policy especially in terms of disconnections, making illegal connections difficult,
- Appropriate systems and procedures in the organisation to handle illegal connections once they are found,
- Monitor disconnected lines, and
- Monitor inactive connections, connections with zero consumption.

Wrong billing due to inadequate billing procedures. Wrong billing has a direct effect on revenue. Customers often refuse to pay any amount if they receive wrong bills and eventually faith in the system is lost cultivating a non-payment culture by the customers. Furthermore, many customers remain happily unbilled. Wrong billing is a result of wrong data and poor billing procedures.

Meter Reading Problems. Meter reading problems contribute to wrong bills and often lost revenues.

Fraudulent practices. There are three major sources of fraudulent practices in Commercial Operations, usually carried out through cashiers, financial officers authorised to give credits and meter readers - all resulting in lost revenues. A good billing system with appropriate procedures could stop such practices. Receipting sessions could be crash-proof; automatically suspending a session on interference, whilst strict access and audit control could monitor financial transactions.

4 PRACTICAL APPROACH OF NRW MANAGEMENT

The practical approach of NRW reduction by District Metered Area (DMA) involves the following major steps:

(1) Design of DMAs and updating of customer and pipe network information,
(2) Construction of DMA, on-site measurement of pressure and flow,
(3) Calculation of NRW,
(4) On-site survey for surface leakage, illegal connections, mete accuracy test,
(5) Underground leak detection survey, step-test, stop-cock test,
(6) Repairing of leaks, replacement of customer meter, rectification of illegal connections,
(7) Checking effectiveness, re-calculating NRW,
(8) If the NRW comes down to acceptable level, moving to another DMA or another group of DMAs, if the NRW is still above acceptable level, repeating the tasks from step (4) onward.

This is graphically illustrated in Figure 4-1.

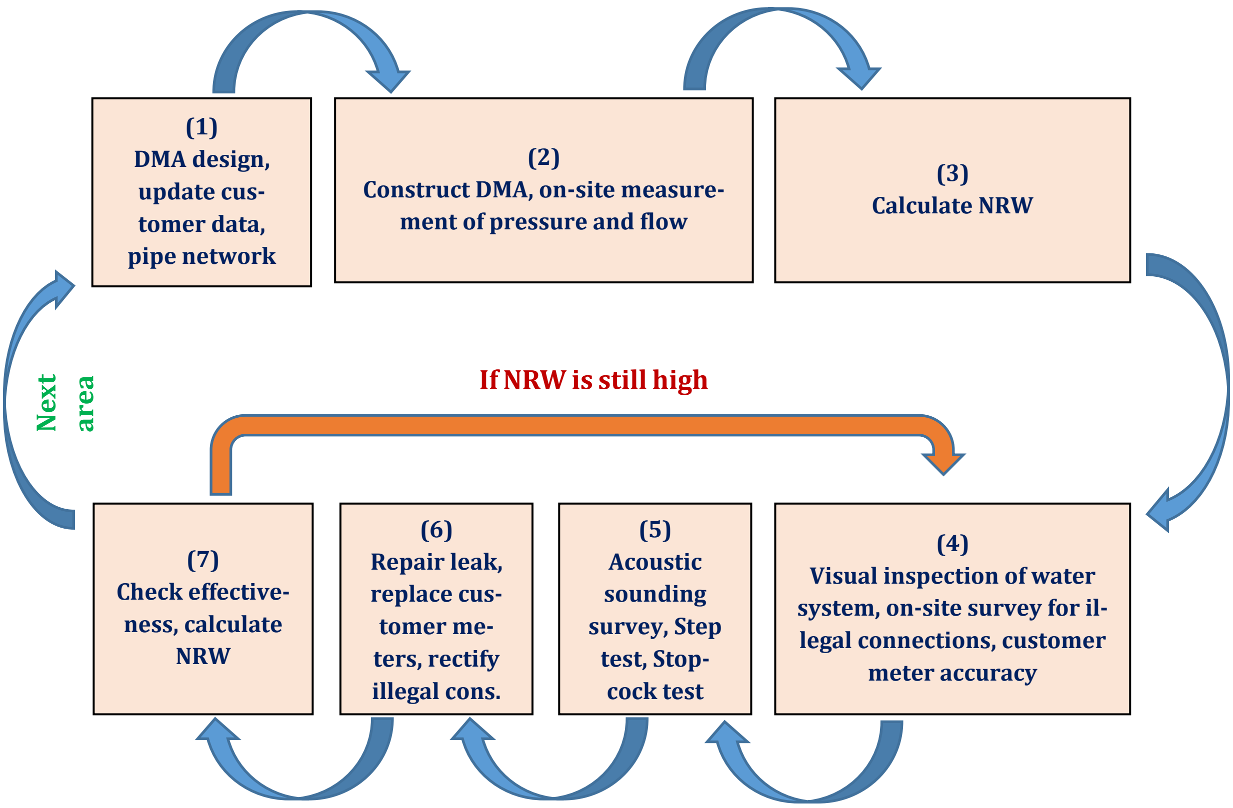


Figure 4-1: Practical approach of NRW management by DMA approach

The succeeding part of this manual deals with the above steps.

5 SELECTION OF DISTRICT METERED AREAS

A District Metered Area is a section of the distribution network which is hydraulically isolated by closed sluice valves except the points of entry and exit where the flows are measured by permanently installed flowmeters. Some DMAs may have multiple points of entry and exits or may not have any point of exit.

By establishing District Metered Area the following benefits will be obtained:

- Larger area is divided into smaller areas which makes leakage management easier,
- Calculation of NRW becomes easier, more accurate,
- NRW reduction works can be prioritized, DMAs having higher NRW could be given higher priority,
- MNF can be monitored continuously, and any pipe burst, or unusual consumption can be quickly noticed. This is not applicable in case of intermittent system such as that of Jenin.

But establishing and maintaining DMAs cost money.

Key features of DMA design and operation with special attention to suit the condition of Jenin are given in the following section.

5.1 DMA Selection Criteria

The followings should be considered:

- Size (geographical area and number of customer connections)
- Variation in ground level
- Pressure requirements
- Number of valves to be closed
- Suitability of place to install district meter(s)
- Use of existing flow meters or valves if there are any
- Consideration to present supply zones

The keys to good DMA design are:

- Minimum variation in ground level across the DMA
- Easily identified boundaries that are robust
- Limit the number of closed boundary valves
- Limit the number of flow meters
- Optimize pressure to maintain customer standards of service and to reduce leakage

Size of DMAs:

IWA recommended DMA size is from 500 to 2500 properties and 6-10 km pipe network length. The number of properties will be on higher side in densely populated areas and on lower side in sparsely populated areas. Smaller DMAs have several advantages over bigger ones, but they cost more to setup and maintain. Size of DMAs (pilot areas) in Jenin during this project varied from about 400 to 900 properties.

Consideration to present supply zones:

If there are already established supply zones they can be taken as starting points for creation of new DMAs. Depending upon the local situation and sizes of such zones DMAs can be designed by including one or more zones. In such instances the size of the DMA depends upon the size of the existing zones and the number of zones included into one DMA.

The above-mentioned criteria are applicable in general when the whole supply system is divided into DMAs. When a few DMAs have to be selected and established as pilot areas then the following additional criteria should also be considered:

- Pipe network is easy to separate,
- The amount of water used at night is small,
- Water supply method inside the PA can be changed without causing much inconvenience to the customers (For example, change supply schedule or supply duration in order to measure MNF),
- Water supply change in the PA does not affect other areas,
- The pipe network drawing is well maintained,
- Possible to do nighttime work on leakage survey (security concern),
- Training for reduction measures can be done. The effect of reducing non-revenue water is expected to be high.

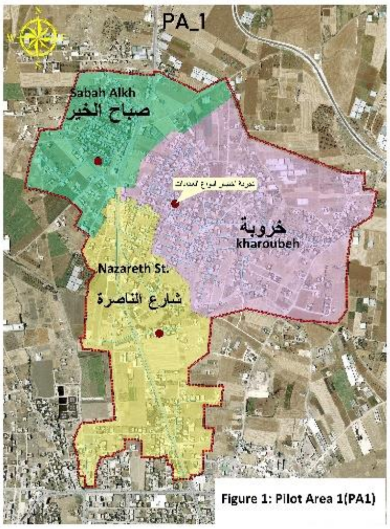


Figure 1: Pilot Area 1(PA1)

5.2 Preliminary Survey to Identify Areas

a. Collect available drawings and information of pipeline and other items from related department (water department in case of Jenin). The items should include:
   - pipe network,
   - valves,
   - pumping stations,
   - wells,
   - existing supply blocks,

- administrative boundary,
- customer points, etc

b. Tentatively mark potential areas on the drawings considering the criteria listed above.

c. Conduct site survey moving around the proposed boundary and judge if that area is suitable or not. Some modification to the boundary may be required sometimes.

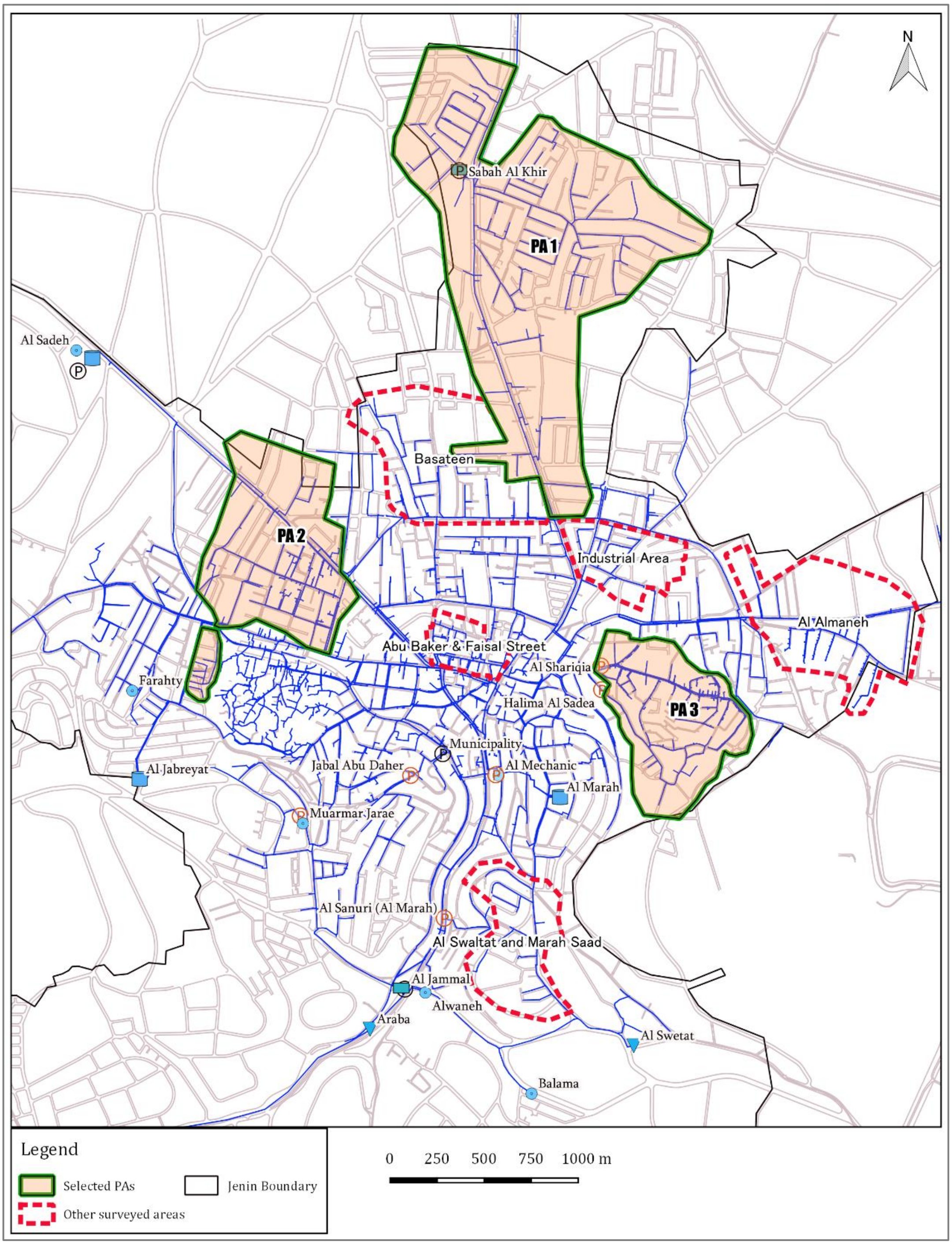


Figure 5-1: Surveyed and selected Pilot Areas

For example, Figure 5-1 shows the potential areas proposed for PAs from which three were finally selected.

The following pictures show some instances of preliminary survey work at site.




d. Prepare a summary table of features including approximate area, number of customer connections, length of pipe network, supply timings, water source etc., then estimate number and size of valves, bulk meters, customer numbers etc. A sample is shown below.

Table 5-1: Summary table for initial screening for DMA

DMA No.	Name of Area	Area (m^2)	Customer (Nos.)	Lengh of Pipe Network (m)	Water Source
1	DMA 1_1 (Sabah Al Khir)	367,907	168	3,880	Mekorot water via Al Jalameh Connection and Sabah Al Khir PS
	DMA 1_2 (Kharoubeh)	696,814	238	6,637	
	DMA 1_3 (Al Nasreh St.)	752,032	183	5,347	
	Sub-total	***1,816,753***	***589***	***15,864***	
2	DMA 2_1 (New Camp)	47,053	99	875	Al Saadeh Well via Al Jabreyat Reservoir
	DMA 2_2 (Al Zahraa)	651,566	367	10,174	
	Sub-total	***698,619***	***466***	***11,049***	
3	DMA 3_1 (Sharqiya 1)	302,021	268	6,730	Al Saadeh Well + Al Mechanic Well via Al Marah Reservoir
	DMA 3_2 (Sharqiya 2)	199,866	93	2,181	
	Sub-total	***501,887***	***361***	***8,911***	
4	Abu Baker & Faisal Street	99,413	300	2,781	?

DMA No.	Name of Area	Area (m^2)	Cus-tomer (Nos.)	Lengh of Pipe Network (m)	Water Source
5	Al Alwaneh	500,214	102	5,380	?
6	Industrial Area	197,731	134	2,110	Al Marah reservoir
7	Al Swetat and Marah Saad	305,585	111	2,591	Al Swetat connection (Mekorot water)
8	Basateen	502,452	172	5,011	Same as PA1

5.3 Finalization of DMA Selection

Table 5-2: Summary table for selection of DMAs

DMA	Crossing pipe size (Inch)	Bulk Meter size (Inch)	Valve size (Inch)	Chamber	Remarks
DMA-1 Sabah Al Kheir, Kharoube, and Al Nazareth Street					
Source (Inlet to tanks)	8	8	8	Not required	Existing meter not working, to be replaced
Inlet to PA (Outlet of PS)	6	6	6	Required	Outlet of BPS, near BPS
Outlet of PA (Diamond circle)	6	6	6	Required	Outlet goes to Al Basateen
Small branch to Sabah Al Kheir area	2	2	2	Required	24-hrs supply
Sub-area 1 (Sabah Al Kheir)	6	6	6	Existing	Existing meter not working, to be replaced
Sub-area 2 (Kharoubeh)	4	4	6	Existing	
Sub-total		***6***	***6***	***3***	
DMA-2 New Camp and Al Zahraa					
Sub-area 1 (New Camp)	6	6	6	Required	
Sub-area 2					
Separate line to Al Zahraa	2	2	2	Required	
Main inlet near New Camp	6	6	6	Required	
Inlet (1) near Camp gate	4	4	4	Required	To branch road to Az Zahara
Inlet (2) near Camp gate	6	6	6	Existing may be used	On main road
Sub-total		***5***	***5***	***4***	
DMA-3 Al Sharqeah and Haleemah Al Sa'dia					
Inlet	6	6	6	1	Near AlaSadi well on the road
Near junction of Al Sharqeah and Haleemah Al Sa'diah			2		For modification of connection
For measurement of production from Al Sadi well		3	3	Not required	
Sub-total		***2***	***3***	***1***	
Total		**13**	**14**	**8**	

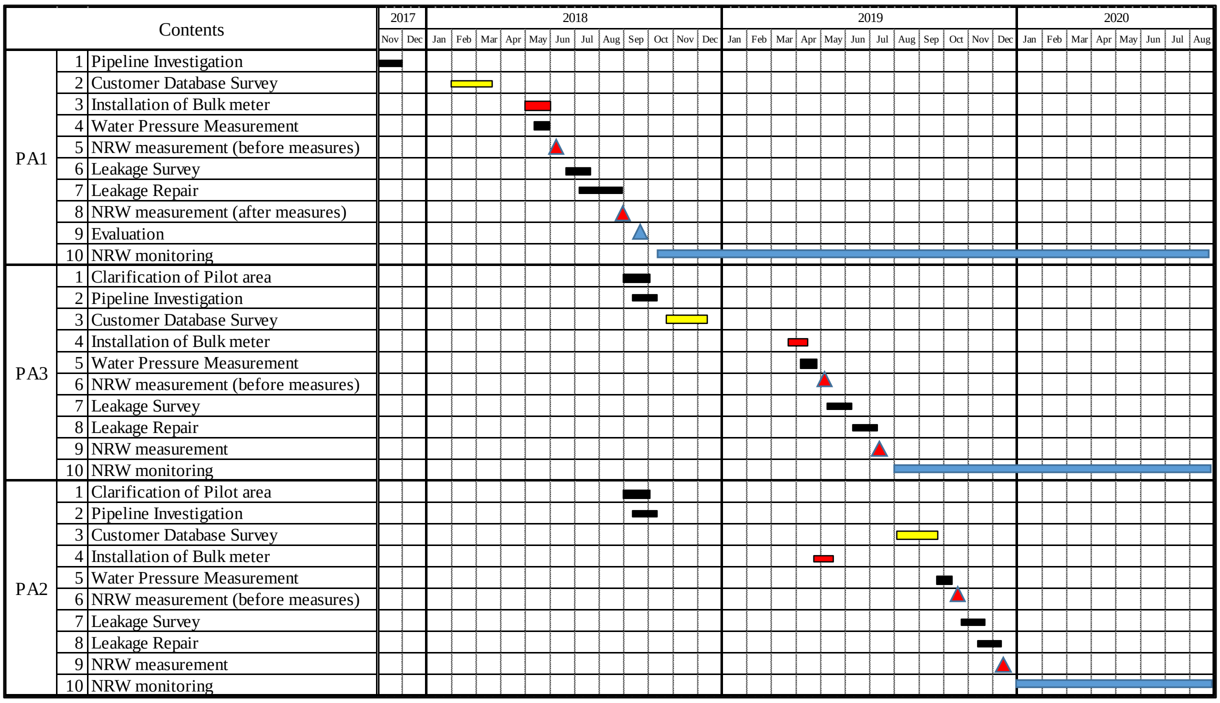
From among those proposed, select the required number of area considering all the relevant features such as size, customer numbers, supply source, pipe network length etc. If necessary, repeat the site survey. In the present project the following three areas were selected.

- ✧ PA1(DMA1): Sabah Alkheir + Kharoubeh + Nazaereth Street
- ✧ PA2 (DMA2): Alzahra + New camp
- ✧ PA3 (DMA3): Alsarkia + Haleema Alsa'dia

5.4 Scheduling & Planning

In this stage the schedule and plan for the NRW activities should be established.

Following is an example of schedule established for NRW activities in three pilot areas of the project (top figure) and additional DMAs prepared by JM (bottom figure):



Contents			2020												2021											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Al-Jenan	1	Customer Database Survey & Door to Door									■															
	2	Clarification of Pilot area									■	■														
	3	Procurement of flow meters, etc.												■	■											
	3	Consutruction of chamber and installation of Bulk meter														■										
	4	Water Pressure Measurement										■														
	5	Start of NRW measurement (before measures)																■								
	6	Leakage Survey (Underground)														■										
	7	Leakage repair (Underground)																	■	■						
	8	Leakage repair (Surface patrolling)																	■	■						
	9	NRW monitoring and evaluation																				▪	▪	▪	▪	▪
	10	Installation of PPWM																■								
Al-Basateen North	1	Customer Database Survey & Door to Door																■								
	2	Clarification of Pilot area																■								
	3	Procurement of flow meters, etc.												■	■											
	4	Consutruction of chamber and installation of Bulk meter														■	■									
	5	Water Pressure Measurement									■															
	6	Start of NRW measurement (before measures)																	■							
	7	Leakage survey (Underground)																			■					
	8	Leakage repair (Underground)																			■	■				
	9	Leakage repair (Surface patrolling)																				■	■			
	10	NRW monitoring and evaluation																							▪	▪
	11	Installtion of PPWM																	■							
Al-Basateen South	1	Customer Database Survey & Door to Door																	■							
	2	Clarification of Pilot area																	■							
	3	Procurement of flow meters, etc.												■	■											
	4	Consutruction of chamber and installation of Bulk meter															■									
	5	Water Pressure Measurement											■													
	6	Start of NRW measurement (before measures)																		■						
	7	Leakage Survey (Underground)																			■					
	8	Leakage repair (Underground)																				■				
	9	Leakage repair (Surface patrolling)																				■	■			
	10	NRW monitoring and evaluation																							▪	▪
	11	Installation of PPWM																		■						

The plan should also include the resources required to carry out the activities.

6 UPDATING CUSTOMER DATABASE AND PIPE NETWORK

NRW countermeasures require detailed network and customer information. If those data are not already available, it is necessary to prepare them. For Jenin pipe network maps down to 50 mm pipe size and customer meter points were prepared during an earlier study (Diagnostic Study) completed in 2016. It is necessary to update these maps/data by field survey as these are very important for NRW management.

6.1 Customer Database Survey (CDS)

6.1.1 Preparation works

In addition to the importance of the CDS to the NRW calculation it is also necessary for the customer management and the O&M for water department.

The preparation works for the CDS activities includes:

- ✧ Confirmation of the DMA boundary by understanding the water pipeline network,
- ✧ Obtaining high resolution basemap of the area (through line ministry or other route)

Figure 6-1: Preparing polygons of each building

- ✧ Creating the building polygons by digitizing them by GIS software (or they may be requested from the engineering department if available). See next example of the prepared part of PA1 polygons in Jenin Municipality.
- ✧ Geocoding (giving address) for the digitized buildings in the target area. It will be very useful if the municipality has an official geocoding for the buildings that may be used in the CDS work. For the households which are already connected to the municipality water network their house connection ID (HC_ID) can be used to recognize the building but the polygon coding will be more general and useful to recognize both subscribers and nonsubscribers.

Next map is an example of the used coding in the pilot project in Jenin:

The basemap may be not up-to-date and some new buildings may be missing on it. In such a case, indicate such new constructed building by adding its polygon on the GIS map. See below.

6.1.2 Office & site work

a) Preparing the GIS maps

- ✧ Print the DMA area map which includes the digitized polygons at a scale sufficiently clear to mark the meter point and house connection route,
- ✧ The map should be good enough to be understood by the CDS team leader on site.

See the next map as an example of prepared map for Sabah Al Khir area.

b) Preparing the required format for data collection at site

The CDS format shall contain all required technical and social data from site. The following data are usually important and need to be collected.

Table 6-1: Recommended Data Items to be Collected During CDS

S.N.	Data Items	S.N.	Data Items
1	House number, address	9	Roof tanks
2	Owner's name		- Number
3	If the house has municipal water connection or not		- Total capacity
4	Customer's name (if different from owner)	10	Ground tanks
5	Customer number (house connection ID)		- Number
6	No. of persons in the family		- Total capacity
7	Water use category (domestic, commercial, institution etc)	11	Any other sources of water
8	Meter Iiformation	12	Any sign of unauthorized water use
	- S. No.		
	- Type		
	- Diameter		
	- Visible problem in water meter; position, unreadable, not firmly fixed etc		
	- Connector size		

The form used in Jenin pilot areas is shown below.

Customer Database Survey— Surveyor N(اسم الباحث):___________

التاريخDate : ___________

Pilot Area 2:	Locality Nameاسم الحي				
.House NOرقم البيت/المحل		Owner's Nameاسم المالك			
House Statusحالة المنزل/المحل	1. Registeredمشترك		2. Not Registered غيرمشترك		
Family sizeعدد الافراد		Storage tank number & total capacityعدد الخزانات :		m3السعة	
If the house owner answer "YES or Registered", please fill up below. في حال انه مشترك اكمل:					
HC_ID_ No.رقم المشترك		رقم العداد Water Meter NO.			
Reg. Categoryالتصنيف	1. منزليDomestic 2. تجاريCommercial 3. مؤسسةInstitution 4. زراعيAgriculture				

Registered(customer) مشترك	Illegal connection وصلة غير قانونية		
	Visible problem in water meter مشكلة ظاهرة في العداد	Not horizontal غير افقي	
		Unreadable قراءة العداد صعبة	
		Not accessible يصعب/او لايمكن الوصول لمكان للعداد	
		Not firmly fixedغير مثبت جيدا	
Not_Registered(Not_customer) غير مشترك	Illegal connection وصلة غير قانونية		
	Gets water from مصدر الماء	NM من عداد الجار	
	Gets water from مصدر الماء من	Private well(PW) من بئر جوفي خاص	
	Own private reservoir لديه بئر/خزان خاص (PR)		
	Buys from vender (PT)يشتري تنكات		
ملاحظات Comments: If you discover something, please write down below.			

Figure 6-2: Customer database survey form

c) Preparing the CDS teams

- ✧ The CDS team shall be not less than 3 persons; one for filling the CDS repot, the second one is to direct the team with the map drawing and the third one will assist to record the technical data about the domestic meter and the house connection.
- ✧ The office data entry and analysis team: this team will collect the site reports day by day and the collected data should be computerized and archived.

d) Data analysis:

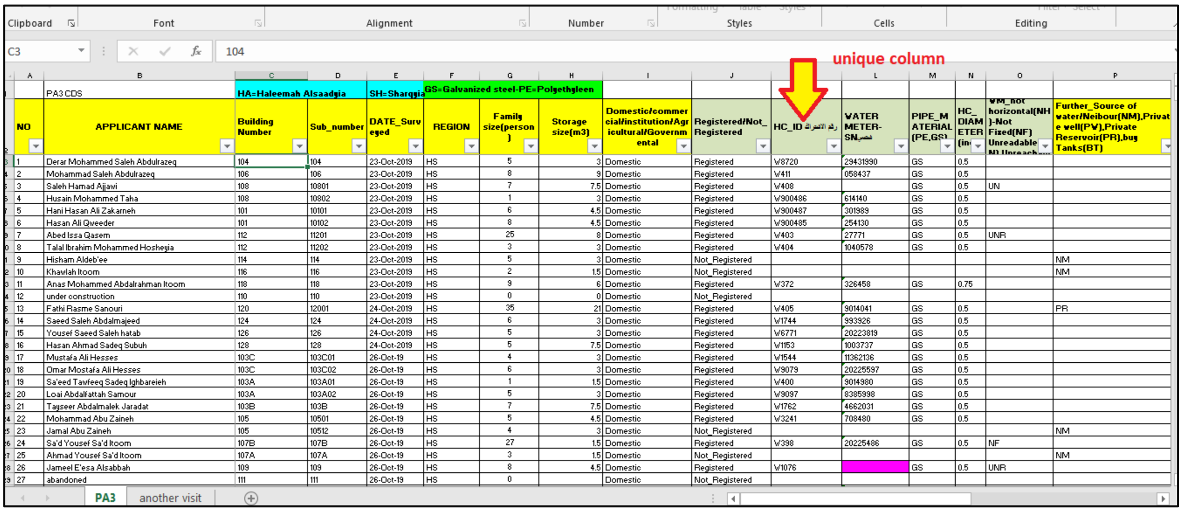
- ✧ At this stage of work the captioned CDS data is ready to be analyzed and the technical data related to the house connection can be transferred to the domestic meter shapefile, and the other social data can be stored in the polygon shapefile then to be categorized upon requirement.

Following is an example of categorizing the building polygons according to the subscription status; whether they are subscribers (connected with municipal water network) or nonsubscribers (not connected with municipal water network).

6.1.3 Compiling and summarizing the survey data

Compile the collected data in spreadsheet program (such as MS Excel). Sample of compiled data is shown below.

There should be a unique identifier for each row (surveyed household). This should be same in GIS and Excel so that the Excel data base can be easily linked to GIS when required.



NO	APPLICANT NAME	Building Number	Sub_number	DATE_Surveyed	REGION	Family size(person)	Storage size(m3)	Domestic/commercial/institution/Agricultural/Governmental	Registered/Not_Registered	HC_ID رقم الاشتراك	WATER METER-SNمعصب	PIPE_MATERIAL(PE,GS)	HC_DIAMETER(in	WM_not horizontal(NH)-Not Fixed(NF) Unreadable(UN) Unreach...	Further_Source of water/Neibour(NM),Private well(PW),Private Reservoir(PR),buy Tanks(BT)
1	Derar Mohammed Saleh Abdulrazeq	104	104	23-Oct-2019	HS	5	3	Domestic	Registered	W8720	29431990	GS	0.5		
2	Mohammad Saleh Abdulrazeq	106	106	23-Oct-2019	HS	8	9	Domestic	Registered	W411	058437	GS	0.5		
3	Saleh Hamad Ajjawi	108	10801	23-Oct-2019	HS	7	7.5	Domestic	Registered	W408		GS	0.5	UN	
4	Husain Mohammed Taha	108	10802	23-Oct-2019	HS	1	3	Domestic	Registered	W900486	614140	GS	0.5		
5	Hani Hasan Ali Zakarneh	101	10101	23-Oct-2019	HS	6	4.5	Domestic	Registered	W900487	301989	GS	0.5		
6	Hasan Ali Qweeder	101	10102	23-Oct-2019	HS	8	4.5	Domestic	Registered	W900485	254130	GS	0.5		
7	Abed Issa Qasem	112	11201	23-Oct-2019	HS	25	8	Domestic	Registered	W403	27771	GS	0.5	UNR	
8	Talal Ibrahim Mohammed Hosheyia	112	11202	23-Oct-2019	HS	3	3	Domestic	Registered	W404	1040578	GS	0.5		
9	Hisham Aldeb'ee	114	114	23-Oct-2019	HS	5	3	Domestic	Not_Registered						NM
10	Khawlah Itoom	116	116	23-Oct-2019	HS	2	1.5	Domestic	Not_Registered						NM
11	Anas Mohammed Abdalrahman Itoom	118	118	23-Oct-2019	HS	9	6	Domestic	Registered	W372	326458	GS	0.75		
12	under construction	110	110	23-Oct-2019	HS	0	0	Domestic	Not_Registered						
13	Fathi Rasme Sanouri	120	12001	24-Oct-2019	HS	35	21	Domestic	Registered	W405	9014041	GS	0.5		PR
14	Saeed Saleh Abdalmajeed	124	124	24-Oct-2019	HS	6	3	Domestic	Registered	W1744	993926	GS	0.5		
15	Yousef Saeed Saleh hatab	126	126	24-Oct-2019	HS	5	3	Domestic	Registered	W6771	20223819	GS	0.5		
16	Hasan Ahmad Sadeq Subuh	128	128	24-Oct-2019	HS	5	7.5	Domestic	Registered	W1153	1003737	GS	0.5		
17	Mustafa Ali Hesses	103C	103C01	26-Oct-19	HS	4	3	Domestic	Registered	W1544	11362136	GS	0.5		
18	Omar Mostafa Ali Hesses	103C	103C02	26-Oct-19	HS	6	3	Domestic	Registered	W9079	20225597	GS	0.5		
19	Sa'eed Tawfeeq Sadeq Ighbareieh	103A	103A01	26-Oct-19	HS	1	1.5	Domestic	Registered	W400	9014980	GS	0.5		
20	Loai Abdalfattah Samour	103A	103A02	26-Oct-19	HS	5	3	Domestic	Registered	W9097	8385998	GS	0.5		
21	Tayseer Abdalmalek Jaradat	103B	103B	26-Oct-19	HS	7	7.5	Domestic	Registered	W1762	4662031	GS	0.5		
22	Mohammad Abu Zaineh	105	10501	26-Oct-19	HS	5	4.5	Domestic	Registered	W3241	708480	GS	0.5		
23	Jamal Abu Zaineh	105	10512	26-Oct-19	HS	4	3	Domestic	Not_Registered						NM
24	Sa'd Yousef Sa'd Itoom	107B	107B	26-Oct-19	HS	27	1.5	Domestic	Registered	W398	20225486	GS	0.5	NF	
25	Ahmad Yousef Sa'd Itoom	107A	107A	26-Oct-19	HS	3	1.5	Domestic	Not_Registered						NM
26	Jameel E'esa Alsabbah	109	109	26-Oct-19	HS	8	4.5	Domestic	Registered	W1076		GS	0.5	UNR	
27	abandoned	111	111	26-Oct-19	HS	0		Domestic	Not_Registered						

Figure 6-3: Excel screen capture of CDS data

6.2 Pipe Network Updating

Map of pipe network with correct alignment and pipe information is essential for many NRW reduction activities; namely leak detection, network maintenance, and hydraulic modeling.

Revision and updating of existing GIS layers of water network pipeline, pipe fittings, and related facilities can be achieved through multiple methods; updating from existing softcopy and hardcopy drawings, maintenance records, field inspections and trial pit excavations, hearing from field staff, by conducting pipe location surveys and so on.

In case of Jenin pilot areas, pipe network down to 50 mm was updated by field survey with pipe locator and high accuracy GPS machine. For smaller pipes and house connections pipe routes were marked approximately on GIS map from visual survey.

The following section outlines the method of pipe network update using pipe locator and GPS machine. This is possible when the pipe material is metallic. In case of plastic pipes locating buried pipes is complicated.

6.2.1 Preparation of map of existing pipe network

This map is used as a starting point for update.

- ✧ Print out map (scale 1:500 or 1:1000) showing roads, landmarks, buildings, pipe network, valves, and as many details as possible
- ✧ Prepare GPS
- ✧ Prepare pipe locator
- ✧ Prepare marking color spray

- ✧ Prepare two teams; one to locate pipe and another to record GPS coordinates of pipe and valves

6.2.2 Confirmation of pipe alignment (route) and valves location at site

- ✧ This is done with high accuracy GPS machine
- ✧ The pipe locator team; take reference of printed map, start locating pipe from one side of the area
- ✧ Locate buried valve similarly
- ✧ Mark the locations of pipe and buried valves with spray color
- ✧ The GPS team; take GPS coordinates at valves, pipe junctions, bends, road crossings, etc

6.2.3 Preparation of AutoCAD pipeline network

- ✧ Download the GPS data from GPS machine after coming back to office
- ✧ From the recorded GPS data prepare pipe network map
- ✧ This will generally be in AutoCAD format, but depending on the type of machine it may be recorded directly in some GIS formats

6.2.4 Digitizing from AutoCAD pipeline network to GIS

- ✧ If the GPS machine does not have the facility to directly convert the record to GIS format, then digitize the AutoCAD format network in to GIS.
- ✧ Take reference for diameter, age, depth etc from existing drawings, if any. If no drawing exists, then determine by hearing survey with field staff.
- ✧ In some cases, it may be necessary to dig test pits to confirm alignment, size, and depth of pipe. If required, dig the test pits and confirm.

The network map should preferably contain the following items and their attributes:

- ✧ *Pipe*: material, diameter, installed year, type of use (transmission, distribution, etc.)
- ✧ *Fitting*: type, diameter, installed yea
- ✧ *Appurtenances* (valves, washouts, air valves): diameter, installed year, condition (working or not)
- ✧ *Wells*: identification number (well No.), supply station, production rate, construction year
- ✧ *Pumping station*: identification number, number of pumps and their capacities, supply station, construction year, operating schedule
- ✧ *Reservoir*: identification number, type, dimensions, storage capacity, elevation of low and high water levels, construction year, supply area
- ✧ *Booster station*: identification number, number of pumps and their Q-H-P characteristics, construction year, operating schedule
- ✧ *Pressure break tank*: size, construction year
- ✧ *Pressure reducing valve*: type, size, installed year, pressure settings, condition

- *Bulk meter*: size, type, condition, installed year
- *Washout valve*: size, type, installed year
- *Air valve*: size, type, installed year
- *Fire hydrant:* type

The following figure shows GIS of updated pipenetwork in PA2.

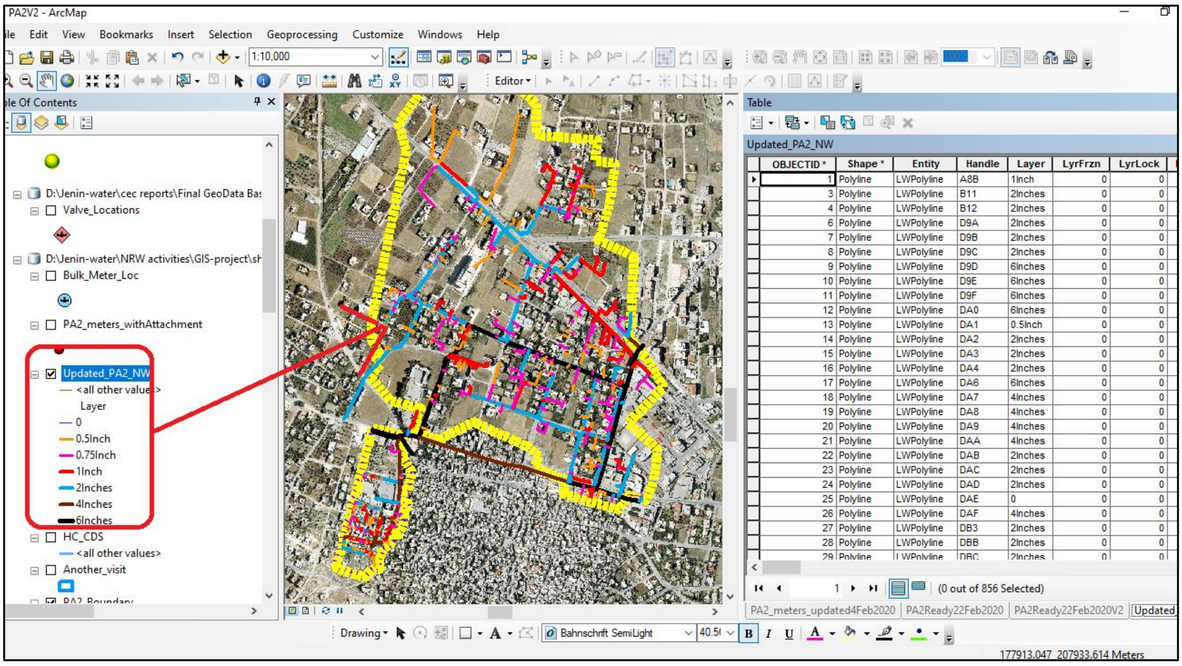


Figure 6-4: Example of GIS map of updated pipe network

6.2.5 Consideration for hydraulic analysis

Availability of high accuracy GIS network maps makes network model preparation work easy and fast. In order to make the GIS maps useful for model preparation certain methods should be followed while preparing the maps.

To make the updated pipe network maps useful for hydraulic analysis prepare the map according to the following steps:

- Create nodes at all the junctions and end points of links,
- Create links (such as pipes) by connecting the nodes. Activate and use snapping option to snap the links with nodes,
- Pipes are drawn as links and fittings are drawn as nodes,
- In GIS, valves and pumps are drawn as nodes. But these are required to be drawn as links in EPANET. This requirement should be considered while preparing GIS map if the map is intended for use in modelling with EPANET. However, some other modeling programs such as WaterGEMS can use valves and pumps as nodes,

- ✧ Check if the network prepared by other is properly snapped by zooming in to the maximum extent possible (say 1:1). Even unsnapped objects look like snapped when viewed at larger scales (such as 1:10,000 or so) but when zoomed in they might not have been snapped. To avoid this problem, activate snapping environment and use snapping tools while working in AutoCAD or GIS.

7 PRESSURE MEASUREMENT

Pressure measurement is conducted to understand the supply situation and to know if the available pressure is within the desired range. It shows from what time to what time water reaches the area and at what pressure.

7.1 Preparation Works

7.1.1 Select candidate locations and prepare tapping points

- Depending upon the available number of pressure loggers select the locations
- The locations should be spread all over the area
- The locations should be at expected highest, lowest, and average pressure points
- Making new tappings may not be feasible in many cases. In such cases can be measured at the nearest house connection
- Insert a Tee in the house connection, two side of the Tee for house connection and one side for pressure logger
- Prepare connectors and hoses

7.1.2 Prepare and program pressure loggers

- Install software of the logger in working computer
- Program the logger
- Make logging interval of about 15 minutes
- Make total duration of about one week (it should cover at least one full supply cycle)
- The loggers can be programmed to start logging immediately after programming or from a pre-decided date and time. If you are ready for installation immediately after programming, set the program to start logging immediately after programming. Otherwise set to start when you expect the loggers will be installed
- Note which logger is installed at which location

7.2 Install Loggers

- Connect the loggers to prepared tapping points with the connector
- Make sure there is no water leakage
- If the loggers are installed when there is no water supply, then check when water supply starts
- Cover the loggers with some box etc to protect them from environment and vandalism

7.3 Download and Analyze Data

- After completion of logging period, disconnect the logger and close the tapping point by a plug or valve
- Connect the loggers to the computer and download the pressure data
- Export/save data in the MS Excel format.

- Export the chart in image format for quick viewing.
- Prepare graphs of your liking from the data downloaded in MS Excel format.
- Analyse data to find out maximum, minimum, and average values etc as per requirement

The following figure shows pressure profiles at 4 locations in PA1.

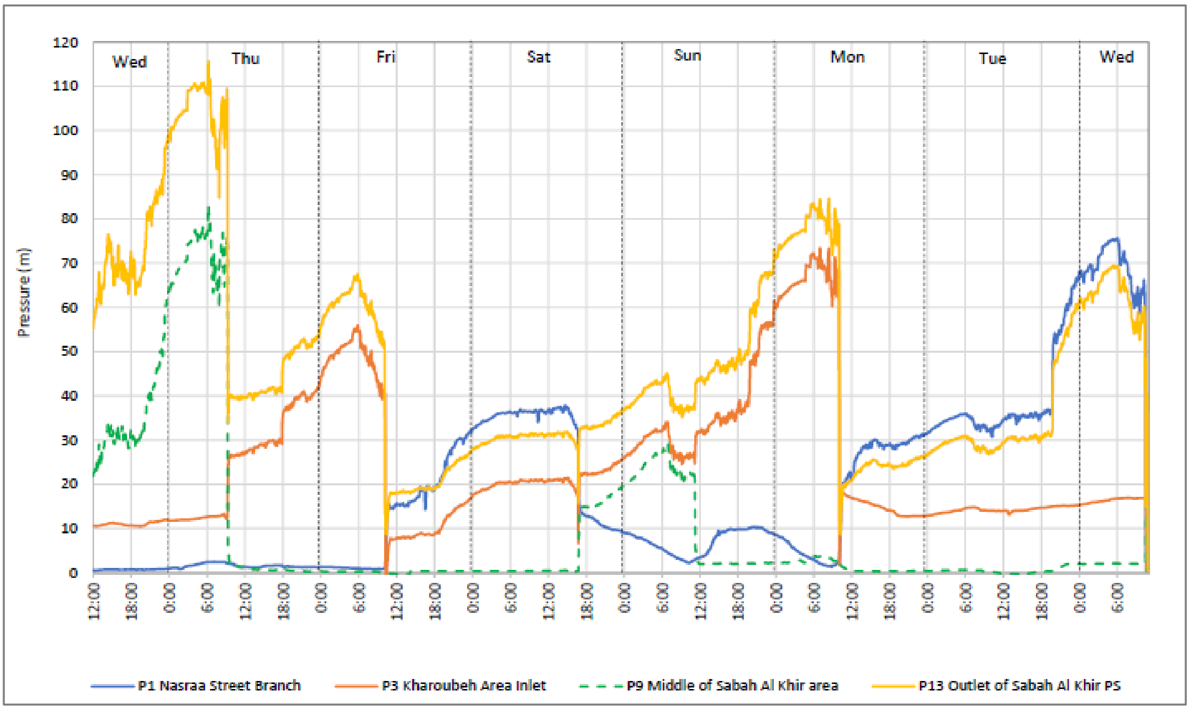


Figure 7-1: Pressure profiles at selected four locations in PA1

8 PREPARATION OF DMA

This work can be taken in parallel with previous two tasks; CDS & pipe network update and pressure measurement.

8.1 Detail Investigation and Updating of DMA Boundary

Its main purpose is to:

- Confirm the boundary,
- Estimate the required size and number of valves, bulk meters, fittings, and data loggers, and
- Estimate the required number of chambers to house bulk meters and valves

With updated network map in hand, walk along the proposed boundary and investigate all suspicious locations where there might be a possibility of any pipe crossing the proposed boundary. This can be checked easily in case of intermittent supply system like that of Jenin if the proposed area and its adjoining area have different supply schedules. In areas of continuous supply or if the adjoining areas have supply on the same timing in intermittent system, then further investigation by pressure measurement on both sides of proposed boundary is required.

8.2 Preparation of Schematic Drawing and Estimating the Required Number of Valves, Flowmeters etc

Once the boundary is confirmed, prepare schematic drawing showing details of bulk meter, valves, chambers, and so on. An example of the schematic drawing is shown below.

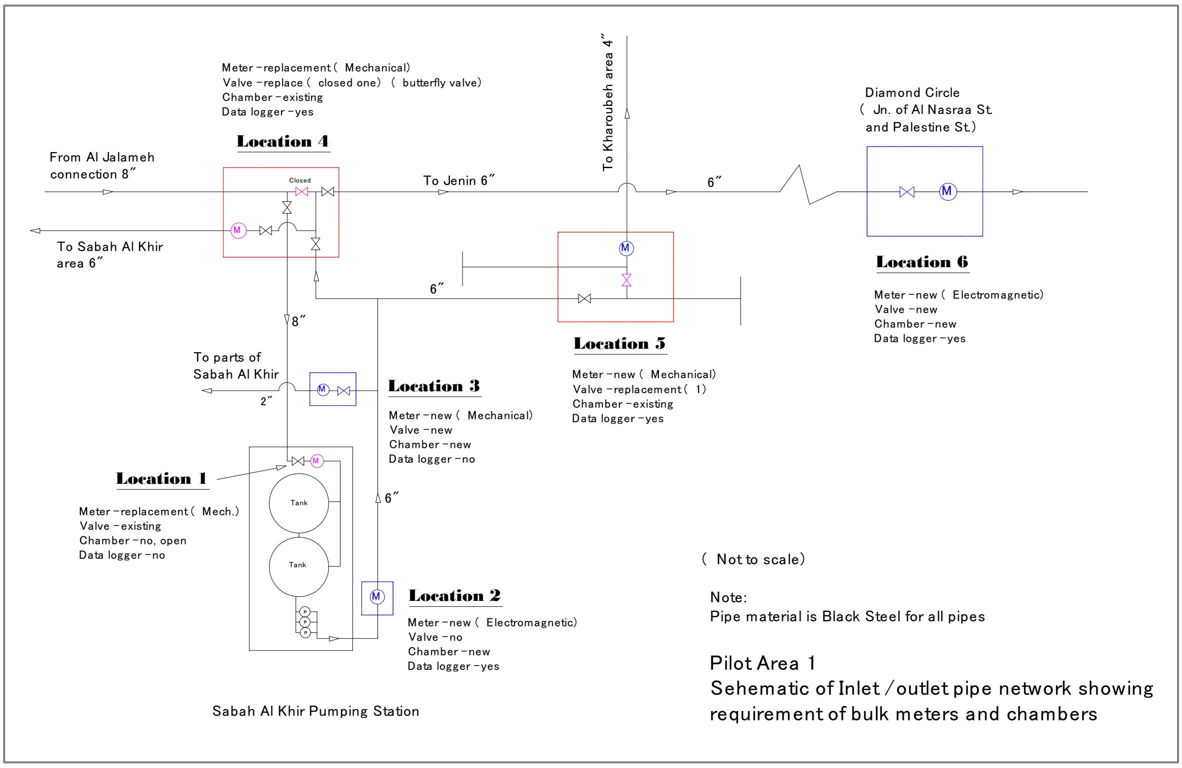


Figure 8-1: Pipe network schematic of PA1 for DMA design

From the schematic, find out how may and what size of valves, meters, and fittings are required.

It is recommended to reduce the number of bulk meters required to measure in and out flow to and from a DMA as much as possible. The more the number of bulk meter, the more is the chance of metering problem. This is mainly done by installing isolation valves in the boundary with adjoining area. But in some cases it may not be possible to do so because the isolated area may not have any other water source. In such cases, bulk meters should be installed on the boundary. If there is any probability of flow reversal, then flow meters which can measure flow on both directions (such as ultrasonic or electromagnetic type) should be considered.

Thus, do not forget to count the valves required for isolation, if any, in preparing the BOQ.

8.3 Preparation of Detail Drawing

At each location, prepare detailed drawings showing how the valves, meters, and fittings will be arranged. It will also help to fix the size of chamber.

Bulk meters generally require straight pipe sections both at upstream and downstream. The exact length depends upon the type of meter. This requirement sometimes results into long chamber dimension.

If the chamber size becomes too long when both the meter and valve are installed in the same chamber, then consider two separate chambers; one for bulk meter and another for valve. For the valve, only a valve box may be enough in some cases.

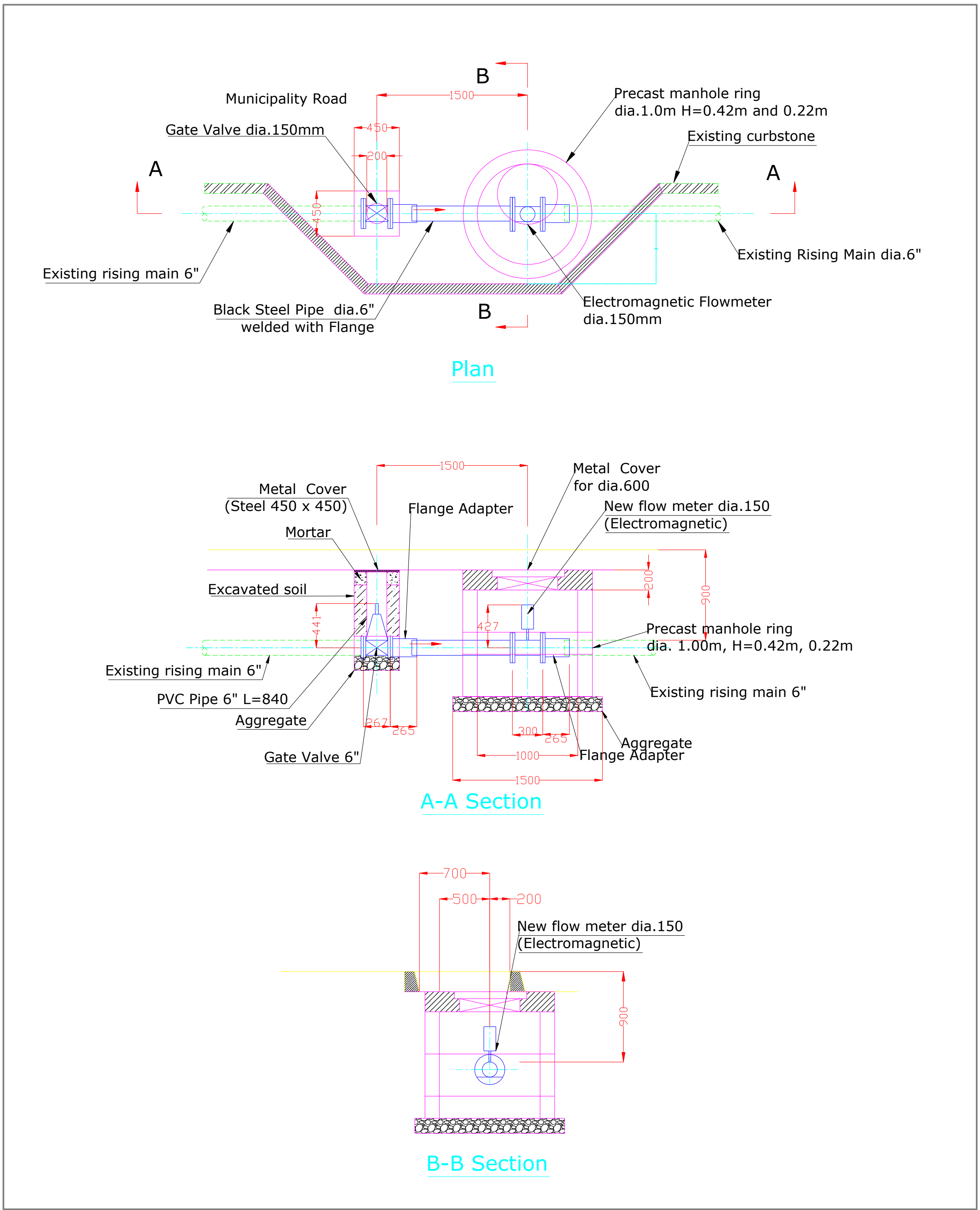


Figure 8-2: Design drawing showing arrangement of valve and meter

8.4 Design of Chambers & Preparation of BOQ

From the above step the size of chamber required will be known. Considering applicable standard, design the chambers. And then prepare the bill of quantities, separately for chambers and other items including valves, bulk meters, fittings, and data loggers.

8.5 Procurement of Bulk Meters, Valves, and Fittings

Follow prescribed procurement process of your organization and procure required materials. In the same time also procure leak repair materials suitable to the type of pipe in your area.

8.6 Construction Scheduling

Prepare a construction schedule considering;

- ✧ Time required for procurement of meters, valves, and fittings, and their expected delivery date,
- ✧ Time required for road cutting permission, digging and installation of the equipment, and construction of chambers,
- ✧ Availability of required skilled manpower and essential tools (such as excavator, welding machine, and their operators).

9 DMA CONSTRUCTION WORKS

Start construction works as per planned construction schedule.

9.1 Install Bulk Meters and Valves

- For new installation, meters and valves should be installed first and then chamber should be constructed later
- If the meter is to be installed in an existing chamber where there is no valve, then take precaution against potential flooding of chamber during installation of valve
- The valve should be installed first at the upstream side of bulk meter
- Before beginning pipe cutting, water should be stopped on the line. Drain the line by opening nearby washout if available
- The valve may be installed in the same chamber as the bulk meter or in a separate location on upstream side of the meter
- Follow valve manufacturer's requirement of straight pipe sections before and after the meter
- Check and make sure there is no leak from any joint after the installation

9.2 Implement Pipe Rearrangement Work If Required

- Cut and connect pipe with other sections if such rearrangement is required in any DMA
- Welding is practiced for pipe connection in Jenin as the pipes are black steel pipes
- Use couplings/ flanged adaptors where required

9.3 Prepare Tapping Points for Pressure Measurement

- Prepare a 1/2" tapping point near the bulk meter
- Install a ball valve and close the tapping branch. This will be required to connect pressure logger

9.4 Construct Chambers

- After finishing installation of valve, flow meter, and tapping point, construct the chamber
- RCC chamber is recommended as far as possible
- Pre-cast manholes can also be used if pipe size is small, say 100 or 150 mm
- Take precaution against rain water intrusion, elevate chamber cover slightly from the ground level

---

Intrusion of ground water or rainwater into the chamber and flooding the bulk meters and data loggers is a big problem. Making chambers waterproof is challenging as their covers need to be opened frequently for meter reading and/or inspection of meter etc inside the chamber. Constructing a drainage pit in the chamber for easy draining of accumulated water by pumping and raising the base level of meter by about 50 cm from the chamber floor are potential measures to prevent flooding of bulk meters.

9.5 Install Flow/Pressure Data Loggers (Optional)

The current trend is to install flow and pressure data loggers and read these values remotely. This makes reading easy and also helps in remote monitoring of the water supply system. If this option is selected;

- ✧ Procure data loggers which are compatible with the flowmeters. Procurement of the loggers together with the flowmeter in the same procurement package is advisable,
- ✧ Include installation and initial training of the loggers in the procurement package,
- ✧ Procure data hosting services of the logger/meter providers.

10 CALCULATION OF NRW & WATER BALANCE COMPONENTS

Calculation of NRW is relatively simple, it needs just two parameters; system input volume (SIV) and billed authorized consumption (BAC). But splitting NRW into various components of water balance requires considerable efforts. This section outlines the methods of calculating NRW and other components of water balance.

10.1 Method of NRW Calculation

NRW is calculated by the following formula:

NRW = ***WATER SUPPLIED (SIV)*** - **WATER BILLED** ***(Billed Authorized Consumption)***

As seen from above, to calculate NRW, it is necessary to measure SIV and BAC. For calculation of NRW for the whole city, SIV will be equal to the sum of all internal productions and import from outside, if any. At a DMA scale, SIV is measured from the bulk meters at inlet and outlets of the DMA.

NRW ratio is calculated from the following formula:

$$\textbf{NRW \%} = \frac{\textbf{NRW Volume (m}^3\textbf{)}}{\textbf{Water Supplied Volume (m}^3\textbf{)}} \times \textbf{100}$$

- ✧ SIV is measured by production meters or bulk meters
- ✧ BAC is calculated from the reading of consumer meters

10.2 Calculation of SIV for Jenin

All the sources of water supply by JM (as of Feb 2021) are listed in Table 10-1. These can be divided into three types; municipality-owned wells (S.N. 1-3), private wells within the municipality (S.N. 4-13), and water imported from outside (S.N. 14-16).

Steps for SIV calculations are:

- ✧ Make sure meters are installed in all sources and confirm every month the meters are working,
- ✧ Replace/repair as soon as possible if any meter is found to be not working,
- ✧ Confirm there are working meters at water transfer points for water imported from outside,
- ✧ Conduct meter readings every two-week (if possible) or at least every month,
- ✧ If meter reading is not possible at some locations, such as water transfer points from Makorot which is handled by WBWD, or from private wells, then calculate monthly quantity from the official invoices,
- ✧ If any meter is found to be not working in any month, make estimate from similar period in previous years when the meter was working,
- ✧ When the reading dates on the WBWD bills are not exactly for one month, make adjustment for the month (calculate daily average for the duration and multiply it by the number of days in the month). It is also explained in Section 10.4.
- ✧ Add the quantities from all the sources, this is the monthly system input volume (SIV) for the entire city. As an example, SIVs for Jenin for 2020 are shown in Table 10-1 below.

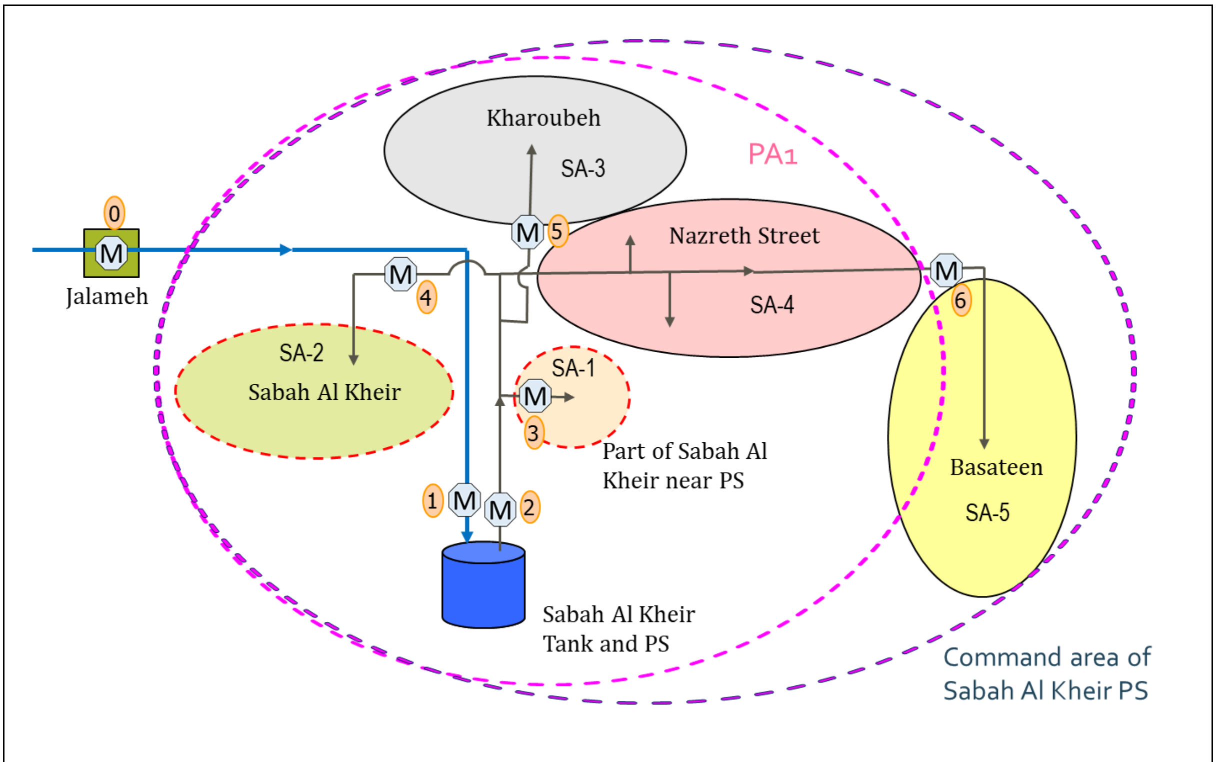
Table 10-1: Case example of SIV calculation of Jenin for year 2020

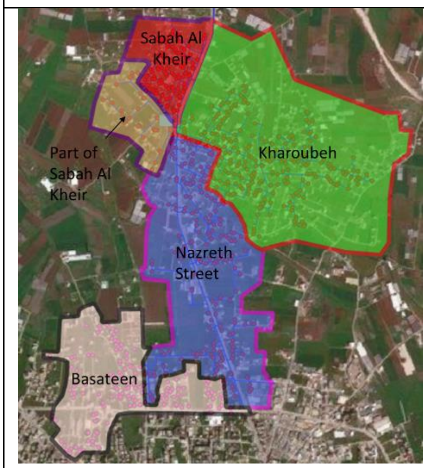
S.N.	Source Name	Jan-20 (m^3/mth)	Feb-20 (m^3/mth)	Mar-20 (m^3/mth)	Apr-20 (m^3/mth)	May-20 (m^3/mth)	Jun-20 (m^3/mth)	Jul-20 (m^3/mth)	Aug-20 (m^3/mth)	Sep-20 (m^3/mth)	Oct-20 (m^3/mth)	Nov-20 (m^3/mth)	Dec-20 (m^3/mth)	Total in 2020 (m^3/year)
1	Al Sadeh well	86,615	83,886	64,332	76,973	77,855	75,119	74,988	75,686	70,115	65,381	63,447	75,036	889,432
2	Al Mechanic well	799	13,592	12,249	11,426	12,693	12,614	11,762	11,107	10,192	10,431	10,020	13,034	129,918
3	Balama well	950	800	695	922	903	965	1,250	1,023	0	1,201	993	1,219	10,921
4	Mechanic well (Tanker Meter)	799	796	894	1,018	1,015	656	561	771	548	488	425	336	8,307
5	Farahaty well	42,098	33,321	47,151	47,160	48,236	21,810	20,787	25,885	21,900	11,284	9,270	11,036	339,938
6	Alawneh well	5,515	4,080	8,555	5,741	5,383	6,528	3,069	3,004	3,432	2,662	982	1,554	50,505
7	Jarrar well	15,609	9,811	13,379	12,183	12,615	14,130	11,805	13,549	13,367	13,204	16,978	8,723	155,354
8	Alaa Saadi well	11,013	13,510	14,916	14,608	14,355	11,752	10,972	11,199	10,111	9,797	9,210	9,903	141,346
9	Abu Sameer well	4,158	4,018	5,882	7,264	12,402	13,745	13,879	12,258	11,311	10,965	9,910	9,575	115,365
10	Abu Hatab Well (No.1)	4,158	9,981	11,099	12,061	12,127	11,276	15,547	18,065	18,279	17,976	16,180	15,751	162,500
11	Abu Hatab Well (No. 2)							3,077	5,396	3,928	4,618	4,469	4,196	25,684
12	JSC Meter (temp.)	0	0	27,817	17,905	182	124	0	0	0	0	0	0	46,028
13	Qasrawi Well	0	0	0	0	0	23,206	27,475	25,768	24,780	24,521	18,210	18,817	162,777
14	Turkman Well					0	0	0	25,117	18,918	16,740	17,430	18,476	96,681
15	Ashraf Well						0	0	0	7,850	7,954	3,848	7,540	27,192
16	Sabah Alkhir (Jalameh)	34,253	24,381	16,900	27,000	38,340	32,813	29,241	30,356	27,117	27,267	27,447	25,547	340,661
17	Swetat	52,034	51,258	52,002	60,000	58,398	51,563	60,514	46,580	51,573	54,468	53,609	68,200	660,198
18	Abu Arab (Main)	30,494	29,447	28,923	30,000	26,133	29,040	25,668	25,885	27,900	27,993	26,550	28,148	336,181
	Total input (m^3)	**288,495**	**278,881**	**304,794**	**324,261**	**320,636**	**305,339**	**310,594**	**331,648**	**321,321**	**306,950**	**288,978**	**317,090**	**3,698,987**
	Total (m^3/day)	**9,306**	**8,996**	**9,832**	**10,460**	**10,343**	**9,850**	**10,019**	**10,698**	**10,365**	**9,902**	**9,322**	**10,229**	**10,134**

10.3 Calculating SIV for Individual DMAs

For individual DMAs or sub-DMAs, SIV is calculated from bulk meters installed at the inlet and outlet of DMAs. For some DMAs or sub-DMAs the SIV may need to be calculated from combination of several meter readings, it depends on the configuration of bulk meters. As an example, configuration of DMAs and sub-DMAs in PA1 and the bulk meters involved in calculation of SIV for each of them is given below.

Case example of SIV calculation for sub-areas (sub-DMAs) of PA1





Sub-area	Sub-area Name	SIV is calculated from
SA-1	Part of Sabah Al Kheir	Reading of bulk meter M3
SA-2	Sabah Al Kheir	M4
SA-3	Kharoubeh	M5
SA-4	Nazreth Street	M2-(M3+M4+M5+M6)
SA-5	Basateen	M6
	Whole PA1	M1-M6
	Whole command area of Sabah Al Kheir PS	Reading of M0 (meter at Jalameh)

Sub-areas in PA1 and Basateen

Method of SIV calculation for sub-areas and the whole area

Figure 10-1: Configuration of DMAs and sub-DMAs and calculation method of SIV for each in PA1

Steps for SIV calculations are:

- ✧ Take bulk meter readings on bi-weekly (as far as possible) or monthly basis,
- ✧ Calculate the volume passed through the meter during the interval,
- ✧ If any meter is found to be not working, estimate the quantity from similar period when the meter was working,
- ✧ Calculate SIV for any DMA or sub-DMA by adding all inlet volumes and subtracting outlet volumes (if any) during the same period.

What to do when the meter reading intervals do not exactly match with the number of days in some month(s)?
When the reading intervals are shorter or longer than a month it is necessary to make adjustment (see example below). ✧ Calculate number of days between the readings from the reading dates, *i.e.*, column (3) below, ✧ Calculate the quantity between the readings by subtracting previous reading from the current reading, *i.e.*, column (4) below, ✧ Calculate average quantity per day, *i.e.*, column (5) below, ✧ Calculate the quantity in the month by multiplying the average daily volume by the number of days in the month, *i.e.*, column (8) below,

Example of bulk meter reading adjustment to match exactly with the number of days in a month is given in Table 10-2.

Table 10-2: Example of adjustment of bulk meter reading to match with the days in a month

Reading Date	Meter Reading	Interval between readings (days)	Quantity between readings (m^3)	Av. quantity per day (m^3)	Month	Days in month	Quantity in month (m^3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				=(4)/(3)			=(5)*(7)
2019/3/1	160,189	-	-	-		-	-
2019/4/2	192,057	32	31,868	996	March	31	30,876
2019/5/1	213,682	29	21,625	746	April	30	22,380
2019/6/1	242,132	31	28,450	No need to adjust	May	31	28,450
2019/7/1	272,253	30	30,121	As above	June	30	30,121
2019/8/1	303,634	31	31,381	As above	July	31	31,381

The above example shows that how the readings of March and April, which were taken for 32 and 29 days respectively, were adjusted for to cover the whole of March (31days) and April (30) days. For other months (i.e., May, June, and July) no adjustment is required as the reading intervals are same as the number of days in those months.

Remote reading of bulk meters

If the bulk meters have flow signal output option and if data loggers are installed, the flow data can be obtained remotely from telemetry system or via web-based services.

Most of the bulk meters installed in DMAs of Jenin pilot areas have flow signal output option and are connected with data loggers. Thus, it is possible to read and download flow data remotely using the web service of data logger provider. As an example, Figure 10-2 shows flow profile and volume at location 2 (outlet of Sabah Al Khir pumping station) for November 2020 (from 1st Nov to 1st Dec. 2020) in Nov 2020 is 23,452.9 m^3.

Data logging and remote reading makes SIV calculation work very simple. Two main advantages are that site visit is not required and flow volume can be extracted for any desired period easily. However, reliability of data transfer is still not very good, so it is recommended to check the meters physically every month, take readings manually and cross-check with the volumes recorded by the loggers.

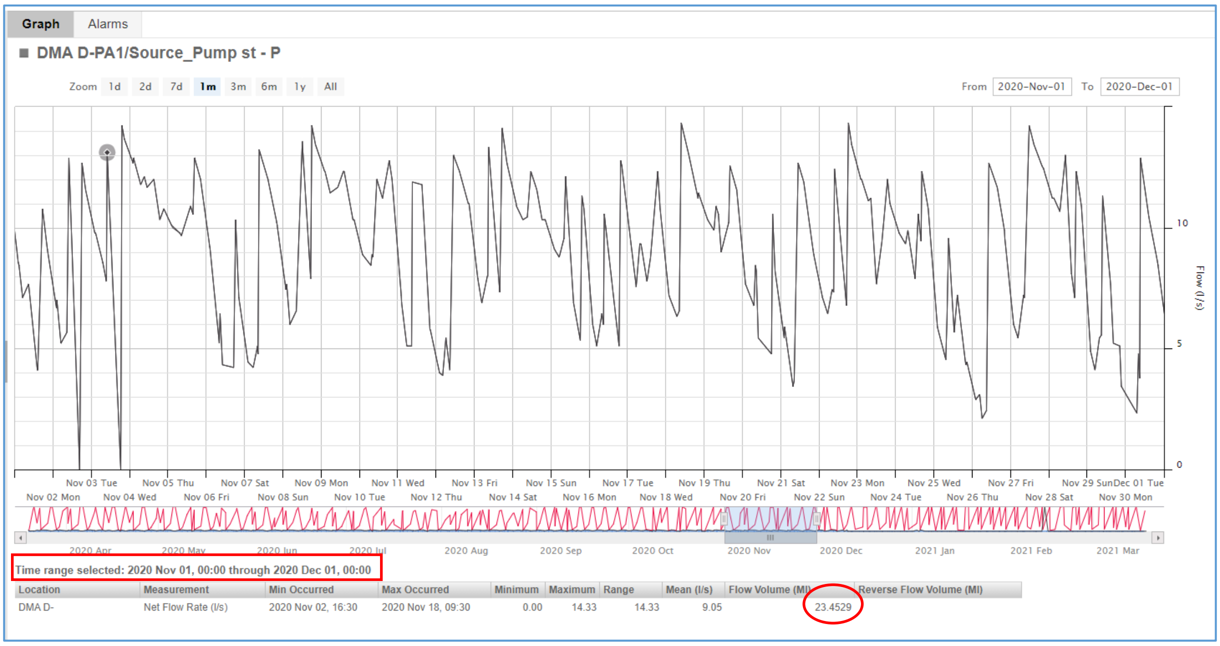


Figure 10-2: Screenshot of data logger at Sabah Al Khir PS

10.4 Calculating Billed Authorized Consumption

- ✧ Collect monthly meter reading data from billing system. Total billed quantity can be extracted directly from most of the billing program. In Jenin AlShamel program is used for billing. From this system, billed consumption can be extracted easily. For further analysis, all consumption and billing data can be extracted from this program in MS Excel format.
- ✧ Make sure the reading dates are there for each reading.

- ✧ Define a unique field which will be used as a key to identify each customer. In case of Jenin Connection ID can be used.
- ✧ Calculate total billed quantity from the data extracted in Excel.
- ✧ Adjust for meter reading lag time.

Adjusting for meter reading lag time (when the reading intervals are not exactly one month)

- ✧ If fixed dates and routes for meter reading is followed in all months, then the interval between all meter readings will be same. But in practice, it seldom happens. Some meters might have been read at shorter interval than one month while other might have taken more than one month. To make calculation of monthly NRW more accurate, it is necessary to match the period of SIV and BAC. For example, if the SIV is for a month of 30 days, the consumption calculated from billing should also be for 30 days. So, the consumption values of each customer should be adjust to make it for exactly 30 days.
  - o Say a particular customer's meter was read on 3rd of December and on 5th of January. And the consumption is 18 m^3. To calculate consumption in December, find the average per day consumption and multiply by 31 (the number of days in December). In the above example, the duration between the readings = (31-3)+5= 33 days. Thus, per day consumption = 18/33=0.545 m^3. So, consumption in Dec = 0.545*31=16.9 m^3.
  - o Similarly calculate adjusted consumption for all customers.

A practical example of meter reading time lag adjustment is given below. This reading is for the month of December.

Table 10-3: Example calculation for adjusting meter reading lag time

Customer-ID	Previous reading date	Current reading date	No. of days between the readings	Previous reading (m^3)	Current reading (m^3)	Consumption (m^3)	Consumption adjusted for 31 days in December (m^3)
(1)	*(2)*	*(3)*	*(4)=(3)-(2)*	*(5)*	*(6)*	*(7)=(6)-(5)*	*(8)=(7)/(4)*31*
W10001	2018/12/04	2019/01/08	35	1562	1574	12	11
W10002	2018/12/17	2019/01/12	26	2349	2381	32	38
W10010	2018/12/04	2019/01/08	35	900	916	16	14

- Add the adjusted consumptions of all customers to find out the total Billed Metered Consumption.
- If there is any authorized billed unmetered consumption, estimate the quantity for the month. This will be Billed Unmetered Consumption.
- Add the above two to get Billed Authorized Consumption (BAC).

Timely and accurate reading of customer meters is very important!

- On every reading cycle (monthly in case of Jenin) start reading the meters from almost the same day of the month (i.e., 5th of each month),
- Follow the same route. This helps keep the reading interval of all meters same in each month. Otherwise, some meters may be read in 25 days while others in 35 days, for example,
- If any meter cannot be read due to some reason (such as dial not clear due to water vapor, gate closed) note the reason and report to the CSS head,
- Try reading those meters again (at least one attempt) which you could not read due to closed gates,
- Check the area surrounding the meter and note if you notice any suspicious illegal connection or meter by-pass,

10.5 Finding Accuracy of Customer Meters

Customer meters are tested to find out the Apparent Loss caused by their inaccuracies. The meters can be tested without removing from site (in-situ test) by portable test systems or they can be removed and tested in a standard test bench.

- ✧ It is not possible to test all meters, so some samples should be selected.
- ✧ The more the number of samples the more accurate will be the result. But that needs more resources and time. If only a few samples are tested, the result may not be representative. So, the number of samples should be reasonable (statistically significant). About 5-10% of total numbers is reasonable.
- ✧ The samples should be representative; distributed from all area, age, type, and water volume passed (throughput). One method for this will be to create GIS grid of required numbers and select one sample from each grid.
- ✧ After the initial screening, check and make sure that the samples include meters of various ages (can be roughly judged from cumulative readings in the meter), brands and sizes.
- ✧ Conduct the tests as follows:

Testing at standard meter test bench
✧ note the reading in the meter, ✧ disconnect the meter, ✧ install a replacement meter in place of disconnected meter if water supply is to continue, ✧ bring the meter to testing lab and get it tested. Expert technician will test and prepare the result.
Testing at site (in-situ test)
✧ if you have a portable testing system, use this, otherwise you can also make a test

system by assembling a higher accuracy meter and piping system by yourself,

- ✧ prepare piping system and connectors to connect the test meter in series with the existing meter,
- ✧ at site, close the valve in front of the existing meter,
- ✧ install the test meter after the meter (in series to the existing meter),
- ✧ open the valve and wait until the flow becomes stable (no air bubbles in water),
- ✧ close the valve once again,
- ✧ take initial readings of both existing meter and test meter, take the readings to the smallest unit possible,
- ✧ open the valve and let water pass for about 7~10 minutes,
- ✧ close the valve,
- ✧ take second readings of both existing and test meter,
- ✧ calculate the consumption by both meters,
- ✧ compare the consumption shown by existing meter with the test meter,
- ✧ and finally calculate the error of existing meter by the following formula

for example;
Initial reading of test meter: 1245.234 m^3
Initial reading of existing meter: 50.392 m^3
Final reading of test meter: 1245.295 m^3
Final reading of existing meter: 50.450 m^3

Therefore,
Volume shown by test meter = 1245.295-1245.234 = 0.061 m^3
Volume shown by existing meter = 50.450-50.392 = 0.058 m^3

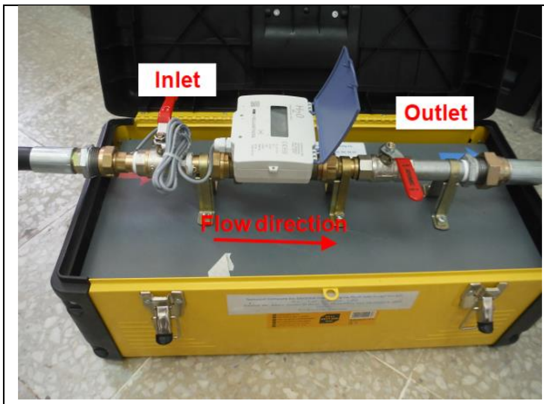
Error of existing meter = $\frac{(Vol.\ by\ existing\ meter - Vol.\ by\ test\ meter)}{Vol.by\ test\ meter} \times 100\%$

$= \frac{(0.058-0.061)}{0.061} \times 100$ = - 4.9%

If the error is negative, i.e., if the consumption shown by existing meter is less than shown by test meter, it is called 'under registration'.

- ✧ After completing the test of all meters, take average of error to calculate overall error of existing customer meters.

The following photos show different stages of the test:



Portable test bench (ultrasonic type)

Connecting the meter with test bench

Filling the pipe of test bench (U/S valve open and D/S valve closed)

Starting test (both valves open)

The following is the result of meter error test conducted in PA1.

Table 10-4: Result of customer meter accuracy test in PA1

S.N.	Volume "V" by Existing meter (m^3)	Volume "R" by Test meter (m^3)	Meter Error $= \frac{(V-R)}{R} \times 100\%$
1	0.07285	0.074	-1.55%
2	0.0482	0.047	2.55%
3	0.0444	0.045	-1.33%
4	0.0843	0.099	-14.85%
5	0.1014	0.114	-11.05%
6	0.0833	0.068	22.50%

S.N.	Volume "V" by Existing meter (m^3)	Volume "R" by Test meter (m^3)	Meter Error $= \frac{(V-R)}{R} \times 100\%$
36	0.0948	0.10296	-7.93%
37	0.1062	0.102104	4.01%
38	0.0954	0.099888	-4.49%
39	0.1031	0.098966	4.18%
40	0.1015	0.102508	-0.98%
41	0.1011	0.10024	0.86%

S.N.	Volume "V" by Existing meter (m^3)	Volume "R" by Test meter (m^3)	Meter Error = $\frac{(V-R)}{R} \times 100\%$	S.N.	Volume "V" by Existing meter (m^3)	Volume "R" by Test meter (m^3)	Meter Error = $\frac{(V-R)}{R} \times 100\%$
7	0.1008	0.102235	-1.40%	42	0.1013	0.100405	0.89%
8	0.1011	0.102383	-1.25%	43	0.0663	0.067	-1.04%
9	0.0885	0.077	14.94%	44	0.0999	0.099647	0.25%
10	0.1394	0.139502	-0.07%	45	0.0989	0.10217	-3.20%
11	0.2675	0.25189	6.20%	46	0.094	0.09962	-5.64%
12	0.127	0.125	1.60%	47	0.0745	0.101357	-26.50%
13	0.1043	0.104261	0.04%	48	0.0948	0.101711	-6.79%
14	0.1044	0.101	3.37%	49	0.071	0.073	-2.74%
15	0.1014	0.09888	2.55%	50	0.1031	0.100534	2.55%
16	0.0974	0.102153	-4.65%	51	0.0949	0.098504	-3.66%
17	0.1045	0.101125	3.34%	52	0.122	0.137	-10.95%
18	0.1124	0.101497	10.74%	53	0.1076	0.1017	5.80%
19	0.0958	0.097868	-2.11%	54	0.1023	0.103723	-1.37%
20	0.099	0.103532	-4.38%	55	0.0872	0.099568	-12.42%
21	0.0995	0.10001	-0.51%	56	0.1094	0.106426	2.79%
22	0.0873	0.090162	-3.17%	57	0.4438	0.335	32.48%
23	0.1088	0.104116	4.50%	58	0.102	0.100169	1.83%
24	0.1045	0.107284	-2.59%	59	0.1034	0.103092	0.30%
25	0.0995	0.100352	-0.85%	60	0.062	0.072	-13.89%
26	0.0782	0.080971	-3.42%	61	0.0173	0.018	-3.89%
27	0.0934	0.100675	-7.23%	62	0.1019	0.100747	1.14%
28	0.0503	0.052641	-4.45%	63	0.1052	0.099945	5.26%
29	0.1018	0.099342	2.47%	64	0.0812	0.072	12.78%
30	0.0977	0.100125	-2.42%	65	0.0922	0.100743	-8.48%
31	0.1014	0.100664	0.73%	66	0.0894	0.100914	-11.41%
32	0.1039	0.104944	-0.99%	67	0.0485	0.050229	-3.44%
33	0.1027	0.104056	-1.30%	68	0.107	0.103052	3.83%
34	0.0979	0.097192	0.73%	69	0.0994	0.101376	-1.95%
35	0.0968	0.097492	-0.71%	70	0.1069	0.10328	3.51%
Overall error (average of all)							**-0.61%**

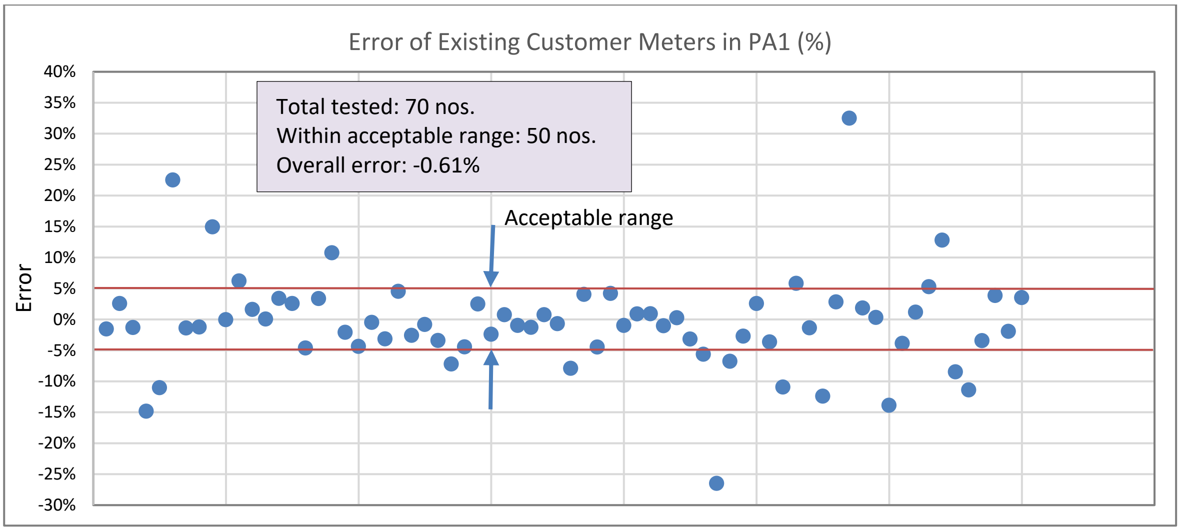


Figure 10-3: Result of existing customer meters accuracy test

For detailed process of testing and recording, please refer to Annex 1- Quick Reference Manual for On-site Accuracy Test of Existing Domestic Meters.

10.6 Finding 'Unbilled Authorized Consumption'

Unbilled authorized consumption is the quantity of water consumed by institutions which are authorized to use water for free. In case of Jenin there are no such institutions in general. But potential consumers include:

- Firefighting services
- Religious institutions (Mosques, Churches etc.)

If there are any, most likely the consumption is unmetered. So, it is necessary to make estimate of the consumption.

10.7 Calculating Water Losses

Water Losses is calculated from the following formula:

Water Losses	=	***NRW***	-	**Unbilled Authorized Consumption**

Generally, the Unbilled Authorized Consumption is very small. If that is negligible, then the Water Losses becomes equal to NRW.

10.8 Splitting Water Losses into Real and Apparent Losses

There are two general approaches for splitting water losses into Apparent Losses and Real Losses; top-down and bottom-up approaches. In the top-down approach Apparent Losses are estimated first and Real Losses are calculated as the difference between Water Losses and Apparent Losses. In the bottom-up approach, Real Losses are estimated based on the measured minimum night flows and Night-Day Factor and Apparent Losses are calculated as the difference between Water Losses and Real Losses. When it is possible to use both methods, it is possible to check if the calculations are consistent or not.

10.8.1 Steps of top-down approach

The followings are the main steps of top-down approach:

Step 1: Estimate the system input volume.

Step 2: Estimate the billed metered consumption and billed unmetered consumption. Enter the appropriate totals in authorised consumption and revenue water.

Step 3: Calculate the volume of non-revenue water as the system input volume minus revenue water.

Step 4: Estimate unbilled metered consumption and unbilled unmetered consumption. Enter their sum in unbilled authorised consumption.

Step 5: Add billed authorised consumption and unbilled authorised consumption to give authorised consumption.

Step 6: Calculate water losses as the difference between system input volume and authorised consumption.

Step 7: Assess components of unauthorised consumption and metering inaccuracies and add these to get Apparent losses.

Step 8: Calculate Real losses as water losses minus Apparent losses.

10.8.2 Bottom-up approach

In the top-down approach, the Real Losses are calculated by subtracting Apparent losses from Water Losses (Step 8 above) but in bottom-up approach the Real Losses are first calculated from minimum night flow analysis and the Apparent Losses are calculated by subtracting these from Water Losses. Thus the bottom-up approach is possible only in areas of continuous supply or where it is possible to saturate customer demands by supplying continuously for at least 72 hours. Method of estimating Real Losses from MNF analysis is given in Annex 2.

10.9 Measure MNF, Pressures, and Estimate Leakage Level

10.9.1 Measuring MNF

Minimum night flow is used to estimate leakage. MNF can be conveniently measured in areas of continuous (24/7) supply. But in areas of intermittent supply MNF can only be measured after saturating customers' demand. Since many customers in areas of intermittent supply areas own large ground and roof-top tanks it takes time to fill all these. Until such tanks are filled, water will keep flowing even at nighttime, so the MNF is becomes less reliable as an indicator of leakage. It generally requires continuous supply of 24-48 hrs to fill such tanks. Thus, for MNF measurement at least 72 hrs continuous supply should be assured.

10.9.2 Measure pressure

Pressure should also be measured during the MNF measurement. This is required to adjust leakage rate. The pressure should be measured at the inlet point where the flow is measured and at the average zonal point (AZP). The AZP represents a location where the pressure will be equal to the average of the zone. AZP can be calculated from hydraulic model if available, or from contour map together with customer locations. This is explained in Annex 2. Alternately, pressure can be measured at multiple locations; high, middle, and low altitude points, which together represent average elevation of the area.

10.9.3 Estimate leakage from MNF and pressure

This is explained in Annex 2.

11 PLANNING AND IMPLEMENTING NRW COUNTERMEASURES

11.1 Leak Detection

Leakage is often the major source of NRW in intermittent supply system. How to detect leaks is explained in a separate chapter of this manual.

11.2 Leak Repair

Timely repairing of leaks with good quality material and workmanship (speed and quality of repair) is important to reduce NRW. This is explained in detail in a separate chapter of this manual.

11.3 Implement Measure Against Utility Tank Overflow

- Check and confirm that the float (altitude control) valves on all storage/service reservoirs are working,
- Repair/replace any defective float (altitude control) valve as soon as possible,
- Do not take the end of the overflow pipe of any reservoir to a drain or ditch. It makes difficult to notice any overflow. Instead keep the end of the pipe at an easily visible place so that any overflow will be easily noticed.

11.4 Illegal Connection Detection and Rectification

Illegal connections/ water use is another major source of NRW in many countries. Key points to be considered for this are described in Section 17.3.

11.5 Detecting and Replacing Faulty Customer Meters

The main method of detecting faulty customer meters is by analyzing monthly consumption pattern. If some customers show unusually low or zero consumption in any month, meters of such customers should be checked. As described before, checking can be done onsite with portable test bench or at meter workshop (refer to section 11.7 for more detail).

11.6 Install Meters on Unmetered Connection

Unmetered connections are not common in Jenin, only a few connections were found without meters during the survey in PA1. There is a possibility of water wastage from unmetered connections. Install/ ask the customers to install water meters in such connections as soon as possible.

11.7 Check Accuracy of Production Meters and Replace Defective Meters

Accuracy of production meters should be checked periodically, preferably on half-yearly or yearly basis.

Any error in measurement of produced water or system input volume (SIV) results in inaccurate NRW ratio.

In case of Jenin, JM buys majority of its supply from private suppliers (well owners) and external sources through West Bank Water Department (WBWD). Thus, accuracy of bulk meters is important not only to get accurate NRW values but also to prevent wrong payment to the suppliers.

11.7.1 Methods of checking

1) Testing at a test bench
This needs a test bench capable of testing bulk meters and substitute meters to replace the meters during testing. In this method, the meters are removed, substitute meters are installed, and the removed meter is tested at the test bench. Once the test is completed, depending on the test result, the same meter or a new meter is installed back. JM currently does not have any test bench for bulk meters. So this method is not feasible.

2) In-situ testing
In this method the meters are tested in-situ (at site, without removing) by installing a portable ultrasonic flowmeter in series with the bulk meter in question. This method is simpler but the test result is less accurate than method 1). It is assumed that the measurement by the ultrasonic flowmeter is accurate.

The followings are the main steps of this method:

(a) Check if suitable pipe section is available to install ultrasonic flowmeter. Refer to the manual of ultrasonic flowmeter for requirement of straight pipe sections both upstream and downstream. Generally, 5d upstream and 3d downstream straight pipe sections are required, where d is the internal diameter of the pipe,
(b) Install the ultrasonic flowmeter, set the totalizer to zero,
(c) Take the reading of the bulk meter at the same time when setting zero totalizer,
(d) Wait for at least 24 hours, the more the test duration the better,
(e) After the decided test duration, at the same time note the totalized volume in ultrasonic flowmeter and take reading of the bulk meter. Remove the ultrasonic flowmeter.
(f) Calculate the error of bulk meter by the following formula:

$$Error\ (\%) = \frac{\text{Volume by bulk meter} - \text{Volume by ultrasonic meter}}{\text{Volume by ultrasonic meter}}$$

11.7.2 Case example

Cost-effectiveness of source meter checking and replacement in Jenin

The source meters of private wells were checked by portable ultrasonic flowmeter as a part of regular NRW management activity. Five of the eight private well meters were found to be defective (have errors beyond the permissible range ± 5%). Details of this checking is given in Table 11-1 and Table 11-2. Cost-benefit analysis was made considering replacement of the defective meters with mechanical meters. Its result is presented in the following section and Table 11-3.

Table 11-1: Detail of source meters checked

ID	Starting date	Measurement duration (hrs)	Quantity recorded in 24-hr period		Measurement Error of the Source Meter (%)	Size of bulk meter (mm)	Remarks
			Well's bulk meter	UFM			
1	20-May-21	24	817.00	795.44	2.7%	75	Error acceptable
2	20-May-21	48	428.00	296.50	44.4%	75	
3	02-Jun-21	24	405.00	390.05	3.8%	50	Error acceptable
4	14-Jun-21	24	818.00	779.40	5.0%	75	Error acceptable
5	14-Jun-21	24	678.00	607.80	11.5%	150	
6	21-Jun-21	48	505.50	362.50	39.4%	75	
7	26-Jul-21	24	592.00	640.52	-7.6%	75	
8	18-Aug-21	96	53.25	168.25	-68.4%	100	

Aggregate error of five meters whose errors are beyond the acceptable range is summarized in Table 11-2.

Table 11-2: Aggregate error of five meters having error beyond permissible range

S.N.	Description	Quantity in 24-hr period		Over-reading by existing bulk meters	
		Well's bulk meter	UFM	m^3/day	%
1	Meters having error more than permissible (not within ± 5%) (S.N. 2, 5-8)	2,256.8	2,075.6	181.2	8.7%

From the above, the calculated SIV for NRW calculation of whole Jenin is more than actual by 181.2 m^3/day.

JM can save the water charge equivalent to the purchase cost of 181.2 m^3/day by replacing the 5 defective meters. Even the new meters will have some error but they will likely be both positive and negative and cancel each other. Considering this case, the cost-benefit analysis of testing of 8 and replacing 5 meters by mechanical meters is summarized in Table 11-3 below.

Table 11-3: Cost-benefit analysis of source meter testing and replacement

S.N.	Description	Quantity	Unit	Remarks
1	Benefit			
	Apparent loss reduced	181.20	m^3/day	Replacing 5 meters only
	Average purchasing price of water	2.10	NIS/m^3	From 2016 annual report
		0.636	USD/m^3	
	Benefit (saving in water charge payment to private wells) =181.2*0.636	115.28	USD/day	
		42,077.20	USD/year	
2	Cost			
	Cost of checking 8 and replacing 5 meters	11,495.00	USD	
3	Cost recovery period	0.273	Year	
		3.28	Months	

The above result shows that source meters are significant part of error in calculation of NRW and by replacing defective meters (meters having errors beyond acceptable range), JM can recover the cost in about three months.

12 LEAKAGE DETECTION

12.1 Introduction

Water leakage from pipeline causes a variety of problems:

- ✧ Wastage of precious water,
- ✧ Risk of contamination of water,
- ✧ Risk of land subsidence and property damage,
- ✧ Inconvenience to motorists and pedestrians, and so on.

Therefore, water leakage survey should be carried out as **preventive measures** to sustain the implementation of appropriate O&M activities and the subsequent improved water supply.

The leakage from water pipeline is categorized into:

- ✧ Surface leakage (also called visible leakage), and
- ✧ Underground leakage.

The surface leakage is usually easy to discover and repair within a short period of time while a series of special survey should be done to discover underground leakage. Underground leakage needs a longer period of time to discover, i.e., it runs for a longer duration than surface leakage, thus water leakage is more by underground leakage.

There are various methods to detect and pin-point leakage. The most common methods applicable to the condition of project site are:

(i) Visual survey for surface leakage, (ii) Acoustic survey for underground leakage, (iii) Step test, and (iv) Stop-cock method.

12.2 Visual Survey for Surface Leakage

Surface leakage needs to be found and repaired first, then only we can move to underground leakage. To find the surface leakage, an elaborated site survey including walking some distance should be conducted.

12.2.1 Preparation for surface leakage survey

- ✧ Understand which area is supplied on which day and time. Such a map has been prepared by this project but the schedule might have been changed. So, confirmation of supply areas according to latest supply schedule is required.
- ✧ Prepare a schedule of survey according to the supply day and time of each area.
- ✧ Print out pipe network map of the planned survey area at a scale of about 1:500~1:1000, or alternately, export the shape file of pipe network in to KML file and transfer into your

mobile device (if you want to avoid paper map and plan to use your mobile device).

- A team of two persons is recommended.

12.2.2 Method for surface leakage survey

- The survey method is nothing but careful watching for any sign of leakage on the road surface.
- Start walking slowly from a corner of the survey area, one person on each side of road, watching carefully if any sign of water leakage appears.
- If you find some water on the road or damp patch of soil, investigate further. It may be due to various reasons such as discarded washing water by a customer, overflow from roof-top tanks, water from kitchen, and so on.
- If such possibilities are not found and you suspect it is from a leakage, mark its location on the paper map or your mobile device. Also take GIS coordinates of the location.

12.2.3 Confirmation survey for surface leakage

- If the suspected leakage could not be confirmed in the first survey, check the location after one or two days of water supply stoppage in the area. Check if the leakage dried up.
- Recheck during next supply day. Has the leakage reappeared?
- If the leakage sign reappears, investigate by using sounding equipment.
- If it is possible to conduct Stop-cock method in that area, conduct it and investigate further.
- If necessary, excavate around the suspected area.

12.3 Acoustic (Sounding) Survey to Detect Underground Leakage

This system is based on the hearing of sound generated by leaking water. Underground leak detection is a challenging job and needs considerable resources; time, trained manpower, and equipment. The job is even more challenging when the water supply system is intermittent and customers own big underground tanks to store water for non-supply hours because the sound generated by the tank filling can be similar to the sound of a leak.

12.3.1 Preparation for underground leakage survey

- Understand which area is supplied on which day and time. Such a map has been prepared by this project but the schedule might have been changed. So, confirmation of supply areas according to latest supply schedule is required.
- It is necessary to know exact location of the pipelines on the ground. Prepare a pipe network map which shows accurate location of pipes, valves, and other appurtenances. Additional information of pipe such as pipe material and diameters are helpful.
- It may be necessary to conduct pipe network confirmation survey beforehand if such map is not available.
- Prepare survey teams. Each team should have well trained three (3) members in it.

- ✧ When checking water meters through house-to-house visits, a check sheet is needed to record the result. Prepare it in advance.
- ✧ Check and prepare the equipment. Check batteries, charge equipment beforehand if necessary.

Pipe network confirmation survey

- ✧ Refer to the main NRW Reduction Manual for detail,
- ✧ In this survey, exact location of pipe on the ground is identified by using pipe locating tools. Location of the pipe is then recorded in GIS by taking coordinates by a high precision GPS machine.
- ✧ The Jenin water and wastewater department owns metal pipe locator and high precision GPS machine as well as the skilled manpower to operate them.
- ✧ Pipe network information in Jenin is reasonably accurate for pipes within the pilot areas and new DMAs implemented by JM because pipe network confirmation survey has been conducted there.

12.3.2 Procedure for underground leakage survey

There are two steps for underground leakage survey:

Step (1): Area-Wise Approach

In this step it is necessary to listen to all exposed metal parts (valves, fire hydrants and water meters) within a defined area by using listening sticks and then specify the pipes with real /pseudo leakage sound. As a typical example practiced in August 2018 in Jenin, domestic water meters and correspondingly connected distribution pipes were checked by using listening sticks. This survey is to be conducted during daytime for safety reason. The key steps in this approach are:

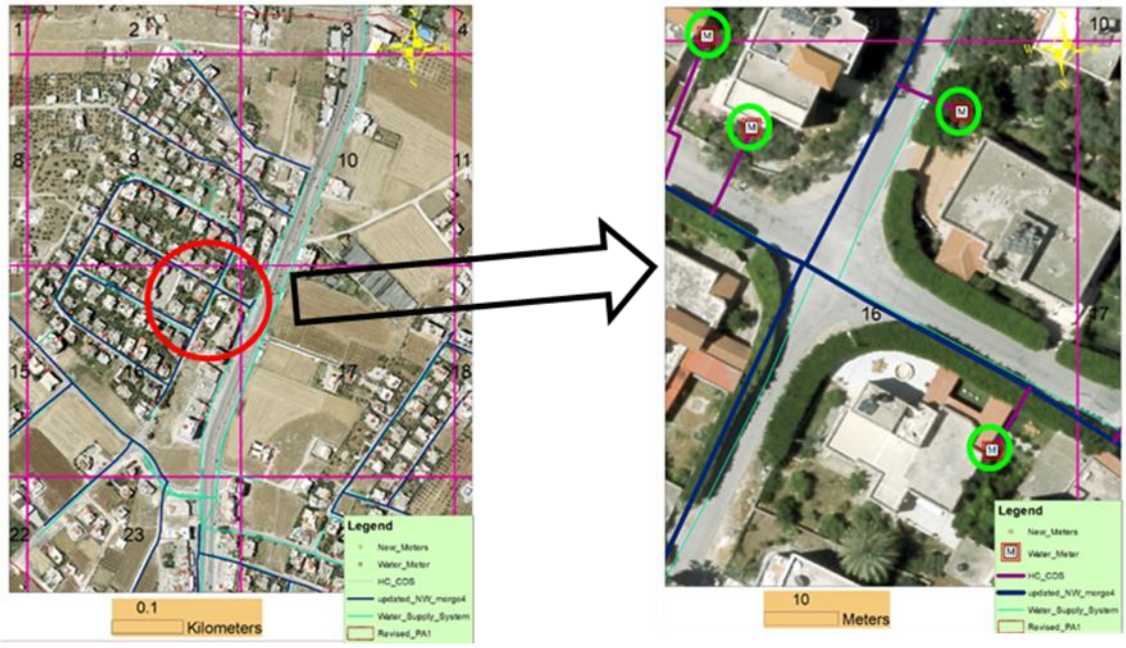


Figure 12-1: Selected area for survey (left) and zoomed in map of the area

- Select a grid or an area in the map,
- Prepare zoomed-in map (scale 1:500-1:1000),
- Listen to any exposed part of pipe, fittings, hydrants, meters, valves etc,
- Record the location on the map and fill up the check sheet if any suspicious sound is found,
- Continue the process until the whole area is covered.


Figure 12-2: Showing the activities under Step (1) 'Area-Wise Approach'

Step (2): Line-Wise Approach

When a suspected leak sound is found during Step (1) 'Area-Wise Approach', the leak detection survey should continue along the connected distribution pipelines by using ground microphone.

The red line on the right map shows the alignment of distribution pipeline with high possibility of leakage along the pipe and its house connections, according to the result of Step (1) 'Area-Wise Approach' conducted during daytime. In Step (2), a road hearing survey should be conducted along this pipeline using ground microphone during night time when external noise is less.

The sound of pseudo leakage is easily confused with the real leakage sound, since both have the same frequency band. Thus, it is necessary to tell the difference between them through practices.

Figure 12-3: Line-Wise Survey Using Ground Microphone

12.3.3 Precaution against external sound interference (Pseudo Sound)

There is a need to wait before starting the survey because when the water-feed has just begun, there tends to be many noises caused by the running water.

The surveyors record all the detected sound as possible /probable leakage sound while executing leakage survey. The detected sound may include pseudo leakage sound, which is similar to the leakage sound and is a critical obstacle during the survey. In order to differentiate the real from the pseudo leakage sounds, it is necessary to obtain many years of site experience.

Typical examples that may be confused with leakage sound are as follows.

a) Turbulent flow sound inside pipe

When the water passes flow-regulating devices such as gate valves, pressure reducing valves and reducers, it generates vibration-like sound of which frequency is like the leakage sound and which is hard to differentiate especially when the distance is far. When the gate valve is not opened fully, the sound of turbulent water is so similar to the leakage sound. So, at the location where gate valves or other flow-regulating devices are installed, it is necessary to conduct the leakage survey when the valves are fully closed or opened.

b) Circuit sound such as electric power cables

Electric current flow generates low frequency sound of 300 Hz or more by electric discharge vibration, from underground cables, transformers on utility poles, streetlights etc.

c) Sound from filling of customer tanks

Sound from filling of customers' water tanks is similar to the leakage sound.

d) Stream sound in drainage

The stream sound in drainage including the fall sound in the manhole is similar to leakage sound and thus hard to differentiate.

e) Sound of running vehicles

The running sound of cars is transitory and easy to distinguish because the volume changes irregularly. However, the friction sound of the tire with the road surface is easily confused with the leakage sound.

f) Noise of wind

Sound of low velocity wind is different from that of leakage but when the velocity of wind increases the sound becomes similar to that of leakage and it becomes difficult to distinguish between the sound of wind and leakage.

g) Town noise

In urbanized area, various sounds such as from air-conditioning equipment and running cars are mixed together, which is similar to the leakage sound.

13 STEP-TESTING AND STOP-COCK METHODS

Flow step-testing is a method to identify areas of potentially high leakage / unauthorized water use within a DMA or area of a distribution system by sequentially closing and opening sectional valves within the area. In this method, sections of network are closed by valves one-by-one (in steps) while monitoring inflow to the area at the same time. If closing some sections (blocks) results in a disproportionately higher drop in inflow, that indicates a potential high leakage / unauthorized water use in that block. Flow step-testing method can be helpful to identify areas of higher leakage when it is difficult to do intensive sounding surveys due to various reasons. For smaller areas stop-cock method gives more accurate and reliable result. Outline of these methods with practical examples of their application in the Pilot Area is given in this section of the manual/guideline.

13.1 Step-Testing

The principle of the flow step-testing is to divide an area into several blocks by internal valves, monitor inflow to the area by a meter, systematically reduce the size of the area by closing valves on the inlets to each block (isolating the block) one-by-one while monitoring the flow rate going into the whole area through the meter. A large drop in flow rate when a valve to particular block is closed (isolated) indicates higher leak in that block.

The step-testing gives more reliable result if:

- the supply system is a continuous (24×7) system,
- the testing is done during minimum night flow (MNF) time (often between 01.00 a.m. and 04.00 a.m.), and
- supply to known big customers is temporarily closed or their meters are monitored during the testing time.

In case of intermittent system the test should be done after the area is supplied long enough to satisfy the demand of customers and the customer tanks are filled. Even then the test gives only some idea of higher water loss but it does not give any definite result because it is likely that some customers might have still been filling tanks or using water during the test period.

13.1.1 Basic requirements for flow step-testing

(1) The configuration of distribution system should be such that by closing a valve (or valves) it should be possible to completely isolate a particular section of the network,
(2) The distribution system should have enough number of valves or it should be possible to install a few new valves to isolate sections of the network,
(3) It should be possible to measure inflow to the planned test area by means of an existing bulk meter or by installing portable ultrasonic flowmeter,

(4) The size of the individual steps depends on the size of the area, configuration of pipe network, and availability of isolation valves. In an area of about 500 connections a step size of approximately 50 connections is preferable. It is advisable not to have more than 10 steps.

13.1.2 Methods of step-testing

There are two main methods of step-testing; 1) Isolation method, and 2) Close and open method.

(1) Isolation Method
This method involves the successive closing of valves starting from the furthest point from the meter resulting in gradual reduction in the area being supplied by the meter. The sequence of closing valves is progressively carried out working back to the meter where the flow should drop to zero. Under this method the entire DMA is de-pressurized for some time and this can cause back-siphonage or the risk of infiltration of ground water in pipe network. The example given in 1.2 below uses this method.

(2) Close and Open Method
This method involves closing valves to isolate each individual step and once the reduction of flow has been recorded the valves are reopened. This method does avoid parts of the system being without water for a longer period of time but it requires waiting time after each step till the flow is stabilized. Otherwise, the reduction in flow rate from some steps can be compensated by additional flow from recharging of previous steps, thus making interpretation of result more difficult.

13.1.3 Overall procedure of step-testing

Overall methodology of step-testing by isolation method is explained below. Refer to Figure 13-1 for the map.

(A) In case of continuous (24×7) supply

(1) Plan to conduct the test during MNF time (between 01.00 a.m. and 04.00 a.m.). Make sure the area is completely hydraulically isolated from adjoining areas,

(2) Check and confirm that all the internal valves are fully open,

(3) Start recording/logging flow from the bulk meter. This process should continue until the end of the testing period,

(4) Close valve 1, note the exact time of closing, wait for a few minutes,

(5) Close valve 2, note the exact time of closing, wait for a few minutes,

(6) Close valve 3, note the exact time of closing, wait for a few minutes, and finally

(7) Close valve 4, note the exact time of closing. The flow rate should now be zero. If not, there is some problem between the meter and valve 4, so investigate,

(8) Open the valves in reverse order, i.e., open valve 4, then 3, 2, and 1. Note time of opening of each valve. After opening each valve, wait for a few minutes until the flow rate stabilizes,

(9) Download flow data from the logger. Plot a graph of time versus flow rate. Mark the time of closing and opening of each valve. Calculate reduction in flow rate when the valve of each block is closed. The block which resulted in the highest reduction in flow rate is suspected to have the highest leakage.

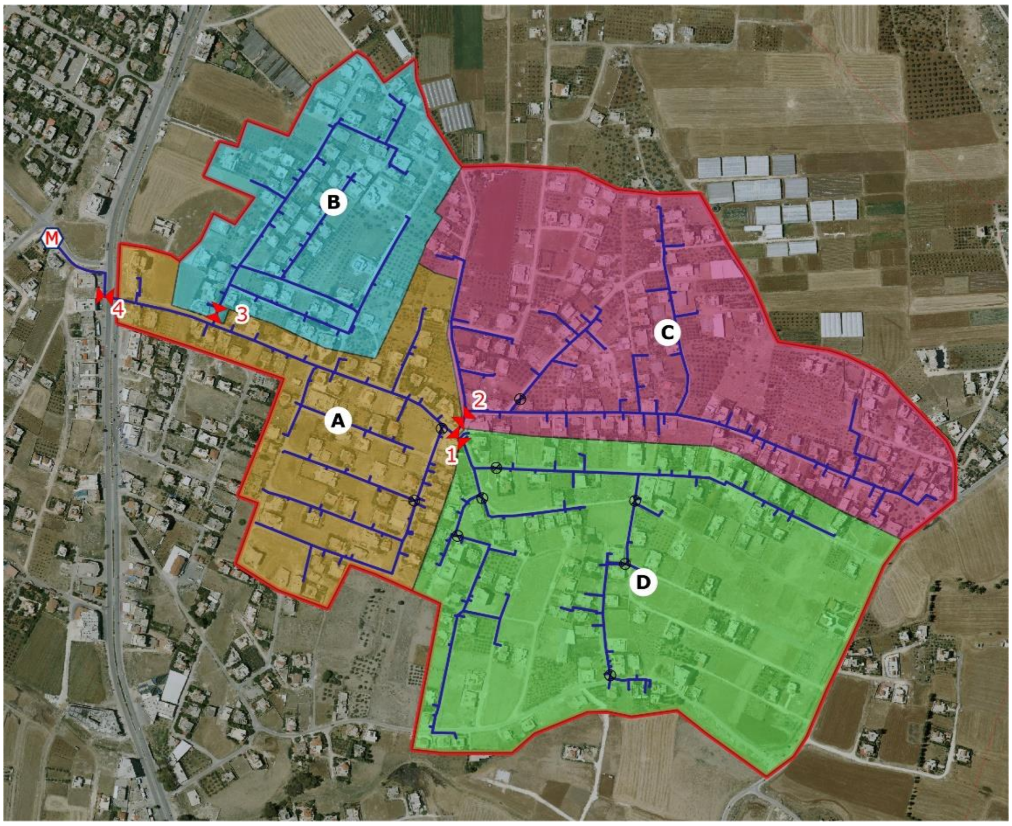


Figure 13-1: Flow step-testing blocks

(B) Case of intermittent supply

(1) Testing time can be any time when the customers' demand is satisfied and their tanks are filled,

(2) Check and confirm that all the internal valves are fully open,

(3) Confirm that water passing through the meter is going only in this area, not in any other area outside it. Start recording/logging flow from the bulk meter. This process should continue until the end of the testing period,

(4) Close valve 1, note the time of closing, wait for a few minutes,

(5) Close valve 2, note the time of closing, wait for a few minutes,

(6) Close valve 3, note the time of closing, wait for a few minutes, and finally

(7) Close valve 4 note the time of closing. The flow rate should now be zero. If not, there is some problem between the meter and valve 4, so investigate,

(8) Open the valves in reverse order, i.e., open valve 4, then 3, 2, and 1. Note time of opening of each valve. After opening each valve, wait for a few minutes until the flow rate stabilizes,

(9) Download flow data from the logger. Plot a graph of time versus flow rate. Mark the time of closing and opening of each valve. Calculate reduction in flow rate when the valve of each block is closed,

(10) Calculate the percentage of flow rate reduction for each block when this block is closed,

(11) Find the number of connections in each block from GIS or customer record. Calculate the percentage of connections in each block,

(12) Compare percentage of connections in each block to the percentage of flow reduction by closing that block. Any block which has disproportionately larger flow reduction indicates that block has bigger leakage problem.

13.1.4 Detail procedure of step-testing

(1) Identify potential step testing blocks within the planned step-testing area,
(2) Prepare a map indicating blocks and valves needed to hydraulically isolate each block,
(3) Confirm working condition of existing valves, install new valves if required,
(4) Find out the number of total connections, non-domestic customers, special need customers such as hospital etc in each block,
(5) Prepare for flow measurement; if there is no suitable DMA meter, prepare space for installing portable ultrasonic flowmeter,
(6) Conduct the test,
(7) Plot the time versus inflow rate graph, calculate reduction in inflow rate after closing each block,

In case of intermittent supply system continue to (8) and (9).

(8) Compare the percentage of connections to the percentage of inflow rate in each block,
(9) Identify the blocks where the inflow rate is disproportionately higher compared with the percentage of connections.

Explanation

(1) Identifying potential step testing areas

Number of steps should be decided depending on the configuration of pipe network, size of each step, and whether valves already exist or need to be installed new. Figure 13-1 shows an area which has branched pipe configuration. If medium size steps are preferred this area can be divided into 4 steps. It is possible to divide this area into more than 4 steps also the steps will become smaller and will take much longer time to do the test.

(2) Preparing map indicating blocks and valves needed to hydraulically isolate each block
Update pipe network map including valves. GIS map with the latest basemap will be easier to use than paper-based map. Find out the valves required to isolate the blocks. Check if existing valves can be used or new valves should be installed.

(3) Confirming working condition of existing valves, installing new valves if required,
Check if the proposed existing valves are operational, i.e., if they can be fully closed and open. If not, replace them with new operational valves. Install new valves where required.

(4) Finding out the number of connections in each block
This is easier done if customers are mapped in GIS. Count the number of customer connections in each block. Calculate the percentage of connections in each block. Roughly, the flow going into each block should be in the proportion of the number of connections. If any customer who has non-domestic water use (such as industry) exists in any block, estimate the water requirement of such customers and add it to their block. For the example of Figure 1, the number and percentage of connections are as shown in Table 13-1.

Table 13-1: Number of connections in each block

Step	Block No.	Number of connections	Percentage of connections (%)
1	D	73	25.1
2	C	69	23.7
3	B	57	19.6
4	A	92	31.6
Total		291	100.0

(5) Preparing for flow monitoring
If there is a permanent flowmeter installed upstream of the test area and if it is possible to supply only the test area by closing all other branches during the test, then this flowmeter can be used. If the meter is not available or other branches cannot be closed during the test, then a temporary flow measurement system should be adopted. This can be a temporary installation of any type of meter or use of portable clamp on ultrasonic flowmeter. In the above example, there exists an electromagnetic flowmeter upstream and it is possible to close supply to all other branches, so the existing flowmeter can be used.

(6) Conducting the test

If the supply is continuous (24×7) conduct the test during minimum night flow time which is generally during 1:00~4:00 a.m. If the supply is intermittent, wait until customer demands are satisfied (customer tanks filled) and then start the test. Extension of supply time may also be necessary sometimes. For the method of test, refer to Section 1.3 above. Record the flowrate using data logger at logging interval of about 1 minute from the beginning to completion of the test.

(7) Plotting the graph and calculating percentage reduction in inflow to each block
Download flow data from the logger if it is logged. Plot time versus flow rate for the duration of test. An example of such plot is shown in Figure 13-2.

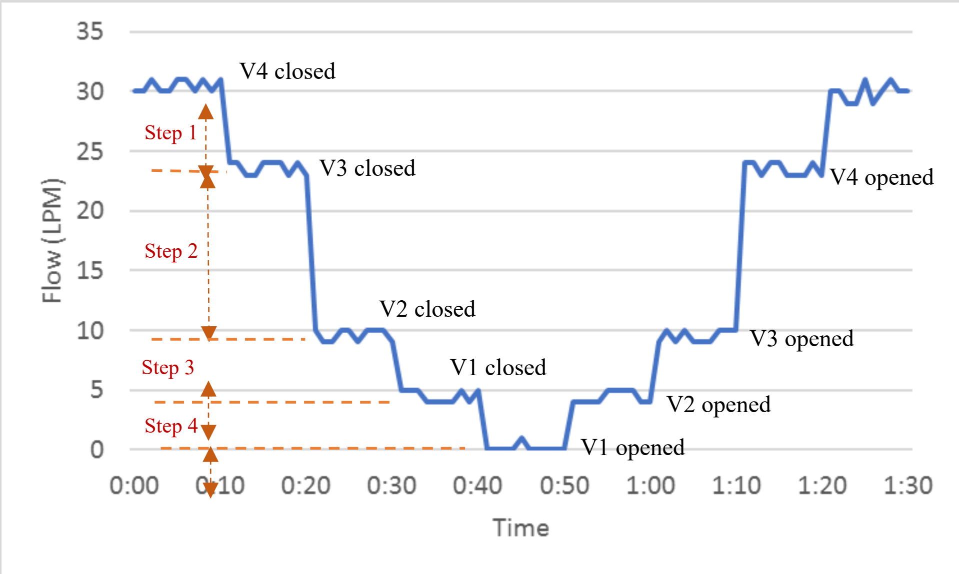


Figure 13-2: Example plot of Time versus Inflow for Step-testing

Reduction in flow rate after closing of each block can be calculated as shown in Table 13-2.

Table 13-2: Example calculation showing reduction in flow rate after closing each block

Step	Block No.	Flow rate before closing (LPM)	Flow rate after closing (LPM)	Reduction in flow rate (LPM)	Reduction in flow rate %	Remarks
1	D	30	23	7	23	
2	C	23	9.5	13.5	**45**	Disproportionately high flow, likely high leakage / illegal use
3	B	9.5	4.5	5	17	
4	A	4.5	0	4.5	15	
Total		30	0			

(LPM: Liters per minute)

The flow measurement time is around mid-night, so it would reflect MNF if the area had a continuous (24×7) supply system. In that case block C could have been said straight forward to have the highest leakage / illegal use because closing this block resulted into the highest drop in inflow rate.

(8) Comparing the percentage of connections to the percentage of inflow rate in each block

If the area is not a continuous supply area there is more possibility that the customer demands are still not satisfied and some customer's tanks might have been filling during the step-test period. In such a case comparison of customer number and inflow percentage in each block gives more reliable result.

The customer data of Table 1 and flow data of Table 13-2 can be combined and compared as shown in Table 13-3. The block C has about 24% customers but 45% inflow. Thus this block likely suffers from the highest leakage / illegal use.

Table 13-3: Example comparison of customer number and flow reduction

Step	Block No.	Percentage of connections (%)	Reduced flow rate %	Remarks
1	D	25.1	23	Almost similar
2	C	23.7	**45**	Disproportionately high flow, likely high leakage / illegal use
3	B	19.6	17	Comparable
4	A	31.6	15	Inflow percentage is lower. Less likely to have leakage / illegal uses
Total		100.0		

13.2 Stop-Cock Method

As its name implies, principle of this method is simple; close all the customer taps at the customer meter and see if any water is flowing into the area. The inflow water when all known customer taps are closed is either leakage or illegal use.

This method gives more reliable result compared to step-testing but is more labor-intensive because it requires closing of all customer taps. This method is thus suitable only for smaller areas where the customer meters are easily accessible and pipe network structure is such that it is possible to monitor water inflow to the area by an existing or temporarily installed flow meter.

13.2.1 Basic requirements for stop-cock method

The main requirements for this method are:

(1) All the customer meters should be easily accessible to the water utility staff,

(2) Each customer connection should have a stop-cock or it should be possible to install stop-cocks in front of customer meters without much problem, and
(3) It should be possible to measure inflow to the planned test area by means of an existing bulk meter or by installing a temporary flowmeter.

13.2.2 Procedure of stop-cock method

(1) Inform the customers in the test area about the purpose and timing of test,
(2) Prepare a detailed map showing pipe network and customer meter locations,
(3) Check and confirm availability and working condition of stop-cocks at each customer connection. Replace defective ones and install new if some connections are found to be lacking the stop-cocks,
(4) Check and confirm the condition of bulk meter which is to be used for the test. If required prepare for installing temporary flowmeter / portable meter,
(5) Conduct the test, and
(6) Analyze the result.

Explanation

(1) Informing the customers
The customers should be taken into confidence by informing about the purpose and planned timing of the test. The test should be planned during such time when it is most likely that customers are at home to open the gates if their meters/taps are inside the gated compound.

(2) Preparing a detailed map
The map should preferably be in GIS format and should show all pipe network down to customer meters. The location of customer meters should be clearly indicated. If possible, pertinent customer information such as names, use type, recent consumption volume etc should also be prepared separately and taken together with the map for reference.

(3) Checking and confirming availability and condition of stop-cocks
As a preparatory step, each customer connection should be checked for availability of stop-cocks and working condition of available stop-cocks. Not-working stop-cocks should be replaced. New stop-cocks should be installed if any connection is found to be without it.

(4) Preparing for inflow measurement
If there exists a bulk meter which can be used exclusively to measure inflow to the test area by closing all other areas, it can be used. In this case, it should be tested and confirmed that no water flows to the areas other than the test area during the test period. This can be checked by closing all the branches after the bulk meter and confirming that the flow rate comes down to zero when the inlet pipe to the test area is closed. If a bulk

meter with such arrangement is not available, then flow measurement can be done by installing a temporary flow meter (or portable ultrasonic flow meter) near the inlet point of the test area.

(5) Conducting the test

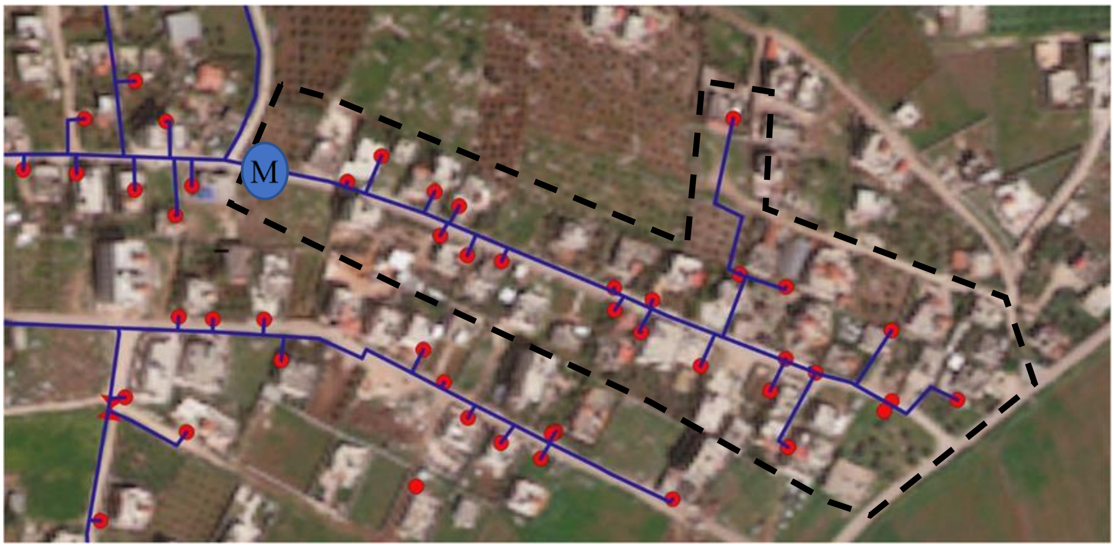
The test procedure is as below:

1) start recording/logging flow at the bulk meter / temporary / portable flow meter,
2) close the stop-cocks of each connection inside the test area. Some connections might have been already closed by the customers. Note such connections if found. Note the time after completion of closing all the connections,
3) wait for a few minutes and note the flow rate. If there is no leakage or illegal water use at that time, the flow rate should be zero,
4) open the stop-cocks which were open before the start of the test. Leave the stop-cock closed if they were found to be closed before the start of the test.

(6) Analyzing the result

Download the logged flow data. Plot a graph of time versus flow rate. If the flow rate does not come to zero after closing all the stop-cocks, consider further dividing the area into smaller parts and conducting the test in each part separately to narrow down the search for leak or illegal water use.

Example layout of area and result of the stop-cock test method are shown below.



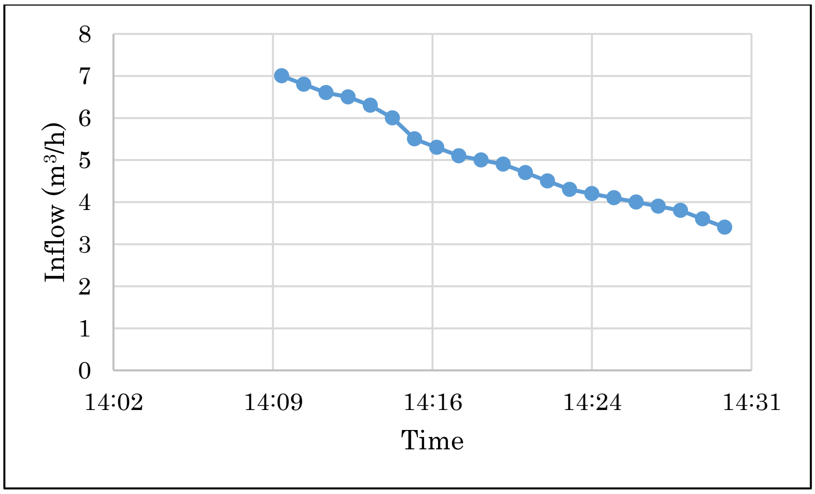


Figure 13-3: Example layout of area tested by stop-cock method (above) and result

In the above example, the pipe network and customer meter location map is prepared in GIS. Inflow to the test block is monitored through a temporary or portable flow meter M. All the After starting to record the flow at around 14:00 hrs, the house connections were closed one by one by closing the stop-cocks near the customer meters. The closing process started from the far end of the network and progressed towards the bulk meter.

The time versus inflow rate plot shown below the layout indicated that the inflow rate decreased gradually when the house connections were closed but it did not come down to zero even when all the known connections were closed. It remained at about 3.2 m^3/hr. Meaning of this is simple; this area This indicated that there existed a big leakage or illegal connection in this area.

13.3 Case Study of Step-Testing, Stop-Cock Methods and Intensive Survey done in 24-hr Supply Area of PA1

Sub-area 1 of PA1 has continuous (24×7) water supply. NRW measurement of this area showed high NRW ratio (~50% or more) for several months. Surveys conducted for leakage detection and unauthorized connections were not able to find the causes of this high NRW. Thus, the following two methods were applied.

A. Flow Step-Testing

Figure 13-4 shows the location, network layout and valves prepared for the test.

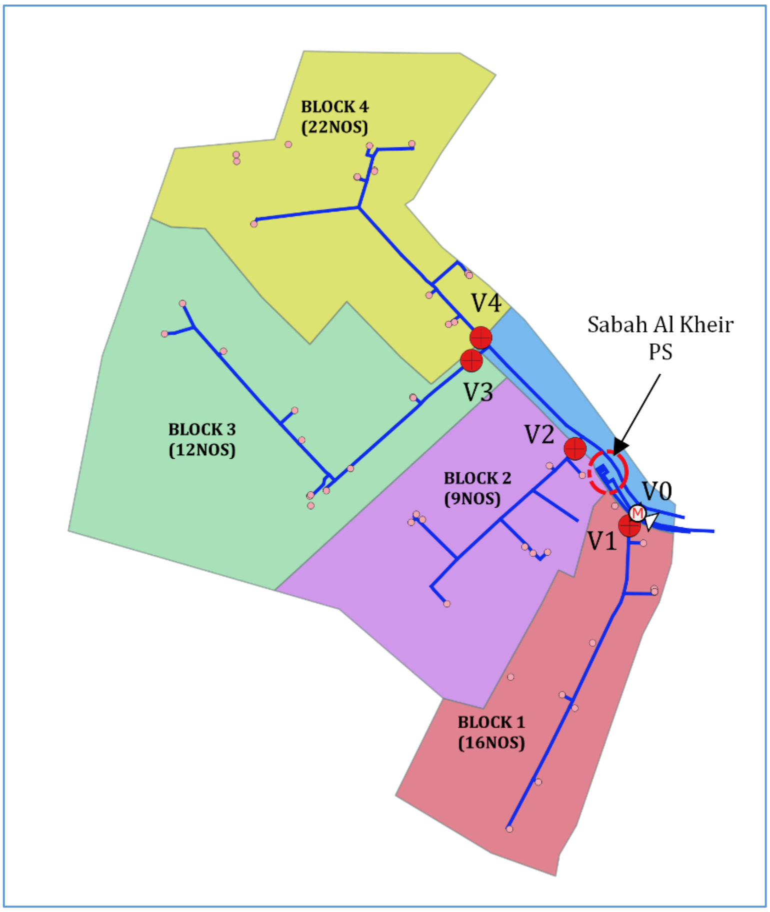


Figure 13-4: Layout of Step-Testing blocks showing valves and customer numbers

The area is supplied through a single 50 mm inlet. The inlet has a permanently installed mechanical flow meter with pulsar connection for data logger, a valve (marked as V0), and a tapping for pressure measurement. There is also portion of exposed pipe where ultrasonic flowmeter could be installed.

Four isolation (step) valves (V1, V2, V3, and V4) were installed at four branches. By closing these valves, the area was divided into four hydraulically isolated blocks, named as Block 1 through Block 4.

Number of customers in each block:

Block	Block 4	Block 3	Block 2	Block 1	Total
No of customers	22	12	9	16	59
Percentage of customers	37.3%	20.3%	15.3%	27.1%	100.0%

(1) Test procedure

The test was done three times: twice in the daytime and once during early morning (minimum night flow time; 03~04 am). Each time the process was:

✧ Install portable ultrasonic flowmeter at the inlet pipe and start logging flow data.

✧ Close the valves V4 through V0 sequentially as follows:
Step 1: Close V4 completely, wait until the flow reading becomes stable (2~3 minutes)
Step 2: Close V3 completely, wait until the flow reading becomes stable (~1 minute required in every step)
Step 3: Close V2 completely, wait until the flow reading becomes stable
Step 4: Close V1 completely, wait until the flow reading becomes stable
Inflow became 0 after closing the four valves, so closing V0 was not required.

✧ Now open the valves in reverse order, from V0 through V4:
Step 1: Open V1 completely, wait until the flow reading becomes stable (2~3 minutes required in every step)
Step 2: Open V2 completely, wait until the flow reading becomes stable
Step 3: Open V3 completely, wait until the flow reading becomes stable
Step 4: Open V4 completely, wait until the flow reading becomes stable

(2) Results

Tests were conducted on 23rd and 24th July. The flow values after each step are summarized below.

Table 13-4: Results of step-test in PA1

Date & Time		All open (LPS)	Closing sequence			
			V4 (Block 4) closed	V4 and V3 (Block 4 & 3) closed	V4, V3, & V2 (Block 4, 3, & 2) closed	V4, V3, V2 & V1 (Block 4, 3, 2, & 1) closed
Test 1 23rd July 16:40~17:10	Flow rate (LPS)	1.624	1.521	1.204	0.71	0
	Flow reduction of each block	0	-6.3%	-19.5%	-30.4%	-43.7%
Test 2 24th July 2:18~2:43	Flow rate (LPS)	1.397	1.281	0.996	0.477	0
	Flow reduction of each block	0	-8.3%	-20.4%	-37.2%	-34.1%
Test 3 24th July 3:54~4:15	Flow rate (LPS)	1.332	1.26	0.996	0.475	0
	Flow reduction of each block	0	-5.4%	-19.8%	-39.1%	-35.7%

The flow results for Test 1 and Test 2 are shown graphically below.

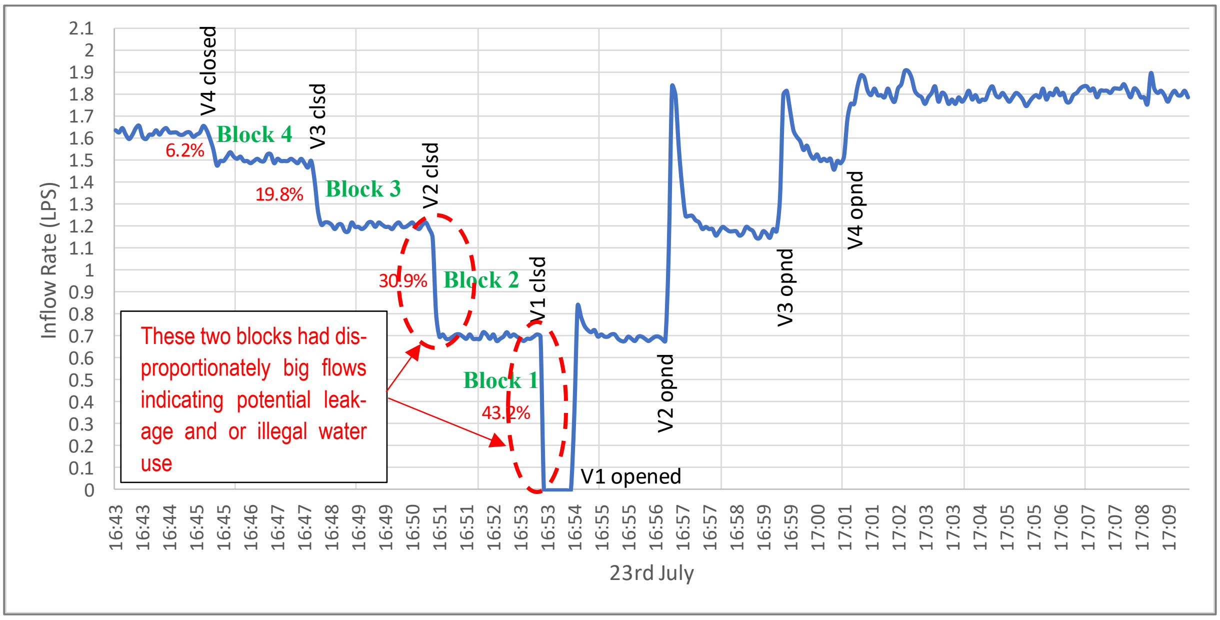


Figure 13-5: Flow profile of Test 1

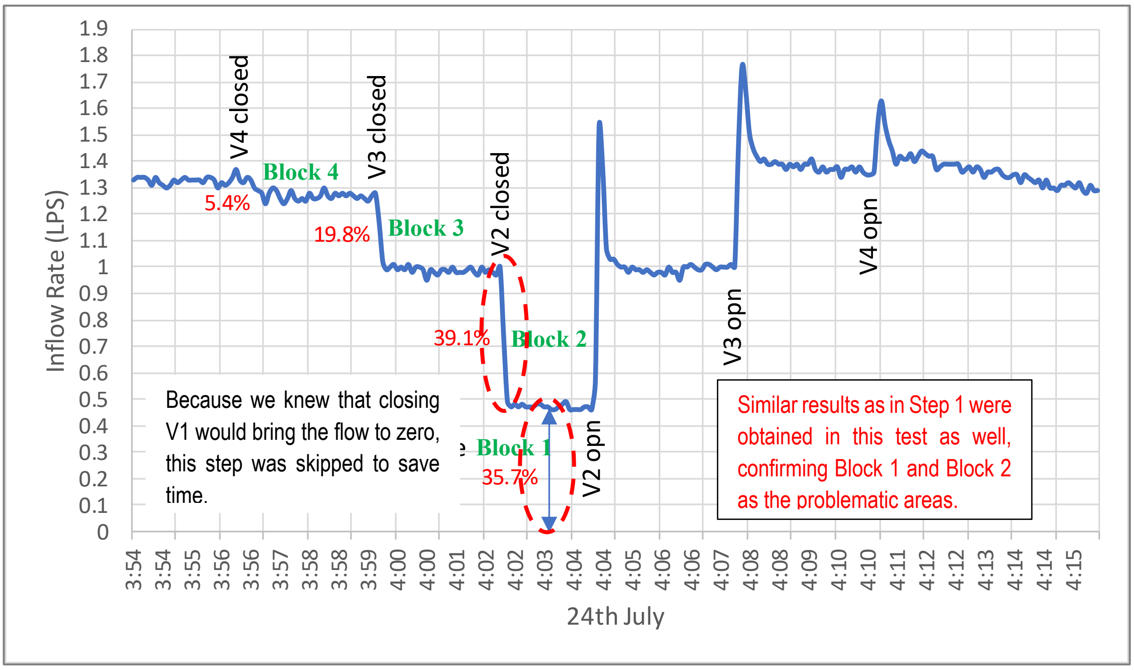


Figure 13-6: Flow profile of Test 2 (conducted during night time)

The above result clearly showed that Block 4 and Block 3 did not have much problem but the remaining two blocks (Block 2 and 1) had problems.

B. Stop-Cock Method

The test was done for Block 1 and 2 as these blocks indicated disproportionately big in-flow. The test was done during daytime.

The inflows to the blocks after closing all known consumption are shown below.

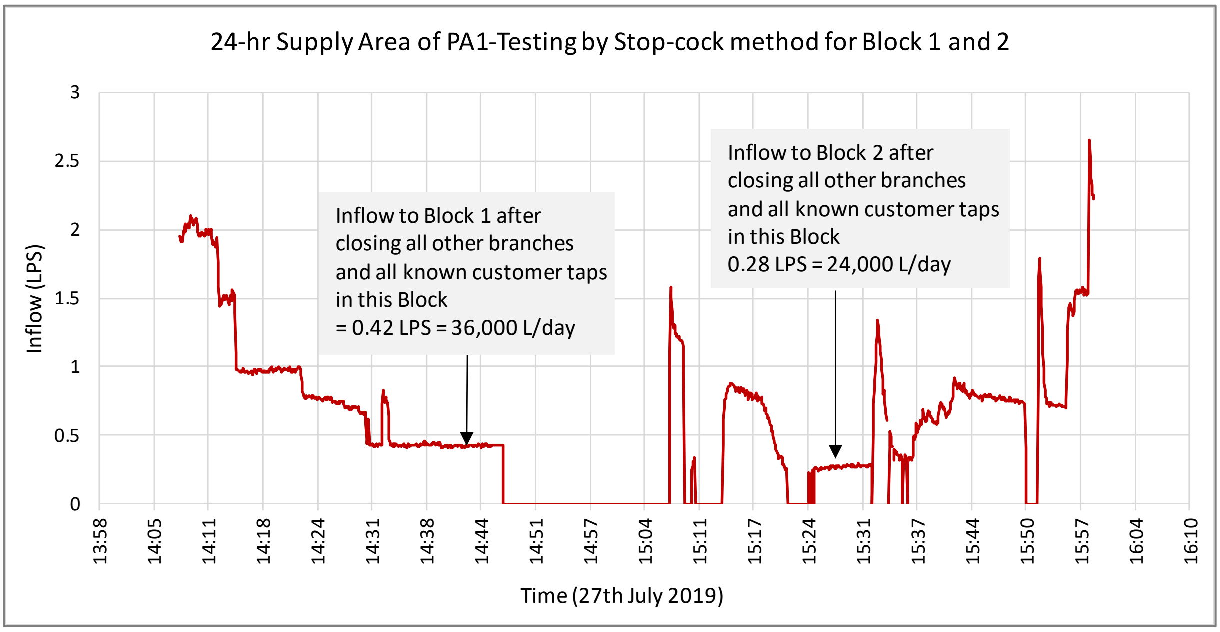


Figure 13-7: Inflow to Sub-area 1 during Stop-cock method survey

The above figure shows that significant quantity of water was flowing into these blocks even after closing all known consumption.

C. Repetition of Flow Step-Testing

The two problematic blocks were intensively surveyed for any possible sign of leakage and illegal water use. A lot of water like a swamp was found outside the compound of one customer in Block 2. He was informed about the possibility of leakage. The water dried down the next day but we were never told about the reason. In Block 1 nothing could be found even after digging several suspected places and inspecting every house for any illegal water use. Repetition of the step-test next month on 5th August 2019 showed that the inflow to Block 2 decreased drastically after that event (Figure 13-8) .

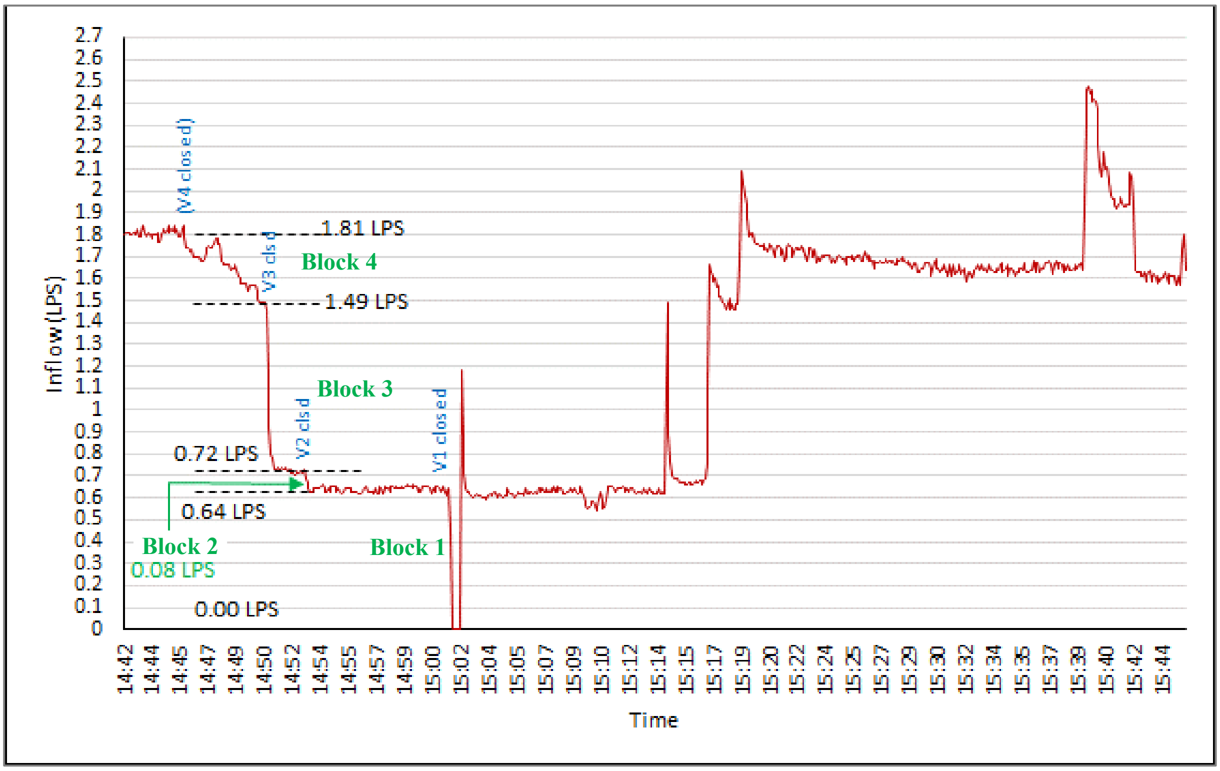


Figure 13-8: Result of flow step-testing on 5th August 2019

In the subsequent months from August to October the monthly water inflow to 24-hr area remained high crossing 3000 m^3 per month and resulting in a very high NRW. For example, NRW of this area in June reached 61.5%.

D. Next Stage of Intensive Works (In Nov 2019)

In order to find out the reason for this high inflow and thus high NRW in this Sub-area, intensive surveys were again conducted in November 2019. The survey included:

- repetition of step tests,
- stop-cock method,
- sounding surveys,
- sectioning (sub-stepping) of branch in this block, and
- excavation along the branch pipe.

(1) Repetition of Flow Step-Testing

Flow step-testing was repeated to see if any changes occurred in inflow to each block compared with the results of August. The result (as shown in Figure 13-9) showed that steps 4, 3, and 2 remained almost same as of last time but step 1 increased disproportionately. About 50% water was going into this block (block 1) while it only had 27% of total connections.

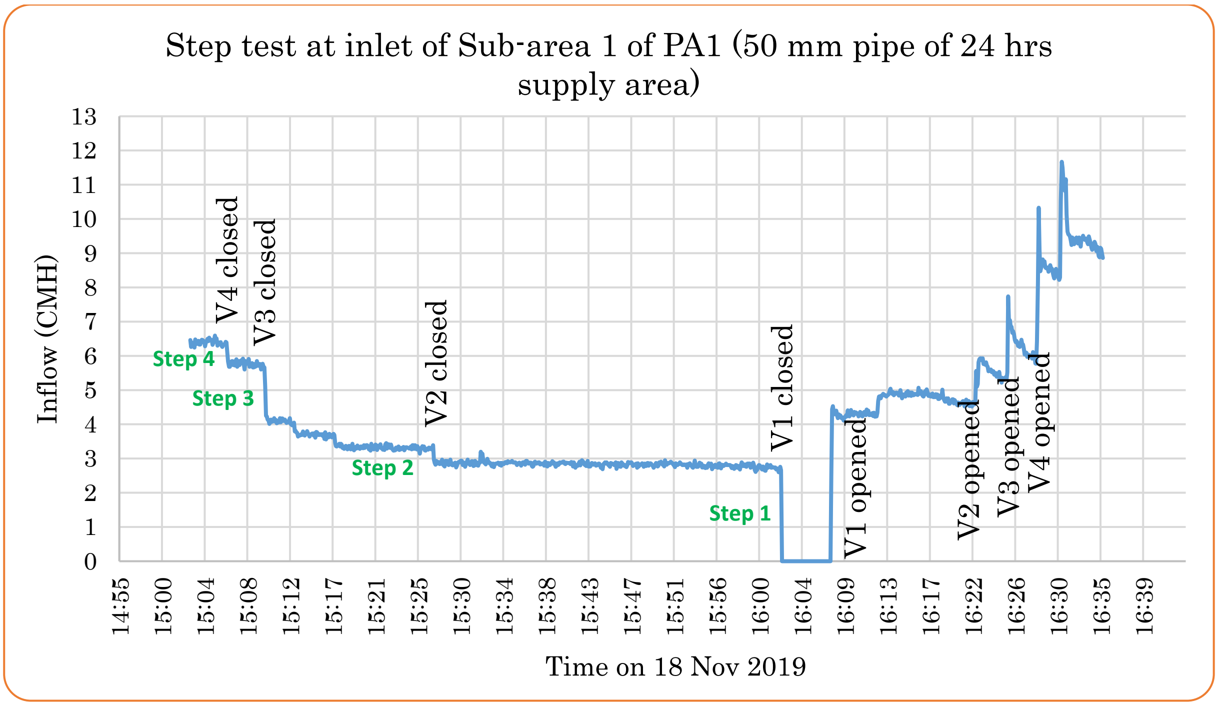


Figure 13-9: Result of flow step-testing on 18th Nov 2019

(2) Repetition of Stop-Cock Method in Block 1

All the three valves (V4, V3, and V2) were closed while leaving V1 open. All known customer meters in block 1 were closed. Even then the inflow to block 1 was found to be about 12 m^3/h on 24th Nov, as shown in Figure 13-10. This was a huge flow, going to unknown. This clearly indicated that the main problem lied in block 1. Survey was conducted for visible leakage and unauthorized connection in this block but nothing significant could be found.

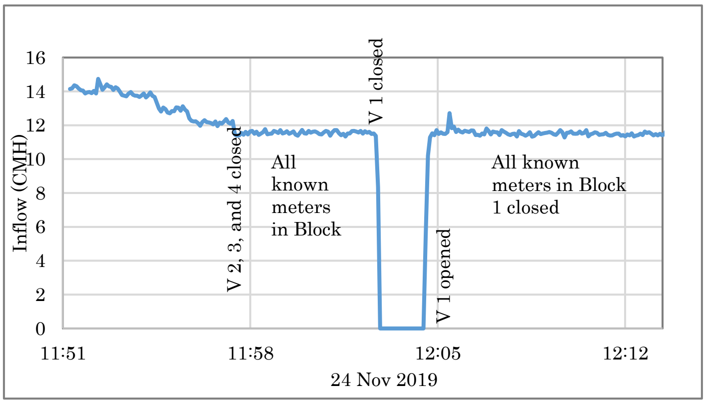


Figure 13-10: Result of stop-cock method in block 1 conducted on 24th Nov 2019

(3) Sounding Survey in Block 1 and Replacement of a Suspected House Connection

Sounding survey by using listening stick and ground microphone was conducted. Loud sound was first heard at the meter near V1-2 shown in Figure 13-11.

Since the house connection was passing through compound wall the connection was modified by discarding the old connection and making a new connection direct to the meter. The sound near the meter disappeared. But inflow to this block did not decrease even after this change.

(4) Dividing the Branch into three Segments to Narrow Down the Problematic Section

To narrow down the problematic area, the branch in block 1 was divided into three sections by installing valves V1-1 and V1-2 as shown in Figure 13-11. These could be considered as sub-steps. All the other 3 branches (V4, 3, and 2) were closed while this branch remained open (V1 open). Then the first sectioning valve V1-1 was closed. Inflow was monitored by the ultrasonic flowmeter installed at the inlet. The inflow remained almost same even when V1-1 was closed. This clearly indicated that the problem lied between V1 and V1-1. There was a big water flow noise in the house connections in this area but no definite indication of water leak or water passage could be found. The sound was particularly loud at the meter of second house connection (marked with yellow outline). This house had a big underground tank and the house was a shop, so not much water was used. Investigation using ground microphone was made around the tank and meter but nothing unusual could be found. Then the next step of excavation was applied.

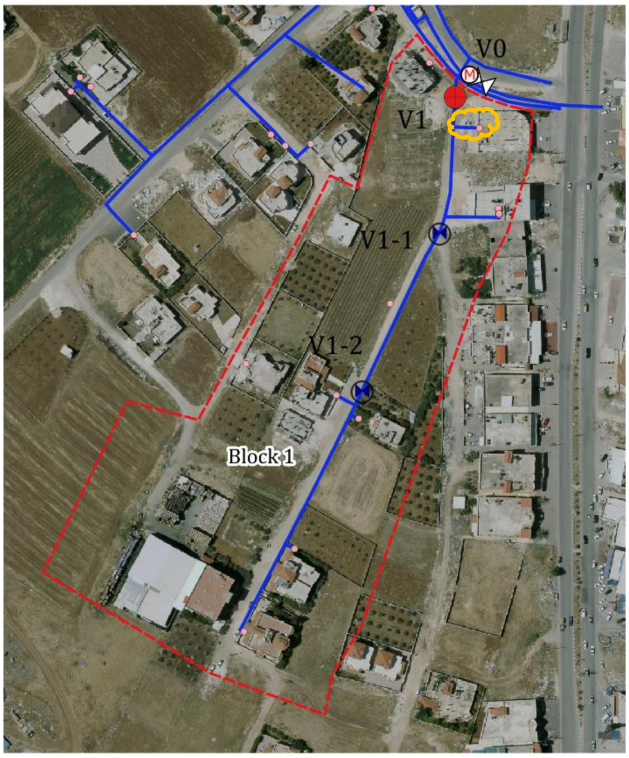


Figure 13-11: Sectioning of Block 1

(5) Excavation along the Branch Pipe in Block 1

Excavation started from V1 and proceeded forward. First HC was closed, no sound of water flow could be heard. When we reached the second house connection a big sound of water flow was heard. Meter of this HC was closed, no water was entering or leaving the ground tank.

During the excavation, the connection was broken from the tapping point. The tapping was by a tee and the HC pipe was a 25 mm GI pipe in good condition. This tapping was then closed by a plug. As soon as it was plugged the sound disappeared, and the flowmeter at the inlet showed a perfect zero. The result of step-test immediately after this is shown in Figure 13-12. It proved that the unknown water was passing through this HC.

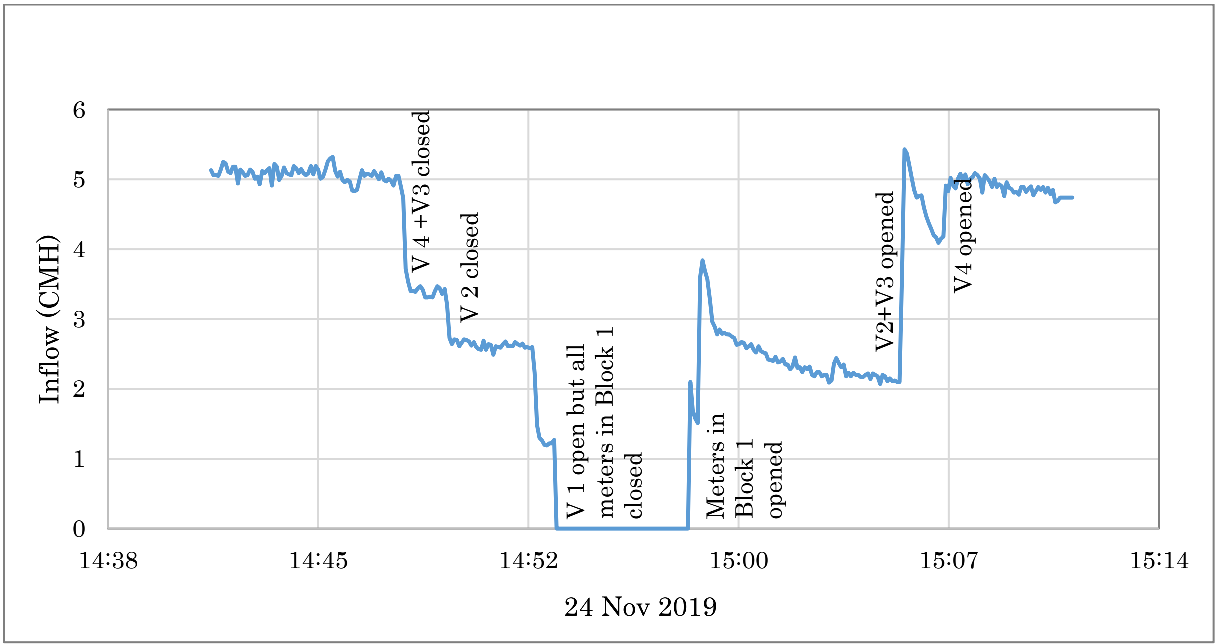


Figure 13-12: Result of step test after finding and closing the problematic house connection on 24th Nov 2019

In the next step the plug was opened and the HC was connected in order to do investigation by sounding. No definite conclusion could be reached by the survey. The HC was then disconnected. It was noted that backflow water kept coming from the HC for more than 40 minutes when it was disconnected. The water coming out from this HC was turbid in the beginning, but it became clear like drinking water after about 5 minutes. From where this water came is still not clear.

There was a suspicion that this line might have been connected with some irrigation line. So excavation was done along this HC until the compound wall of the building. No branching was found. Inside the compound it was not possible to excavate as it was covered by a thick concrete surface and was a private property. When the pipe was pulled from outside, about 12 m long pipe came out but no sign of branch was visible in that section.

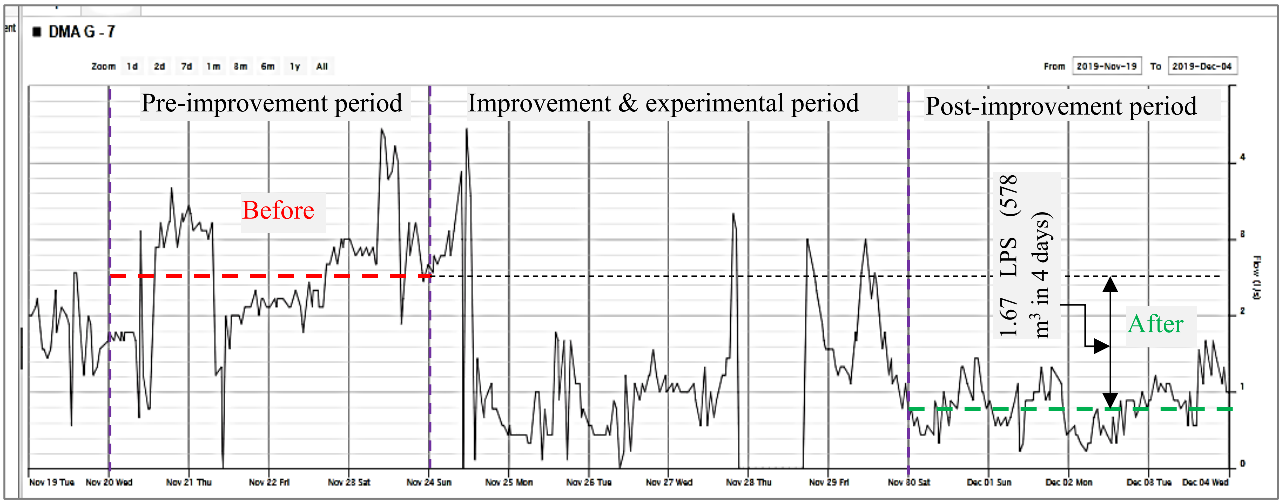


Figure 13-13: Inflow to 24-hr area before and after closing the connection

Average inflow to the 24-hr area decreased after closing this HC as shown in Figure 13. This figure is extracted from the flow profile recorded by data logger installed at the inlet of 24-hr branch. As a result of this work, water saving of about 1,200 to 1,500 m³ per month compared to the months from May to October 2019 was achieved. Before May 2019 the inflow in this area was already lower, in the range of 1,700 to 2,000 m³/month.

To sum up, two big leaks /illegal water uses were found in the 24-hr supply area of PA1 by the intensive survey work including flow step-testing and stop-cock methods and substantial reduction in water loss was achieved.

13.4 Combination of Stop-Cock and Sounding Survey

This method is suitable for smaller areas where it is possible to supply water from only one entry point and isolate the area from the surrounding areas. Then water inflow to the area is monitored at the entry point by means of a temporary flowmeter and all customer taps within the area are closed one-by-one. If there is no leakage or unknown (illegal) connections in the area, the water inflow rate should become zero. Otherwise, it indicates either leakage or unknown (illegal) connections in the area. Then sounding survey can be done at each connection to find out leakage or illegal water use. This method is simple and gives more clear result compared to step-testing but is more labor-intensive because it requires closing of all customer taps.

The followings are the basic requirement to apply this method:

- It should be possible to hydraulically isolate the test area from adjoining areas except at one entry point and measure inflow to it by means of an existing bulk meter or by installing a temporary flowmeter at that point,
- All the customer meters should be easily accessible to the water utility staff,
- Each customer connection should have a stop-cock. If not, it should be possible to install new stop-cocks before the customer meters without much problem.

The method is:

- ✧ Close all known customer connections by closing the valves near customer meters,
- ✧ Check the flowmeter at the entrance to the area,
- ✧ If the inflow becomes zero, the area is perfect, there is no leakage or illegal (unknown) connections,
- ✧ If there is inflow, there must be leakage somewhere and/or illegal (unknown) connections,
- ✧ Survey for the leakage and illegal connections by sounding tools (listening stick and ground microphone).

The following section describes the case study of this applied to a branch of PA1.

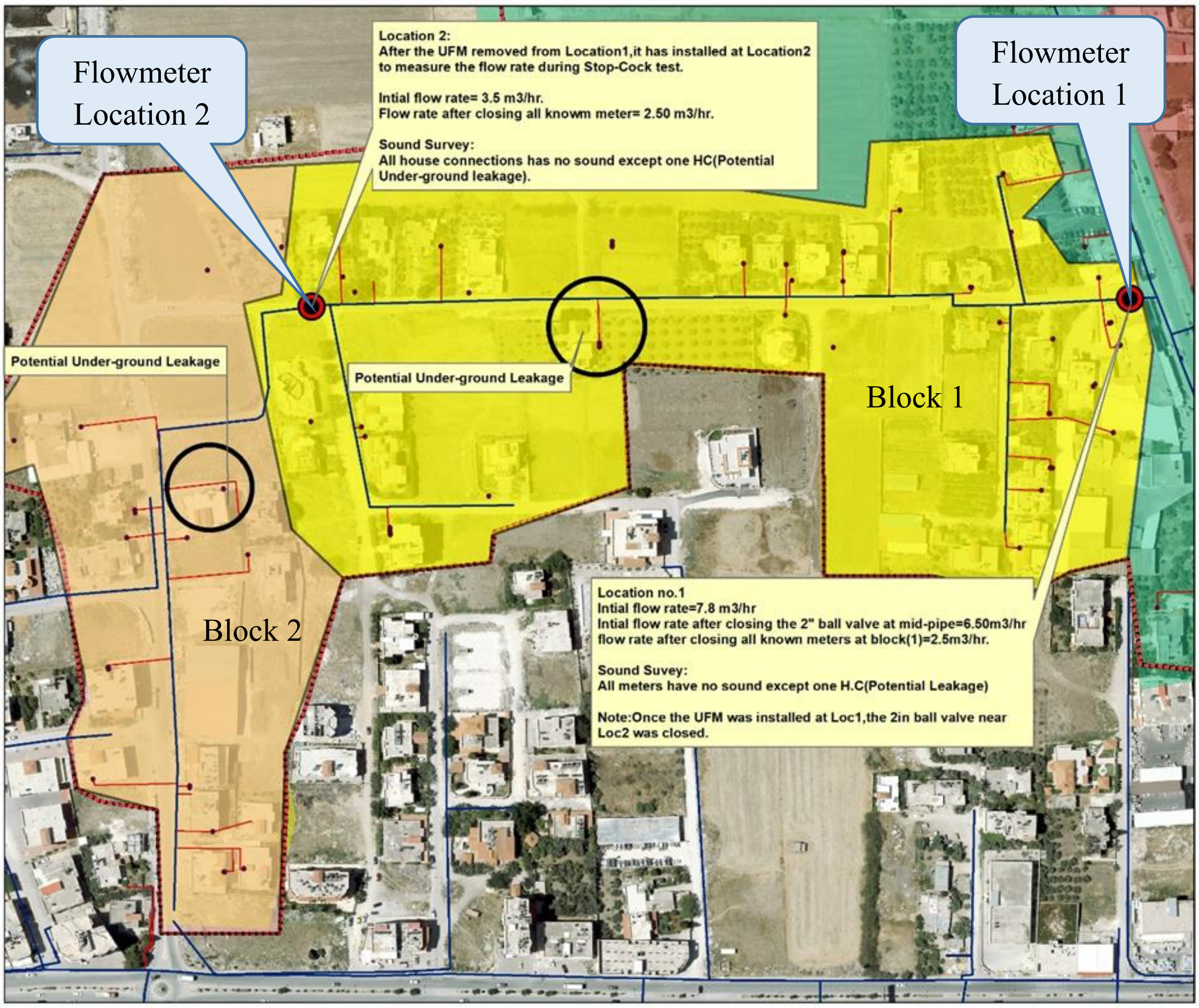


Figure 13-14: Result of stop-cock test and sounding survey conducted in a part of PA1

In the above case:

Block 1

a) Portable ultrasonic flowmeter installed at Location 1; initial flow rate = 7.8 m^3/hr,
b) Block1 isolated by closing an existing valve at Location 2; flow rate = 6.5 m^3/hr

c) All the house connections in Block 1 were closed manually; the flow rate did not become zero, still 2.5 m^3/hr was flowing in,
d) All the house connections were listened **by listening stick** for any water flow/leak sound,
e) Potential underground leakage or illegal water use suspected in one connection.

Block 2

a) The vale at Location 2 was opened and water supplied to Block 2,
b) UFM was installed at Location 2; initial flow rate = 3.5 m^3/hr,
c) All the house connections in Block 2 were closed manually; the flow rate did not become zero, still 2.5 m^3/hr was flowing in,
d) All the house connections were listened by listening stick for any water flow/leak sound,
e) Potential underground leakage or illegal water use suspected in one connection,
f) After excavation, illegal connection was found at the suspected location.

14 PRESSURE MANAGEMENT

High pressure in a distribution system is not good because leakage increases with pressure. On the other hand, if the pressure is too low customers will face problems for securing enough water during limited time of intermittent supply or water will not reach their rooftop tanks. Thus, ideally the water pressure at house connection point should be about 20 m. Practically it is difficult to maintain pressure to the desired exact value, but one should strive to maintain it within a reasonable range. PWA suggested range is 20-60m.

14.1 Pressure-leakage relationship

There is a direct relationship between pressure and leakage rate as shown in the following expression.

$$L_1 = L_0 (P_1 / P_0)^{N1}$$

Where;

P_0 and L_0 are the initial pressure and leakage rate in the network,

P_1 & L_1 are the values at a changed pressure, and

N_1 is the exponent known as Fixed And Variable Area Discharge (FAVAD) exponent. Value of N_1 depends on the type of pipe (rigid or flexible) and the type of leak (for example, from pin hole, longitudinal crack, joint leak etc). Small background leaks in both metal and plastic pipes are very sensitive to pressure with N_1 being close to 1.5; large detectable leaks in plastic pipes also have N_1 equal to 1.5 or higher; and large detectable leaks in metal pipes have N_1 close to 0.5.

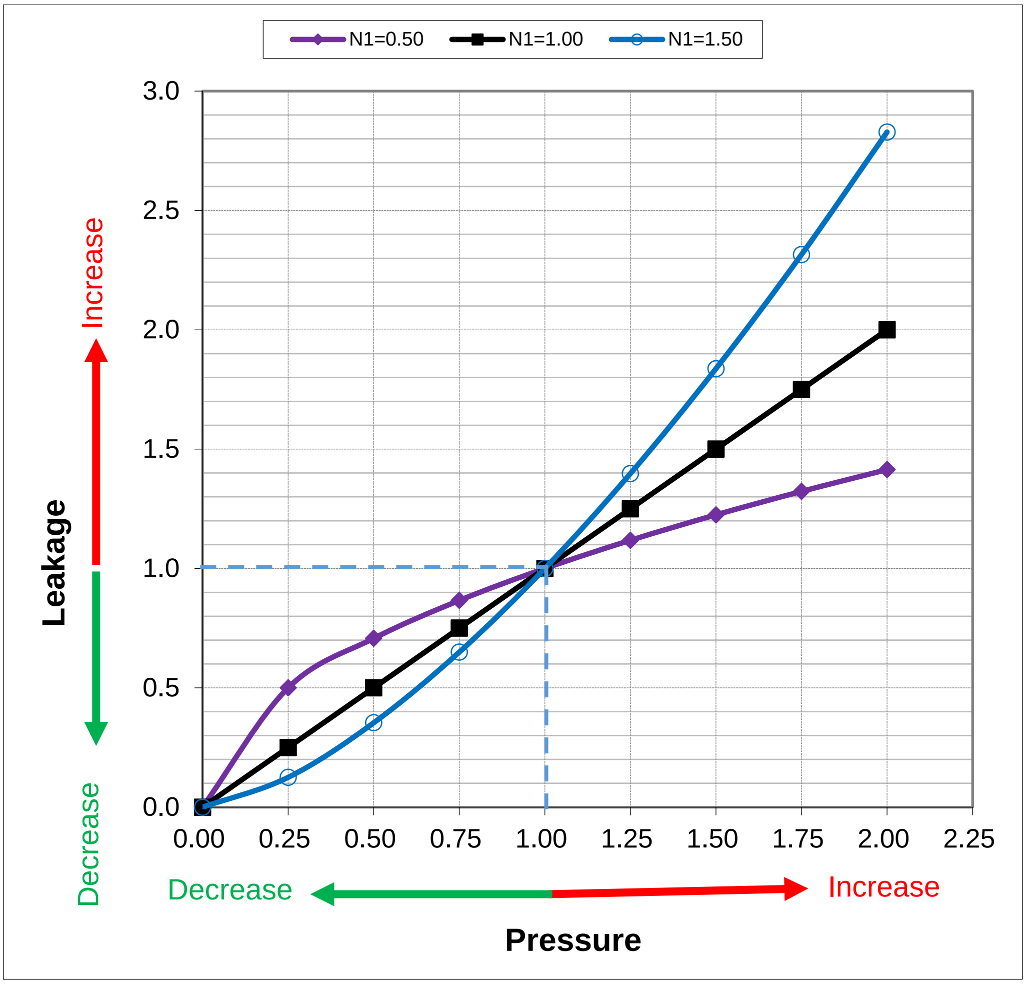


Figure 14-1: Pressure-Leakage Relationship for Various Conditions of N_1

The leakage rate varies more with pressure in non-metallic pipes compared to metallic pipes. Similarly, leakage rate from a longitudinal crack on pipe varies more with pressure than from a pinhole. But for a mixed piping system and leak conditions, a linear relationship is suggested, i.e., if pressure is doubled, leakage rate is doubled and vice versa.

The above figure shows that when pressure increases the leakage rate also increases and vice versa. But the rate of increase or decrease of leakage with pressure depends on the value of N_1. For $N_1=1$ (black line), when pressure is doubled, the leakage rate also doubles from 1 to 2.

So, it is very important to keep pressure within a reasonable range. Unnecessarily high pressure will increase leakage rate.

14.2 Common Methods of Pressure Management

14.2.1 Zoning

- ✧ Supply areas are separated into zones based on topography.
- ✧ Pressure is controlled at each zone through locating reservoirs at suitable elevation or installing pressure reducing system.

14.2.2 Proper size and number of booster pumps

- ✧ Rather than a single high head pump, multiple smaller head pumps are used so that some pumps can be turned off during low demand time.
- ✧ Variable frequency pumps are used.

14.2.3 Pressure reducing valves

- ✧ Use PRV to reduce excessive pressure.
- ✧ Alternately, break-pressure tank (BPT) can be used if topography is suitable and land is available to construct the BPT.
- ✧ When using PRV, pressure modulation (reducing pressure in such a way that it remains almost constant during all hours of the day) can be applied. This helps further reduce unwanted high pressure during low demand time.

14.2.4 Eliminating bottleneck (too small) pipes

- ✧ Find the pipe sections which cause excessive headloss (for example, unit headloss of 50 m/km or more) by means of hydraulic model.
- ✧ Replace those sections by bigger pipe or install parallel pipes to reduce the unit headloss to a reasonable value.

15 LEAK REPAIR WORKS

15.1 Preparation

- ✧ Prepare schedule – prepare priority list on daily basis. Priority should be given to more critical leak considering various factors such as danger to public property, inconvenience to public, volume of water loss, potential of contamination of water supply, availability of repair material in stock, and so on,
- ✧ Get approval for road excavation if required,
- ✧ Arrange equipment such as backhoe, pipe cutter, welding machine, generator, drain pump etc),
- ✧ Arrange repair team members such as backhoe operator, fitter, welder, security guard etc,
- ✧ Arrange safety measures such as sign posts, barricades, reflectors, torch light etc,
- ✧ Estimate and arrange repair materials such as pipe section, fittings, repair clamps, washers etc.

Leak repair by Repair clamp

15.2 Repair Work

- ✧ Start from the highest priority leak,
- ✧ Isolate the pipe section by closing upstream and downstream isolation valves if it is not done yet,
- ✧ Install safety barricades around the place of work,
- ✧ Check and confirm the place of work is safe to start work,
- ✧ Repair the leak by following established procedure,
- ✧ Fill the pipe by opening upstream valve,
- ✧ Confirm no leak appears from or around the repaired part,
- ✧ Take pictures and record GIS coordinates with a GPS or mobile phone,
- ✧ Clean the pipeline by open washout valve downstream of the repair location,
- ✧ Reinstate the road surface temporarily,
- ✧ Clean the work site, remove and take back all safety equipment.

Leak repair by cutting and inserting a pipe piece using couplings

Repairing metallic pipe by flanged connector in one side and dismantling joint in another

15.3 Reporting and Mapping

- ✧ Record materials used, total time taken for the repair work, crew members involved etc and fill up the 'Leak repair record' form,
- ✧ Update GIS map of leak repair records. As an example, GIS map of leak repairing points for Nov 2019, Dec 2019 and Jan 2020 is given below.

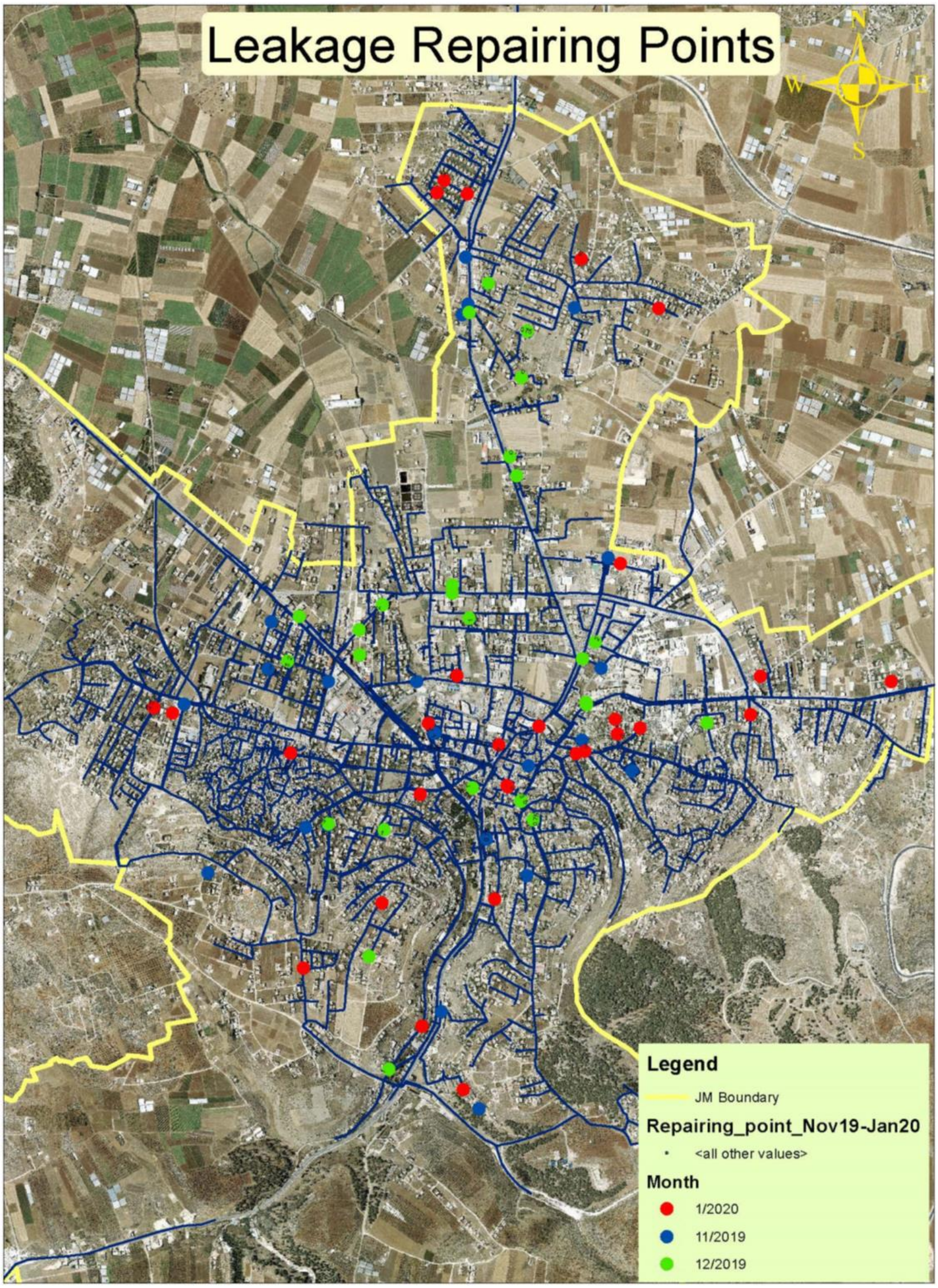


Figure 15-1: Leak repairing points of Jenin in Nov-Dec 2019 and Jan 2020

16 WATER SUPPLY IMPROVEMENT IN PILOT AREAS

Water supply improvement, in the context of Jenin, generally means fixing of supply schedule, equalizing pressure and supply durations. Increasing supply quantity and duration by increasing water resource is not easy because of restricted water resources. But if water loss (physical loss component) can be reduced, the saved quantity can be used as an additional resource.

16.1 Potential Improvement Measures

The improvement plan includes:

1) Fixing supply schedule considering customers' convenience and equality in supplied amount
2) Upgrading pumping system to suit the planned supply system
3) Upgrading service reservoir capacity (storage capacity to be about 6-8 hours' daily demand)
4) Replacing inadequately sized and old pipe network so that all customers get water for reasonable time at adequate water pressure
5) Rearranging supply areas (changing from one source to another) to match source capacity and water demand of areas
6) Providing connection to new customers based on the policy of water utility (as far as possible)
7) As far as possible, the improvement plan should include measures to change intermittent supply to a continuous (24hrs×7days) one. There are many benefits of a continuous system compared to intermittent. The main challenges for this conversion are; increase in water loss from leakage, wastage of water by the customers, and inadequate pumping infrastructure.

16.2 Hydraulic Modelling

Prepare a hydraulic model of the area.

Hydraulic model is an essential tool for preparing improvement plan. For uncomplicated smaller areas the models can be prepared using freely available open source EPANET program together with similar open source and free GIS program QGIS. EPANET is light, powerful, and popular program for both hydraulic and water quality modelling.

If the water utility already owns other modelling programs like WaterCAD, WaterGEMS, and so on, these can also be used. The models prepared by these programs can be converted to EPANET later on without much difficulty.

There are two modelling approaches; conventional demand-based-discharge (DBD) modelling, and pressure-dependent discharge (PDD) modelling (also known as tank model).

The DBD model is applicable where the supply system is saturated and customers withdraw water as per their instantaneous need. This model does not apply when the supply system is intermittent, customers own large storage tanks, and customer's demand is not fully satisfied. In such a situation water is discharged to customers' tanks based on available pressure until the tanks are filled. The customers at the most hydraulically advantageous location get water first. Other customers get water gradually when the demand of the earlier customers is satisfied, i.e., their tanks are filled. The PDD modelling approach reflects this phenomenon more accurately. Also, the leakage increases with increase in available pressure. This can also be modelled in PDD modelling approach.

Hydraulic modelling of PA1 by these approaches is given in Annex 3.

16.3 Implement the Plan

Based on available resources and with the help of hydraulic modelling, identify and prioritize improvement measures. For example, the identified measures for PA1 are as below:

1) Install two new pumps and control panel at Sabah Al Kheir pumping station. Currently only one pump is available and water supply will be stopped if the pump faces any problem. Specification of the new pumps is determined in such a way that these can be used for the current intermittent system or if the supply system is converted to a continuous system in future
2) Fix supply schedule, inform customers of the schedule if the current intermittent system is to be continued
3) Gradually replace inadequately sized (bottleneck) pipes where unit headloss exceeds certain limit, say 20 m/km in this case. Quantity and size of such pipes have been identified tentatively for PA1 and Basateen areas
4) The storage size of service reservoir at Sabah Al Kheir pumping station is 100 m^3. This is only about 10% of total daily demand (supply) of the supply area. A reasonable storage volume would be about 6-8 hrs storage (25%-33% of total daily demand). Thus, it is essential to increase the storage volume. But this requires a bigger funding and may not fall under higher priority of JM.

17 CUSTOMER METER REPLACEMENT AND ILLEGAL USE COUNTERMEASURES

Periodic replacement of customer meters is essential to manage apparent loss component of NRW. Countries such as Japan have by-laws defining the replacement period of customer meter. In Palestine/Jenin the period is not defined yet.

17.1 Identifying Meters to be Replaced

When the replacement period is not defined by law, it is necessary to identify which meters need to be replaced. The following types are candidates for replacement:

- ✧ Meters marked as 'unreadable' by meter readers due to water vapor, broken glass, or any other reason,
- ✧ Meters showing measurement error in excess of permissible range,
- ✧ Meters older than a certain age, say 10 years (this period is 8 years in Saitama Prefecture of Japan),
- ✧ If there is a program to replace all existing meters by a certain type of new meters, then it is easy.

17.2 PPWM Procurement and Installation (Applicable to the Case of Jenin)

JM decided to replace all existing meters with pre-paid type meters. To select suitable type of meter about 6-month long experiment was conducted comparing the reading of three type of meters; mechanical velocity type, mechanical volumetric type, and ultrasonic type. Considering intermittent supply system and likely presence of suspended particles in water the ultrasonic type was selected.

When procuring PPWM it is necessary to consider the following:

- ✧ Software program to operate the credit charging and collection system,
- ✧ Compatibility with existing billing and accounting system of the utility,
- ✧ Communication system of each meter with localized collectors (such as Gateways) for calculating water consumption,
- ✧ Cost,
- ✧ Durability, reliability,
- ✧ Years of use of such products in any other place, and so on.

The following points need to be considered for installation of PPWM:

- ✧ Installation position as recommended by the manufacturer,
- ✧ Install in a box for protection,
- ✧ Suitable place (near the entrance gate),

- ✧ The place having easy access for checking and maintenance of meter,
- ✧ Not in the basement as it makes difficult communication between the meter and collector system.

17.3 Take Measures to Find and Rectify Illegal Uses

Illegal connections/unregistered connections pose serious challenges to water utilities in the developing countries. Despite extensive house to house survey and search for any sign of illegal water use during CDS, extent of illegal connection is still not clear in Jenin.

The problem of finding any illegal use/connection is compounded by the following conditions in Jenin. There may be some similarity with other water utilities in Palestine or these may be specific to Jenin only.

- ✧ There are private water suppliers in parallel to municipal supply. Many households which are not connected with the municipal water network say they use water from private suppliers. It makes difficult to identify any illegal connection as the households may easily hide the municipal connection (unauthorised one) as a connection from private supplier.
- ✧ There are agricultural farms in peripheral areas. There are many farms around PA1. These farms have a mess of spaghetti pipes supposedly supplying irrigation water from private sources. It almost impossible to know which pipe is from where and connected to which pipe. There is some possibility of such farms using municipal water but disguising it as private well water.
- ✧ Many households which use municipal water also augment their water from private tankers. In general, when a customer's consumption becomes suspiciously low some sort of illegal water use can be expected. But in Jenin they say they purchased water from tankers. It is difficult to know the truth.

Please pay attention to the followings to reduce illegal connection in Jenin:

1. Carefully survey nearby farms to know their source of irrigation water,
2. Make punishment tougher so that it acts as a strong deterrent to illegal users,
3. Use GIS to find out missing customers. Superimpose registered customer points on GIS basemap and identify households which do not have municipal water connection. Check such households systematically to find out the source of water such households are using, and investigate if they are using municipal water illegally,
4. Monitor disconnected lines as they might have reconnected themselves,
5. Monitor inactive connections as they might have secretly activated and used water,
6. Check connections with zero consumption for the real reason of zero consumption [explained in more detail in the next section],

7. Check households who have water connection but resist checking of their water line/ water meter by JM staff,
8. Encourage meter readers to carefully observe and report any sign of illegal connection,
9. Encourage people to anonymously report any illegal connection, provide some rewards (such as rebate in water charge) for customers who provide information about illegal connection.

17.4 Check Meters Which Show Zero or Suspiciously Low Consumption

About 20% of meters in each month's meter reading show zero consumption in Jenin. This trend has remained same even after installing pre-paid meters.

The zero consumption or suspiciously low consumption might have been due to genuine reason or due to foul play by the customers. So it is necessary to check such meters every month to find out if any of those customers are using water illegally.

The process of the checking can be as follows:

1. Each month, after completion of meter reading and data input, sort out customers in Al Shamel (billing program) from low to high consumption,
2. Do same to PPWM customers,
3. Extract the details of those customers whose consumption is zero or less than certain minimum value, such as less than 1 m^3,
4. Prepare a GIS map of those customers,
5. Organize a dedicated team(s) of technicians (2 persons in each team) from Water Section and CSS,
6. Together with the extracted consumption database and GIS map, visit each of such customers and examine for potential cause of zero (or very low) consumption,
7. If any customer claims other source of water such as private well or tanker, investigate further to confirm the claim,
8. For each case investigate and find the reason,
9. If necessary, escalate the issue to higher level such as the WWD director or Mayor.

18 EVALUATION OF NRW REDUCTION MEASURES

Effectiveness of NRW countermeasures is evaluated by continuously monitoring NRW levels every month.

18.1 Continue Monitoring NRW on Monthly Basis

NRW tends to rise with time as new leaks keep occurring and existing leaks get bigger. Continuous monitoring of NRW is essential to understand the situation and keep NRW level under control. For that the followings are main steps:

- ✧ Get reading of all source meters on monthly basis and calculate SIV,
- ✧ Take reading of all bulk meters in DMA (DMA meters) on monthly basis and calculate SIV of each DMA,
- ✧ Get the readings of customer meters every month (or every reading cycle if they are not read monthly) and calculate Billed Authorised Consumption on monthly basis. Apply meter reading lag time correction as necessary,
- ✧ Calculate NRW,
- ✧ If a sudden and unexplained rise of NRW is noticed in any month, investigate possible reasons and apply countermeasures.

18.2 Cost-Benefit Analysis of NRW Activities

The cost-effectiveness of each NRW countermeasure differs depending on the prevailing causes of NRW. To understand which countermeasure is the most cost-effective it is necessary to keep detail record of expenditure and resulting NRW decrease due to each countermeasure.

[A cost-benefit analysis report of NRW reduction activities in PA1 has been prepared as a separate report. Please refer to this report for detail.]

The followings are the main steps to prepare cost-benefit analysis:

The concept is illustrated in Figure 18-1 and explained briefly in the following section.

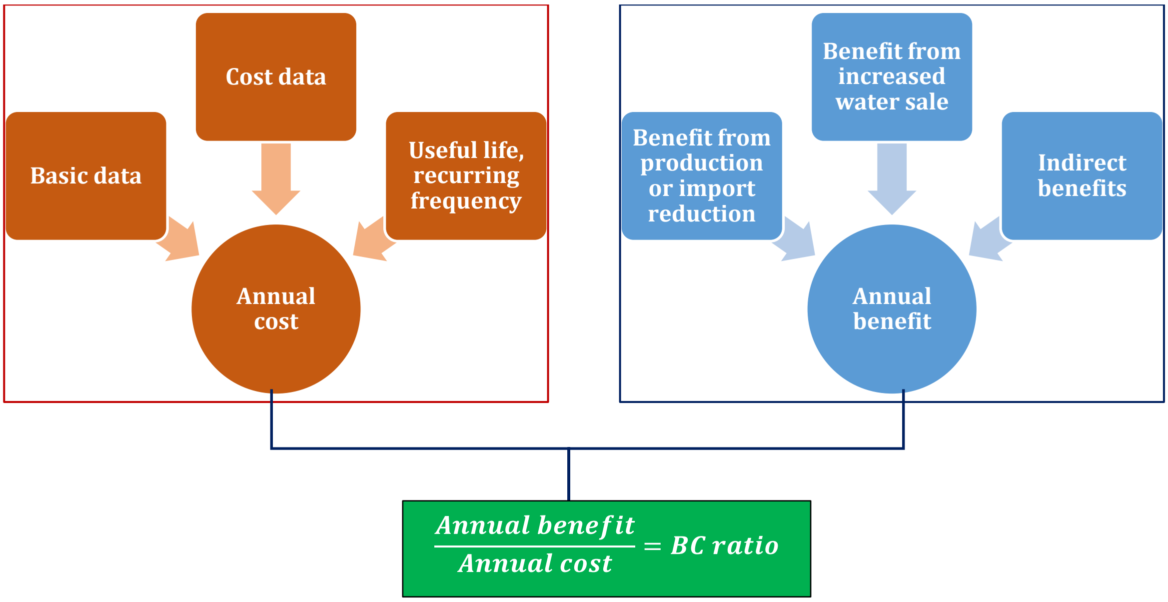


Figure 18-1: Outline of method for calculating benefit-cost ratio of NRW activities

18.2.1 Collect basic data of the area

The following basic data are important:

- Customer (connection) numbers
- Pipe network length
- Average daily/monthly water supply volume
- Average daily/monthly billed volume
- Average daily/monthly NRW volume
- Unit cost of water production (NIS/m^3) (unit cost of supply water)
- Unit selling price of water (NIS/m^3)

18.2.2 Collect cost data

The cost components can be divided into one time cost (medium to long-term) and recurring cost. The following cost data are important:

- Cost of equipment to be installed permanently such as bulk meters, pressure gauges, data loggers
- Cost of permanent construction works such as construction of chambers, installation of bulk meters and valves
- Cost of preparatory activities such as customer database update, pipe network update, customer meter accuracy checking
- Cost of less frequent tasks such as customer meter replacement
- Recurring cost with higher frequency (daily, monthly, annual) such as visual leakage survey, illegal connection survey, stop-cock test, step test, underground leak detection survey, leak repair, equipment hire.

18.2.3 Estimate useful life or recurring frequencies and calculate per year cost

For each cost item estimate useful life or recurring frequencies and from these calculate per year cost.

18.3 Calculate benefits

NRW reduction has direct and indirect benefits. For simpler analysis only direct benefits can be considered. Indirect benefits are more qualitative and exhaustive data and analysis are needed to calculate these.

The direct benefit comes from two ways; by reducing production (thereby saving production cost) or by supplying the additional water saved from reduced NRW. The former is applicable if enough water resources are available, and production can be reduced as a result of reduction in NRW. But this case is not applicable to the situation of Jenin where the demand is higher than the available water resources. Thus, in case of Jenin the direct benefit comes from the second way; by supplying (selling) the saved water additionally to the customers or to the unserved population.

18.4 Calculate cost-benefit ratio

Once the costs and benefits are calculated, the final step is to calculate the benefit-cost ratio by dividing the benefit by cost.

To understand the cost-effectiveness of each NRW countermeasure, the cost and benefit should be calculated separately for each countermeasure. For example, in order to calculate the cost-effectiveness of leak detection and repair, cost for this work and benefit resulted from this work should be calculated separately. To do this, it is necessary to clearly identify how much NRW decreased due to each countermeasure. This is possible if the countermeasures are applied in series, *i.e.*, one after another, not together in parallel. But in reality, it is difficult to avoid the situation where more than one countermeasures are applied together. For example, to save precious water, big visible leaks need to be repaired quickly or found illegal connections need to be rectified quickly while the work of customer meter replacement might be in progress. In such a situation, precise estimate of NRW reduction by each countermeasure is not possible. As an alternative, NRW reduction can be separated into several distinct stages and percentage contribution to NRW reduction by each countermeasure to that stage can be estimated.

This approach has been applied in the report mentioned above.

19 PERFORMANCE INDICATORS (KPIS) RELATED TO NRW

Performance indicators are quantitative measures of an output, performance or service. IWA has defined 133 different types of performance indicators for different functions – water resources, personnel, physical, operational, quality of service, and financial.

Some typical PIs are related to:

- NRW levels
- water production, consumptions and number of service connections
- quality compliance of supplied water
- customer satisfaction, the number of complaints and the time taken to resolve them
- the number of pipe bursts and leaks and the time taken to repair them
- the average percentage of non-functional meters at any time
- the ratio of number of staff to number of customers
- unit operating costs
- external and internal training time

Each of the performance indicators is indicated by a code, shown in a small parenthesis following the title of the indicator such as 'Water Losses per Water Service Connection (Op22)'. The code indicates one of the six categories and indicator number as defined by IWA. For example, Op indicates that the indicator is 'Operational'. For customized indicators a small letter 'c' is added after two letters indicating the category. Key performance indicators adopted in Jordan are shown in Table 19-1.

Table 19-1: Key Performance Indicators in Water Supply of Jordan

Indicator	Definition	Unit	Category
WRc02	Water consumption per capita	L/cap/d	Water resource
QS17	Microbiological water quality compliance	%	Water quality
Op22	Water loss per water service connection	l/Sc/d	Water loss
Fi36	Non-revenue water by volume	% of system input	Financial/ Water loss
Fic01	Collection ratio	%	Financial
Fic03	Operating cost coverage ratio	%	Financial
QSc01	Subscribers receiving continuous supply	%	Service quality
QS22	Non-billing (Service) complaints	% of no. of subs.	Service quality
QS27	Billing complaints	% of no. of subs.	Service quality
PEc01	Total employees per 1000 water subscribers	Nr/1000 subs.	Human resource

19.1 Performance Indicators for NRW

NRW levels can be expressed in several ways; as a percentage of system input, normalized to mains length (such as m^3/km/day) or to the number of customer or connections (such as L/connection/day) etc. In intermittent supply systems, care should be taken not to use the total time but the time during which the system is pressurized.

Some of the important performance indicators for NRW and water losses are outlined in Table 19-2**Error! Reference source not found.** for a quick reference. Exhaustive detail of the indicators is available from IWA. Choice of using a particular indicator depends upon the purpose and availability of background data required to make calculation for the indicator.

Table 19-2: Performance Indicators for Non-revenue Water and Water Losses

Performance Indicator	Function	Comment
NRW by Volume (as a % of system input volume)	**Financial** - Non-revenue water by volume	Can be calculated from a simple water balance; good only as a general financial indicator; not too meaningful, sometimes misleading
NRW by Cost (% of the annual cost of running the water system)	**Financial** - Non-revenue water by cost	Allows different unit costs for Non-revenue water components; good financial indicator
Apparent Losses (m^3/service connection/year or (m^3/km of main/year) *only if service connection density is <20/km*	**Operational**- Apparent Losses	Basic but meaningful indicator once the volume of apparent losses has been calculated or estimated
Real Losses by Volume (% of system input volume)	Inefficiency of use of water resources	Unsuitable for assessing efficiency of management of distribution systems
Normalized Real Losses (liters/service connection/day or liters/km of main/day *(only if the connection density is < 20/km)*	**Operational-** Real Losses	Good operational performance indicator for target-setting for real losses reduction; limited use for comparison between systems This indicator (m^3/km/day) has been used by Tokyo Water Works to prioritize areas for leakage survey. If any area is found to have leakage level of 20 L/km/min (28.8 m^3/km/day) or less then priority for leakage survey is given to other areas
Normalized Real Losses (liters/service connection/day/m of pressure or	**Operational** - Real Losses	Easy to calculate indicator if the ILI is not known yet; useful for comparison between systems

Performance Indicator	Function	Comment
liters/km of main/day/m of pressure *(only if the connection density is < 20/km)*		
Unavoidable Annual Real Losses (UARL)	UARL (liter/day) = (18 x Lm + 0.8 x Nc + 25 x Lp) x P Where, Lm = length of water mains, km Nc = number of service connections Lp = total length of private pipe, km = Nc x average distance from curbstop to customer meter P = average pressure in the system, m	A theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied. A key variable in the calculation of the Infrastructure Leakage Index (ILI) It is not necessary that systems set this level as a target unless water is unusually expensive, scarce or both
Infrastructure Leakage Index (ILI)	**Operational** - Real Losses	Ratio of Current Annual Real Losses (CARL) to Unavoidable Annual Real Losses (UARL); good for operational benchmarking for real losses control, most powerful indicator for comparison between systems.

(1) Volume of NRW as % of System Input (Fi36)

Although the practice is changing gradually, NRW is still being expressed as % of system input by many water utilities. It may be reasonable to express NRW by % of system input for a single DMA or system as long as the change in per capita consumption is insignificant. But % NRW looses its meaning and sometimes even becomes misleading when the per capita consumption changes significantly.

(2) Water Losses per Water Service Connection (Op22)

In Jenin multi-flat buildings are supplied with a single service connection which branches at the meter box with separate meter for each flat (customer). This results into that the number of service connections is always less than or equal to the number of customers.

If connection density is 20 per km of mains or more IWA recommends using L/connection/day as the preferred performance indicator for leakage. IWA recommends using per connection rather than per customer expression on the ground that leakage is more influenced by the number of connections than by the number of customers.

In the context of Jenin information on the number of connections is not readily available for most of the areas. Thus the expression normalized to number of customers is mostly used. Another factor to consider is the use of NRW as a whole, not only the leakage. Although leakage is more influenced by the number of connections, it may not be true for NRW. There might be significant influence of customer number on NRW due to customer meter inaccuracy or illegal uses.

(3) Water Losses per km of Mains (Opc02)

When the connection density is less than 20 per km of main the leakage is better expressed as m^3/km-main/day or any multiples of those units (e.g. L/km-main/min).

The latter expressions (normalized to the number of connections, customers, or mains length) take into account of the differences in number of connections, customers or length of mains. This makes comparison of different systems with different connection densities more reasonable.

It is a practice in Tokyo Waterworks to prioritize areas for leak detection works based on the existing level of leakage per km length of mains per minute. The reference leakage rate is 20 L/km of main/minute (28.8 m^3/km/day). If any area is found to have a leakage rate below this level this area is put aside and leakage level assessment is done in other areas. Priority of leak detection and countermeasures works is given to areas having higher leakage rates.

Prioritization of areas for leak detection and countermeasure works is essential to make best use of available limited resources.

(4) Other Performance Indicators

The following section lists some selected performance indicators from Japan Water Works Association's guidelines for the management and assessment of a drinking water supply service (JWWA Q100). They are reproduced here as a reference and for consideration for their inclusion in future.

(5) External and Internal Training Time

Training time = Training course (time × attendees)/Total number of staff members (unit: hours)

The external training course refers to service-related sessions which water utilities authorize and which their staff members attend as a duty. The host should not be an organization which the attendee belongs to. On the other hand, the internal training course refers to in-house service-related sessions which water utilities hold and which their staff members attend as a duty. Records for external and internal training time should be maintained separately.

The purpose of training is outcomes rather than attendance. If staff members attend training courses but fail to get the qualification, they should be excluded.

Training courses are held to improve personnel's competence and should be authorized by water utilities because they are equivalent to qualifications. If any staff member attends a certain course as a personal interest, it should be excluded because it is very difficult to determine judgment criteria.

Training should be conducted from a utility-wide point of view rather than focused on limited staff members.

(6) Water Supply Service Complaints

Water supply service complaints = (Number of complaints about services/Total number of users) × 1,000 (unit: No./1,000 No.)

The complaint includes inquiries by direct communications at the service counter, on telephone, with written documents, and by electronic mail, and should be recorded in documents.

This indicator represents the ratio of complaints to users, and is one of the indices showing consumers' satisfaction. The complaints relates to services offered, meter readings, the amount of charges, construction, water interruptions, or turbid water. The indicator value is proportional to the level of drinking water supply services. If it is large, water utilities are required to let their consumers understand the services through public relations, to understand consumer needs, and to improve the services.

Many complaints mean that there is a problem in the quality of drinking water supply services, but water utilities should evaluate this indicator with other information.

(7) Complaints for Water Quality

Complaints for water quality = (Number of complaints about water quality/Total number of users) × 1,000 (unit: No./1,000 No.)

This indicator represents the ratio of complaints to users, and is one of the indices showing consumers' satisfaction with water quality. The complaint relates to bad odor, color or taste.

Many complains mean that there is a problem in the quality of drinking water supply services, but water utilities should evaluate this indicator with other information.

(8) Billing Complaints for Water Supply

Billing complaints for water supply = (Number of complaints about water rates/Total number of users) × 1,000 (unit: No./1,000 No.)

This indicator represents the ratio of complaints to users, and is one of the indices showing consumers' satisfaction with water rates.

Many complains mean that there is a problem in the quality of drinking water supply services, but water utilities should evaluate this indicator with other information.

(9) Meter Misreading Ratio

Meter misreading ratio = (Number of reading errors/Total number of readings) × 1,000 (unit: No./1,000 No.)

(10) Incorrect Billing Ratio

Incorrect billing ratio = (Number of incorrect bills/Total number of bills) × 1,000 (unit: No./1,000 No.)

(11) Ratio of Tariff to Production Cost

Ratio of tariff to production = (Water supply rate/Water supply cost) × 100 (unit: %)

(12) Water Supply Pressure Inadequacy Ratio

Water supply pressure inadequacy ratio = (In-spec pressure (points × days)/(Number of reading points × Number of days per year)) × 100 (unit: %)

The in-spec pressure refers to a water pressure range specified in standards or ordinances developed by a water utility, **25 – 60** m for Palestine.

The in-spec pressure (points × days) is the product of the number of measuring points at which and the number of days on which the pressure test is passed.

The number of reading points is the sum of points where water pressure is measured with pressure gauges installed in distribution pipes.

The number of days per year refers to the total number of days in a year.

Table 19-3: Selected Performance Indicators for 9 Jordanian Water Utilities (Year 2014)

Indicator	**Definition**	**Unit**	**Values from 9 water utilities in Jordan (2014)**		
			Min	**Average**	**Max**
WRc02	Water consumption per capita	L/cap/d	52.3	73.7	87.1
QS17	Microbiological water quality compliance	%	98.5	99.4	100
Op22	Water loss per water service connection	l/Sc/d	139	1,133	2,392
Fi36	Non-revenue water by volume	% of system input	27.8	52.1	73.1
Fic01	Collection ratio	%	24.9	80.5	102
Fic03	Operating cost coverage ratio	%	24.1	52.2	111
QSc01	Subscribers receiving continuous supply	%	0.00	12.4	100
QS22	Non-billing (Service) complaints	% of no. of subs.	0.27	11.8	24.1
QS27	Billing complaints	% of no. of subs.	1.00	3.05	8.35
PEc01	Total employees per 1000 water subscribers	Nr/1000 subs.	2.55	9.08	16.6

Source: Mustafa Nasereddin, PhD Thesis (2017) Universität der Bundeswehr München -Developing and Testing Benchmarking System for Water Utilities in Jordan,

19.2 Example of KPIs related to NRW for Jenin City and Pilot Areas

(First 6 months of year 2021)

Table 19-4: KPIs related to NRW (1/2)

No	Indicators	Unit	Jan '21	Feb	Mar	Apr	May	Jun	Jul '21
1	Total system input (water quantity)	m^3/ month	294,787	286,772	294,320	225,828	343,905	331,421	321,977
2	NRW in entire city	m^3/ month	186,360	180,806	186,645	201,193	145,019	190,426	186,244
		% of SIV	63.2%	63.0%	63.2%	58.1%	42.2%	57.5%	57.8%
3	NRW in PA1	m^3/ month	10,056	9,597	9,711	10,977	10,816	24,700	
		% of SIV	47.6%	48.7%	45.7%	45.6%	40.6%	45.6%	
4	NRW in PA2	m^3/ month	NA	NA	NA	20,195	18,863	49614	
		% of SIV	NA	NA	NA	60.3%	56.9%	68.8%	
5	NRW in PA3	m^3/ month	7922	7294	8948	7772	8033	14076	
		% of SIV	52.2%	53.4%	55.2%	49.0%	47.4%	46.7%	
6	Leakage repaired	Num	44	43	49	24	24	40	
7	Leakage response time	day	1.41	1.42	1.82	0.83	0.83	1.43	

Table 19-5: KPIs related to NRW (2/2)

No.	Indicators	Unit	Jan-21	Feb-21
1	**Water supply and consumption**			
	Total SIV	m^3/month	294,788	286,772
	Supply quantity per customer	m^3/con/month	30.9	29.9
	Billed quantity per customer	m^3/km/month	11.6	11.1
2	**NRW**			
	Whole Jenin			
	Volume	m^3/month	184,308	180,806
	Percentage of SIV	%	62.5%	63.1%
	NRW per customer	m^3/con/month	19.3	19
	NRW per km of pipe network	m^3/km/month	1,084	1,064
	PA1			
	Volume	m^3/month	10056	9,597
	Percentage of SIV	%	47.6%	48.7%
	NRW per customer	m^3/con/month	11.7	11.0
	NRW per km of pipe network	m^3/km/month	512.0	488.7
	PA2			
	Volume	m^3/month	Not available	Not available
	Percentage of SIV	%		
	NRW per customer	m^3/con/month		
	NRW per km of pipe network	m^3/km/month		
	PA3			
	Volume	m^3/month	7,922	7,294
	Percentage of SIV	%	52.2%	53.4%
	NRW per customer	m^3/con/month	13.9	12.8

No.	Indicators	Unit	Jan-21	Feb-21
	NRW per km of pipe network	m^3/km/month	715.1	658.4
3	**Leakage**			
	Number of leaks found from all surveys	Num	44	43
	Number of leaks repaired	Num	44	43
	Ratio of leaks repaired to leaks found	%	100%	100%
	Response time for leak repair	hours	33.84	34.08
	Leak points recorded on GIS	Num	44	43
4	**Illegal connections**			
	Illegal connections found	Num	9	2
	Illegal connections action taken	Num	8	2

Table 19-6: KPIs related to Billing and Customer Services

No	Indicators	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul
1	Total number of customers	Num	9,551	9,578	9,523	9,525	9,532	9,532	9,532
2	Number of complaints	Num	52	50	50	70	38	122	59
3	% of solved complaints	%	100	100	100	100	100	100	100
4	Billing ratio in entire city	%	74.0	73.0	71.0	79	98	98	98
5	Billing ratio by estimated reading	%	26.0	27.0	29.0	21	2	2	2
6	Collection ratio in entire city (with debt)	%	63.2	62.0	57.19	60.72	52.03	44.43	56.17
7	Collection ratio in entire city (without debt)	%	34.7	44.8	46.8	50.93	41.16	35.79	46.88
8	Total number of PPWM	Num	3,098	3,153	3,181	3190	3197	3199	3199
9	PPWM % in total customers	%	32.43	32.91	33.40	33.49	33.5	33.5	33.5
10	GIS registered customers	Num	3,145	3,286	3,298	3,362	3,416	3,497	3,497

19.3 Collection and Compilation of Data Related to NRW

It is a continuous process. Currently collected data are shown below. As the number of implemented DMAs gets increasing, similar data should be collected for all DMAs. The data can then be analyzed to understand the situation.

19.3.1 All city SIV data

Refer to Table 10-1: Case example of SIV calculation of Jenin for year 2020

19.3.2 All city NRW data

Year	Month	SIV (m^3/mth)	Adjusted SIV	Billed Vol (m^3/mth)	Tanker supply (m^3/mth)	PPWM cons (m^3/mth)	NRW (m^3/mth)	NRW (% of SIV)
2017								
	Jan			119,999				

Year	Month	SIV (m^3/mth)	Adjusted SIV	Billed Vol (m^3/mth)	Tanker supply (m^3/mth)	PPWM cons (m^3/mth)	NRW (m^3/mth)	NRW (% of SIV)
	Feb			104,516				
	Mar			104,928				
	Apr			104,780				
	May			108,557				
	Jun			101,845	786			
	Jul			122,043	1,113			
	Aug			121,658	828			
	Sep			122,158	1,299			
	Oct			97,656	1,056			
	Nov			105,720	804			
	Dec			106,935	795			
2018								
	Jan	241,282		102,135	477		138,670	57.0%
	Feb	232,788		96,098	-		136,690	59.0%
	Mar	236,026		103,634	1,218		131,174	56.0%
	Apr	320,852		100,891	-		219,961	69.0%
	May	278,123		110,843	915		166,365	60.0%
	Jun	276,533		87,600	-		188,933	68.0%
	Jul	287,549		130,237	1,395		155,917	54.0%
	Aug	286,742		116,937	666		169,139	59.0%
	Sep	261,812		105,290	822		155,700	59.0%
	Oct	240,652		104,042	1,320		135,290	56.0%
	Nov	222,910		95,179	1,446		126,285	57.0%
	Dec	267,622		110,540	1,806		155,276	58.0%
Total of 2018		**3,152,890**		**1,263,426**	**10,065**		**1,879,399**	**60.0%**
2019								
	Jan	264,719		104,280	1,665		158,774	60.0%
	Feb	264,532		94,059	1,461		169,012	64.0%
	Mar	294,489		121,260	1,614		171,615	58.0%
	Apr	287,333		97,719	1,614	998	187,002	65.0%
	May	294,317		121,309		998	172,010	58.0%
	Jun	241,925		101,178		2,365	138,382	57.0%
	Jul-Nov	1,452,579		548,008	1,183	38,498	864,890	60.0%
	Dec	292,679		106,961		9,895	175,823	60.0%
Total of 2019		**3,392,574**		**1,294,774**	**7,537**	**52,754**	**2,037,509**	**60.0%**
2020								
	Jan	288,495	274,545	118,325		13,240	156,930	54.0%
	Feb	278,881	266,281	94,963		19,347	164,571	59.0%
	Mar-May	949,691	908,291	285,426		76,399	587,866	62.0%
	Jun	305,340	0	88,584		27,528	189,228	62.0%
	Jul	304,169		96,052		32,596	175,521	58.0%

Year	Month	SIV (m^3/mth)	Adjusted SIV	Billed Vol (m^3/mth)	Tanker supply (m^3/mth)	PPWM cons (m^3/mth)	NRW (m^3/mth)	NRW (% of SIV)
	Aug	331,648		103,947		30,806	196,895	59.0%
	Sep	321,321		90,565		37,765	192,991	60.0%
	Oct	306,950		95,082		36,095	175,773	57.0%
	Nov	288,978		86,249		31,405	171,324	59.0%
	Dec	317,089		88,030		34,645	194,414	61.0%
Total of 2020		**3,692,561**	**1,449,116**	**1,147,223**	**0**	**339,825**	2,205,512	**59.7%**
2021								
	Jan	294,788		76,885		31,543	186,360	63.2%
	Feb	286,772		74,851		31,115	180,806	63.0%
	Mar	295,420		75,147		33,627	186,645	63.2%
	Apr	346,018		105,145		39,680	201,193	58.1%
	May	343,905		154,916		43,971	145,019	42.2%
	Jun	331,421		95,798		45,197	190,426	57.5%
	Jul	321,977		90,193		45,540	186,244	57.8%
	Aug							
	Sep							
	Oct							
	Nov							
	Dec							

19.3.3 PA1 SIV and NRW data

Area	Input Qty' (m^3)	Con-sumption (m^3)	NRW (m^3)	NRW (%)	Consmp Adj for MR lag time (m^3)	NRW (m^3)	NRW (%)
September 2018							
Whole of Sabah Al Kheir supply area compared to supply measured at Jalameh	32,889	13,496	19,393	59.0%			
Whole of Sabah Al Kheir supply area compared to supply measured at Sabah Al Kheir PS outlet							
PA1 area							
Sub-area 1 (24 hrs supply area)		3,883					
Sub-area 2 (Sabah Al Kheir)							
Sub-area 3 (Kharoubeh)		3,954					
Sub-area 4 (Nazareth St.)		4,396					
Sub-area 5 (Al Basaateen)		1,263					
October 2018							
Input at Jalameh	34,517						
Input at Sabah Al Kheir tank	32,415						
Transmission loss			2,102	6.1%			
Whole (PA1+Basateen) area	32,415	13,837	18,578	57.3%			

Area	Input Qty' (m^3)	Con-sumption (m^3)	NRW (m^3)	NRW (%)	Consmp Adj for MR lag time (m^3)	NRW (m^3)	NRW (%)
PA1 area	**28,239**	**12,462**	**15,777**	**55.9%**	**12,464**	**15,775**	**55.9%**
Sub-area 1 (24 hrs supply area)	1,982	1,084	898	45.3%	1,206	776	39.1%
Sub-area 2 (Sabah Al Kheir)	8,109	2,987	5,122	63.2%	3,173	4,936	60.9%
Sub-area 3 (Kharoubeh)	7,913	4,018	3,895	49.2%	3,870	4,043	51.1%
Sub-area 4 (Nazareth St.)	10,236	4,373	5,863	57.3%	4,215	6,021	58.8%
Sub-area 5 (Al Basaateen)	4,176	1,375	2,801	67.1%			
November 2018							
Input at Jalameh	32,699						
Input at Sabah Al Kheir tank	29,375						
Transmission loss			3,324	10.2%			
Whole (PA1+Basateen) area	29,375	13,048	16,327	55.6%			
PA1 area	**24,708**	**11,583**	**13,125**	**53.1%**	**10,937**	**13,771**	**55.7%**
Sub-area 1 (24 hrs supply area)	1,807	639	1,168	64.6%	646	1,161	**64.2%**
Sub-area 2 (Sabah Al Kheir)	7,425	2,547	4,878	65.7%	2,640	4,785	**64.4%**
Sub-area 3 (Kharoubeh)	5,916	3,675	2,241	37.9%	3,461	2,455	**41.5%**
Sub-area 4 (Nazareth St.)	9,560	4,722	4,838	50.6%	4,190	5,370	**56.2%**
Sub-area 5 (Al Basaateen)	4,667	1,465	3,202	68.6%			
December 2018							
Input at Jalameh	31,126						
Input at Sabah Al Kheir tank	30,326	Transmis-sion loss	800	2.6%			
PA1 area	**27,365**	**11,637**	**15,728**	**57.5%**	**11,193**	**16,172**	**59.1%**
Sub-area 1 (24 hrs supply area)	1,392	714	678	48.7%	645	747	53.7%
Sub-area 2 (Sabah Al Kheir)	5,343	3275	2,068	38.7%	2918	2,425	45.4%
Sub-area 3 (Kharoubeh)	7,411	4113	3,298	44.5%	4016	3,395	45.8%
Sub-area 4 (Nazareth St.)	13,219	3535	9,684	73.3%	3614	9,605	72.7%
Sub-area 5 (Al Basaateen)	2,961						
January 2019							
Input at Jalameh	28,045						
Input at Sabah Al Kheir tank	26,634	Transmis-sion loss	1,411	5.0%			
PA1 area	**24,556**	**11,261**	**13,295**	**54.1%**	**11,572**	**12,984**	**52.9%**
Sub-area 1 (24 hrs supply area)	1,494	684	810	54.2%	684	810	54.2%
Sub-area 2 (Sabah Al Kheir)	4,106	2,780	1,326	32.3%	2780	1,326	32.3%
Sub-area 3 (Kharoubeh)	7,070	3,729	3,341	47.3%	3729	3,341	47.3%
Sub-area 4 (Nazareth St.)	11,886	4,068	7,818	65.8%	4379	7,507	63.2%
Sub-area 5 (Al Basaateen)	2,078						
Feb-19							
Input at Jalameh	27,130						
Input at Sabah Al Kheir tank	26,968	Transmis-sion loss	162	0.6%			
PA1 area	**24,287**	**10,283**	**14,004**	**57.7%**	**11,140**	**13,147**	**54.1%**
Sub-area 1 (24 hrs supply area)	1,339	888	451	33.7%	1000.3	339	25.3%

Area	Input Qty' (m^3)	Con-sumption (m^3)	NRW (m^3)	NRW (%)	Consmp Adj for MR lag time (m^3)	NRW (m^3)	NRW (%)
Sub-area 2 (Sabah Al Kheir)	3,313	2,508	805	24.3%	2620.7	692	20.9%
Sub-area 3 (Kharoubeh)	5,424	3,164	2,260	41.7%	3839.6	1,585	29.2%
Sub-area 4 (Nazareth St.)	14,211	3,723	10,488	73.8%	3679.8	10,531	74.1%
Sub-area 5 (Al Basaateen)	2,681	1,200					
Mar-19							
Input at Jalameh	29,154						
Input at Sabah Al Kheir tank	28,907		247	0.8%			
PA1 area	**26,528**	**10,810**	**15,718**	**59.3%**	**9,567**	**16,961**	**63.9%**
Sub-area 1 (24 hrs supply area)	1,339	810	529	39.5%	758	581	43.4%
Sub-area 2 (Sabah Al Kheir)	5,887	3,450	2,437	41.4%	3,527	2,360	40.1%
Sub-area 3 (Kharoubeh)	7,106	3,503	3,603	50.7%	2,702	4,404	62.0%
Sub-area 4 (Nazareth St.)	12,195	3,047	9,148	75.0%	2,580	9,615	78.8%
Sub-area 5 (Al Basaateen)	2,379						
Apr-19							
Input at Jalameh	27,980						
Input at Sabah Al Kheir tank	22,334		3,840.84	13.7%			
PA1 area	**19,836**	**10,976**	**8,860**	**44.7%**	**9,947**	**9,889**	**49.9%**
Sub-area 1 (24 hrs supply area)	1,742	717	1,025	58.8%	650	1,092	62.7%
Sub-area 2 (Sabah Al Kheir)	4,495	2,787	1,708	38.0%	2,525	1,970	43.8%
Sub-area 3 (Kharoubeh)	4,944	3,484	1,461	29.5%	3,157	1,787	36.1%
Sub-area 4 (Nazareth St.)	8,655	3,989	4,666	53.9%	3,615	5,040	58.2%
Sub-area 5 (Al Basaateen)	2,498						
May-19							
Input at Jalameh	29,252						
Input at Sabah Al Kheir tank	28,557		695.24	2.4%			
PA1 area	**25,819**	**12,705**	**13,114**	**50.8%**	**11,139**	**14,680**	**56.9%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,628	1,170	1,458	55.5%	1,026	1,602	61.0%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	4,761	3,400	1,361	28.6%	3,136	1,626	34.1%
Sub-area 3 (Kharoubeh)Loc5/LogC	6,700	3,942	2,758	41.2%	3,341	3,359	50.1%
Sub-area 4 (Nazareth St.)	11,730	4,193	7,537	64.3%	3,635	8,094	69.0%
Sub-area 5 (Al Basaateen)	2,738						
Jun-19							
Input at Jalameh	29,950						
Input at Sabah Al Kheir tank	29,825		125.26	0.4%			
PA1 area	**27,907**	**12,510**	**15,397**	**55.2%**	**14,854**	**13,053**	**46.8%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	3,210	1,235	1,975	61.5%	1,235	1,975	61.5%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	5,580	3,111	2,469	44.2%	3,192	2,388	42.8%
Sub-area 3 (Kharoubeh)Loc5/LogC	6,401	3,880	2,521	39.4%	4,965	1,436	22.4%
Sub-area 4 (Nazareth St.)	12,717	4,284	8,433	66.3%	5,462	7,255	57.1%
Sub-area 5 (Al Basaateen)	1,918						
Jul-Nov 2019 (total)							

Area	Input Qty' (m^3)	Con-sumption (m^3)	NRW (m^3)	NRW (%)	Consmp Adj for MR lag time (m^3)	NRW (m^3)	NRW (%)
Input at Jalameh	156,948						
Input at Sabah Al Kheir tank	148,487		8,461.00	5.4%			
PA1 area	**134,243**	**70,239**	**64,004**	**47.7%**	**69,595**	**64,648**	**48.2%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	15,626	6,333	9,293	59.5%	6,629	8,997	57.6%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	22,393	17,580	4,812	21.5%	15,637	6,756	30.2%
Sub-area 3 (Kharoubeh)Loc5/LogC	32,141	22,180	9,961	31.0%	22,682	9,459	29.4%
Sub-area 4 (Nazareth St.)	64,084	24,146	39,938	62.3%	24,648	39,436	61.5%
Sub-area 5 (Al Basaateen)	14,244						
Jul-Nov2019 (monthly average)							
Input at Jalameh	31,390						
Input at Sabah Al Kheir tank	29,697		1,692.20	5.4%			
PA1 area	**26,849**	**14,048**	**12,801**	**47.7%**	**13,919**	**12,930**	**48.2%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	3,125	1,267	1,859	59.5%	1,326	1,799	57.6%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	4,479	3,516	962	21.5%	3,127	1,351	30.2%
Sub-area 3 (Kharoubeh)Loc5/LogC	6,428	4,436	1,992	31.0%	4,536	1,892	29.4%
Sub-area 4 (Nazareth St.)	12,817	4,829	7,988	62.3%	4,930	7,887	61.5%
Sub-area 5 (Al Basaateen)	2,849						
Dec-19							
Input at Jalameh							
Input at Sabah Al Kheir tank	25,651		(25,651)				
PA1 area	**22,115**	**12,066**	**10,049**	**45.4%**	**10,923**	**11,192**	**50.6%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,210	1,102	1,108	50.1%	1,004	1,206	54.6%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	3,787	2,851	936	24.7%	2,626	1,161	30.7%
Sub-area 3 (Kharoubeh)Loc5/LogC	5,402	3,768	1,634	30.3%	3,395	2,007	37.2%
Sub-area 4 (Nazareth St.)	10,716	4,345	6,372	59.5%	3,898	6,818	63.6%
Sub-area 5 (Al Basaateen)	3,536						
Jan-20							
Input at Jalameh							
Input at Sabah Al Kheir tank	25,548		(25,548)				
PA1 area	**22,489**	**9,936**	**12,554**	**55.8%**	**10,667**	**11,822**	**52.6%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	3,101	1,189	1,912	61.7%	1,259	1,842	59.4%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	4,864	2,606	2,258	46.4%	2,749	2,115	43.5%
Sub-area 3 (Kharoubeh)Loc5/LogC	4,483	2,508	1,975	44.1%	2,640	1,843	41.1%
Sub-area 4 (Nazareth St.)	10,041	3,633	6,409	63.8%	4,019	6,022	60.0%
Sub-area 5 (Al Basaateen)	3,059						
Feb-20							
Input at Jalameh							
Input at Sabah Al Kheir tank	24,243		(24,243)				

Area	Input Qty' (m^3)	Con-sumption (m^3)	NRW (m^3)	NRW (%)	Consmp Adj for MR lag time (m^3)	NRW (m^3)	NRW (%)
PA1 area	**21,569**	**9,812**	**11,757**	**54.5%**	**10,252**	**11,317**	**52.5%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	1,433	942	491	34.2%	1,089	344	24.0%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	3,808	2,316	1,492	39.2%	2,430	1,378	36.2%
Sub-area 3 (Kharoubeh)Loc5/LogC	4,651	2,751	1,900	40.9%	2,935	1,716	36.9%
Sub-area 4 (Nazareth St.)	11,678	3,803	7,875	67.4%	3,798	7,880	67.5%
Sub-area 5 (Al Basaateen)	2,674						
Mar-May 20 (total)							
Input at Jalameh	???						
Input at Sabah Al Kheir tank	80,000						
PA1 area	**68,533**	**40,239**	**28,294**	**41.3%**	**40,723**	**27,810**	**40.6%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	6,619	4,068	2,551	38.5%	4,122	2,497	37.7%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	15,319	9,657	5,662	37.0%	9,791	5,528	36.1%
Sub-area 3 (Kharoubeh)Loc5/LogC	19,092	11,533	7,559	39.6%	11,760	7,332	38.4%
Sub-area 4 (Nazareth St.)	27,504	14,981	12,523	45.5%	15,051	12,453	45.3%
Sub-area 5 (Al Basaateen)	11,467						
Mar-May 20 (monthly average)							
Input at Jalameh	???						
Input at Sabah Al Kheir tank	26,667						
PA1 area	**22,844**	**13,413**	**9,431**	**41.3%**	**13,574**	**9,270**	**40.6%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,206	1,356	850	38.5%	1,374	832	37.7%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	5,106	3,219	1,887	37.0%	3,264	1,843	36.1%
Sub-area 3 (Kharoubeh)Loc5/LogC	6,364	3,844	2,520	39.6%	3,920	2,444	38.4%
Sub-area 4 (Nazareth St.)	9,168	4,994	4,174	45.5%	5,017	4,151	45.3%
Sub-area 5 (Al Basaateen)	3,822						
Jun-20							
Input at Jalameh	???						
Input at Sabah Al Kheir tank	29,252						
PA1 area	**24,491**	**13,601**	**10,890**	**44.5%**	**13,204**	**11,287**	**46.1%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,541	1,442	1,099	43.2%	1,360	1,181	46.5%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	4,486	3,011	1,475	32.9%	2,941	1,545	34.4%
Sub-area 3 (Kharoubeh)Loc5/LogC	6,725	4,684	2,041	30.4%	4,386	2,339	34.8%
Sub-area 4 (Nazareth St.)	10,739	4,586	6,153	57.3%	4,666	6,073	56.5%
Sub-area 5 (Al Basaateen)	4,761						
Jul-20							
Input at Jalameh							
Input at Sabah Al Kheir tank	32,112						
PA1 area	**27,227**	**15,380**	**11,847**	**43.5%**	**14,633**	**12,594**	**46.3%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,774	1,842	932	33.6%	1,818	956	34.5%

Area	Input Qty' (m³)	Con-sumption (m³)	NRW (m³)	NRW (%)	Consmp Adj for MR lag time (m³)	NRW (m³)	NRW (%)
Sub-area 2 (Sabah Al Kheir)Loc4/logA	6,026	3,588	2,438	40.5%	3,316	2,710	45.0%
Sub-area 3 (Kharoubeh)Loc5/LogC	6,745	4,759	1,986	29.4%	4,766	1,979	29.3%
Sub-area 4 (Nazareth St.)	11,681	5,191	6,490	55.6%	4,733	6,948	59.5%
Sub-area 5 (Al Basaateen)	4,885						
Aug-20							
Input at Jalameh							
Input at Sabah Al Kheir tank	29,905						
PA1 area	**26,513**	**13,420**	**13,093**	**49.4%**	**15,321**	**11,192**	**42.2%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,851	1,513	1,338	46.9%	1,699	1,152	40.4%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	5,729	3,082	2,647	46.2%	3,562	2,167	37.8%
Sub-area 3 (Kharoubeh)Loc5/LogC	6,897	4,177	2,720	39.4%	4,845	2,052	29.8%
Sub-area 4 (Nazareth St.)	11,036	4,743	6,293	57.0%	5,445	5,591	50.7%
Sub-area 5 (Al Basaateen)	3,392						
Sep-20							
Input at Jalameh							
Input at Sabah Al Kheir tank	25,683						
PA1 area	**25,682**	**14,381**	**11,301**	**44.0%**	**14,516**	**11,166**	**43.5%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,619	1,855	764	29.2%	1,851	768	29.3%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	5,930	3,350	2,580	43.5%	3,412	2,519	42.5%
Sub-area 3 (Kharoubeh)Loc5/LogC	8,197	4,900	3,297	40.2%	4,954	3,243	39.6%
Sub-area 4 (Nazareth St.)	8,936	4,396	4,540	50.8%	4,415	4,521	50.6%
Sub-area 5 (Al Basaateen)	1						
Oct & Nov - 2020							
Input at Jalameh							
Input at Sabah Al Kheir tank	49,296						
PA1 area	**48,370**	**25,691**	**22,679**	**46.9%**	**25,741**	**22,629**	**46.8%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	5,834	2,671	3,163	54.2%	2,646	3,188	54.6%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	10,624	6,779	3,845	36.2%	6,767	3,857	36.3%
Sub-area 3 (Kharoubeh)Loc5/LogC	11,978	7,394	4,584	38.3%	7,338	4,640	38.7%
Sub-area 4 (Nazareth St.)	19,934	8,847	11,087	55.6%	8,990	10,944	54.9%
Sub-area 5 (Al Basaateen)	926						
Dec-20							
Input at Jalameh							
Input at Sabah Al Kheir tank	21,407						
PA1 area	**21,407**	**11,621**	**9,786**	**45.7%**	**11,662**	**9,745**	**45.5%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,304	1,131	1,173	50.9%	1,134	1,170	50.8%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	4,280	3,054	1,226	28.6%	3,111	1,169	27.3%
Sub-area 3 (Kharoubeh)Loc5/LogC	5,907	3,359	2,548	43.1%	3,319	2,588	43.8%

Area	Input Qty' (m^3)	Con-sumption (m^3)	NRW (m^3)	NRW (%)	Consmp Adj for MR lag time (m^3)	NRW (m^3)	NRW (%)
Sub-area 4 (Nazareth St.)	8,916	4,077	4,839	54.3%	4,098	4,818	54.0%
Sub-area 5 (Al Basaateen)	-	-					
Jan-21							
Input at Jalameh							
Input at Sabah Al Kheir tank	21,129						
PA1 area	**21,129**	**11,296**	**9,833**	**46.5%**	**11,073**	**10,056**	**47.6%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,295	1,149	1,146	49.9%	1,126	1,169	50.9%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	4,420	2,849	1,571	35.5%	2,796	1,624	36.7%
Sub-area 3 (Kharoubeh)Loc5/LogC	4,628	3,164	1,464	31.6%	3,120	1,508	32.6%
Sub-area 4 (Nazareth St.)	9,786	4,134	5,652	57.8%	4,031	5,755	58.8%
Sub-area 5 (Al Basaateen)	-	-					
Feb-21							
Input at Jalameh							
Input at Sabah Al Kheir tank	19,691						
PA1 area	**19,691**	**9,692**	**9,999**	**50.8%**	**10,094**	**9,597**	**48.7%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,175	1,014	1,161	53.4%	1,071	1,104	50.8%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	4,348	2,474	1,874	43.1%	2,581	1,767	40.6%
Sub-area 3 (Kharoubeh)Loc5/LogC	4,549	2,520	2,029	44.6%	2,583	1,966	43.2%
Sub-area 4 (Nazareth St.)	8,619	3,684	4,935	57.3%	3,858	4,761	55.2%
Sub-area 5 (Al Basaateen)	-	-					
Mar-21							
Input at Jalameh							
Input at Sabah Al Kheir tank	21,264						
PA1 area	**21,264**	**11,307**	**9,957**	**46.8%**	**11,553**	**9,711**	**45.7%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	2,417	1,122	1,295	53.6%	1,128	1,289	53.3%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	4,492	2,954	1,538	34.2%	2,956	1,536	34.2%
Sub-area 3 (Kharoubeh)Loc5/LogC	5,290	3,270	2,020	38.2%	3,460	1,830	34.6%
Sub-area 4 (Nazareth St.)	9,065	3,962	5,103	56.3%	4,009	5,056	55.8%
Sub-area 5 (Al Basaateen)	-	-					
Apr-21							
Input at Jalameh							
Input at Sabah Al Kheir tank	24,047						
PA1 area	**24,047**	**13,086**	**10,961**	**45.6%**	**13,070**	**10,977**	**45.6%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7							
Sub-area 2 (Sabah Al Kheir)Loc4/logA							
Sub-area 3 (Kharoubeh)Loc5/LogC							
Sub-area 4 (Nazareth St.)							
Sub-area 5 (Al Basaateen)	-	-					

Area	Input Qty' (m^3)	Con-sumption (m^3)	NRW (m^3)	NRW (%)	Consmp Adj for MR lag time (m^3)	NRW (m^3)	NRW (%)
May-21							
Input at Jalameh							
Input at Sabah Al Kheir tank	26,645						
PA1 area	26,645	15,501	11,144	41.8%	15,829	10,816	**40.6%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	3,236	1,511	1,725	53.3%	1,574	1,662	51.4%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	5,555	3,369	2,186	39.4%	3,511	2,044	36.8%
Sub-area 3 (Kharoubeh)Loc5/LogC	5,762	4,336	1,426	24.7%	4,410	1,352	23.5%
Sub-area 4 (Nazareth St.)	12,092	6,285	5,807	48.0%	6,334	5,758	47.6%
Sub-area 5 (Al Basaateen)	-	-					
Jun - July 2021							
Input at Jalameh							
Input at Sabah Al Kheir tank							
PA1 area	54,114	29,292	24,822	45.9%	29,415	24,699	**45.6%**
Sub-area 1 (24 hrs supply area)Loc3/Log G7	6,302	3,391	2,911	46.2%	3,493	2,809	44.6%
Sub-area 2 (Sabah Al Kheir)Loc4/logA	11,560	6,969	4,591	39.7%	6,923	4,637	40.1%
Sub-area 3 (Kharoubeh)Loc5/LogC	11,129	8,800	2,329	20.9%	8,842	2,287	20.5%
Sub-area 4 (Nazareth St.)	25,123	10,132	14,991	59.7%	10,157	14,966	59.6%
Sub-area 5 (Al Basaateen)	-	-					

19.3.4 PA 2 SIV and NRW data

Area	Input Quantity (m^3)	Consumption (m^3)	NRW (m^3)	NRW (%)	Consmp Adj for MR lag time (m^3)	NRW (m^3)	NRW (%)
Nov-19							
PA2 area	**12,736**	**7,722**	**5,014**	**39.4%**	**7,127**	**5,609**	**44.0%**
Sub-area 1 (Alzahraa-Loc: Z1,Z2,Z3)	9,995	6,723	3,272	32.7%	6,041	3,954	39.6%
Sub-area 2 (New Camp-Loc: C1)	2,741	999	1,742	63.6%	1,086	1,655	60.4%
Jul-20							
PA2 area	**23,502**	**10,220**	**13,282**	**56.5%**	**9,857**	**13,645**	**58.1%**
Sub-area 1 (Alzahraa-Loc: Z1,Z2,Z3)	19,776	8,718	11,058	55.9%	8,018	11,758	59.5%
Sub-area 2 (New Camp-Loc: C1)	3,726	1,502	2,224	59.7%	1,838	1,888	50.7%
Aug-20							
PA2 area							
Sub-area 1 (Alzahraa-Loc: Z1,Z2,Z3)							
Sub-area 2 (New Camp-Loc: C1)	3,742	1,249	2,493	66.6%	1,238	2,504	66.9%
Sep-20							
PA2 area							
Sub-area 1 (Alzahraa-Loc:							

Area	Input Quantity (m^3)	Consumption (m^3)	NRW (m^3)	NRW (%)	Consmp Adj for MR lag time (m^3)	NRW (m^3)	NRW (%)
Z1,Z2,Z3)							
Sub-area 2 (New Camp-Loc: C1)	4,622	1,172	3,450	74.6%	1,199	3,423	74.1%
Apr-21							
PA2 area	**33,473**	**13,217**	**20,256**	**60.5%**	**13,278**	**20,195**	**60.3%**
Sub-area 1 (Alzahraa-Loc: Z1,Z2,Z3"forward direction",turkman well)- (locZ3 (rev.direction+Court6in))	29,217	12,255	16,962	58.1%	12,205	17,012	58.2%
Sub-area 2 (New Camp-Loc: C1)	4,256	962	3,295	77.4%	1,073	3,184	74.8%
May-21							
PA2 area	**32,768**	**13,499**	**19,269**	**58.8%**	**14,129**	**18,639**	**56.9%**
Sub-area 1	29,035	11,841	17,194	59.2%	12,417	16,618	57.2%
Sub-area 2 (New Camp-Loc: C1)	3,733	1,658	2,075	55.6%	1,712	2,021	54.1%
June and July 21							
PA2 area	**72,101**	**23,339**	**48,762**	**67.6%**	**22,488**	**49,613**	**68.8%**
Sub-area 1	65,165	21,222	43,943	67.4%	20,396	44,769	68.7%
Sub-area 2 (New Camp-Loc: C1)	6,936	2,117	4,819	69.5%	2,092	4,844	69.8%

19.3.5 PA3 SIV and NRW data

Area	Input Quantity (m^3)	Consumption (m^3)	NRW (m^3)	NRW (%)	Consmp Adj for MR lag time (m^3)	NRW (m^3)	NRW (%)
Oct-19							
PA-3 Area	**20,931**	**9,249**	**11,682**	**55.8%**	**9,375**	**11,556**	**55.2%**
Sub-area 1 (Ala Al-Sadi Well/Marah Reservior-Loc1)	12,651	4,665	7,986	63.1%	4,899	7,752	61.3%
Sub-area 2 (Abu Sameer Well)	8,280	4,584	3,696	44.6%	4,476	3,804	45.9%
Jul-20							
PA-3 Area							
Sub-area 1 (Ala Al-Sadi Well/Marah Reservior-Loc1)	19,119	9,957	9,162	47.9%	9,189	9,930	51.9%
Note: WWD merged the two sub areas together so that it was not possible to measure the SIV for each sub area separately							
Aug-20	18,191	8,209	9,982	54.9%	8,847	9,343	51.4%
Sep-20	17,402	8,407	8,995	51.7%	8,528	8,874	51.0%
Oct-20 & Nov-20	31,441	15,593	15,848	50.4%	15,576	15,865	50.5%
Dec-20	14,438	6,792	7,646	53.0%	6,936	7,502	52.0%
Jan-21	15,171	7,097	8,074	53.2%	7,249	7,922	52.2%
Feb-21	13,671	6,216	7,455	54.5%	6,377	7,294	53.4%
Mar-21	16,201	7,209	8,992	55.5%	7,253	8,948	55.2%
Apr-21	15,874	8,070	7,804	49.2%	8,102	7,772	49.0%
May-21	16,960	8,765	8,195	48.3%	8,927	8,033	47.4%
June-July-21	30,117	16,073	14,044	46.6%	16,041	14,076	46.7%

20 HEALTH AND SAFETY PRECAUTION

Prepare and keep first aid box, protective gloves, and gumboots.

20.1 Safety During Night Work

Figure 20-1: Uniform designed and used in this project (left), night time work (middle and right)

- ✧ Prepare and wear uniform. The uniform for night use should have reflective strips.
- ✧ Always carry a working torch light
- ✧ Prepare a photo ID and carry it all the time
- ✧ Prepare and carry a brief introduction of the project, show it in case somebody asks about the work
- ✧ Be watchful of the surrounding: be attentive to stray dogs, any unknown person lurking into the group
- ✧ Avoid dispute and argument with unknown people: if such a situation arises, withdraw and back to safety

20.2 Safeguards During Construction of Chambers and Leak Repair Work

Figure 20-2: Barricade prepared and used in the project as a safety measure

- Barricades: prepare and use barricades around the construction site. Paint the barricades with easily visible bright colors
- Cautionary notice: prepare and install cautionary 'Work in Progress' notice
- Coordination with traffic police: inform traffic police (if existing) in advance and obtain their cooperation for traffic management
- Always wear safety gear such as protective glass cover while doing welding work

20.3 Safeguards During Working Inside Chambers

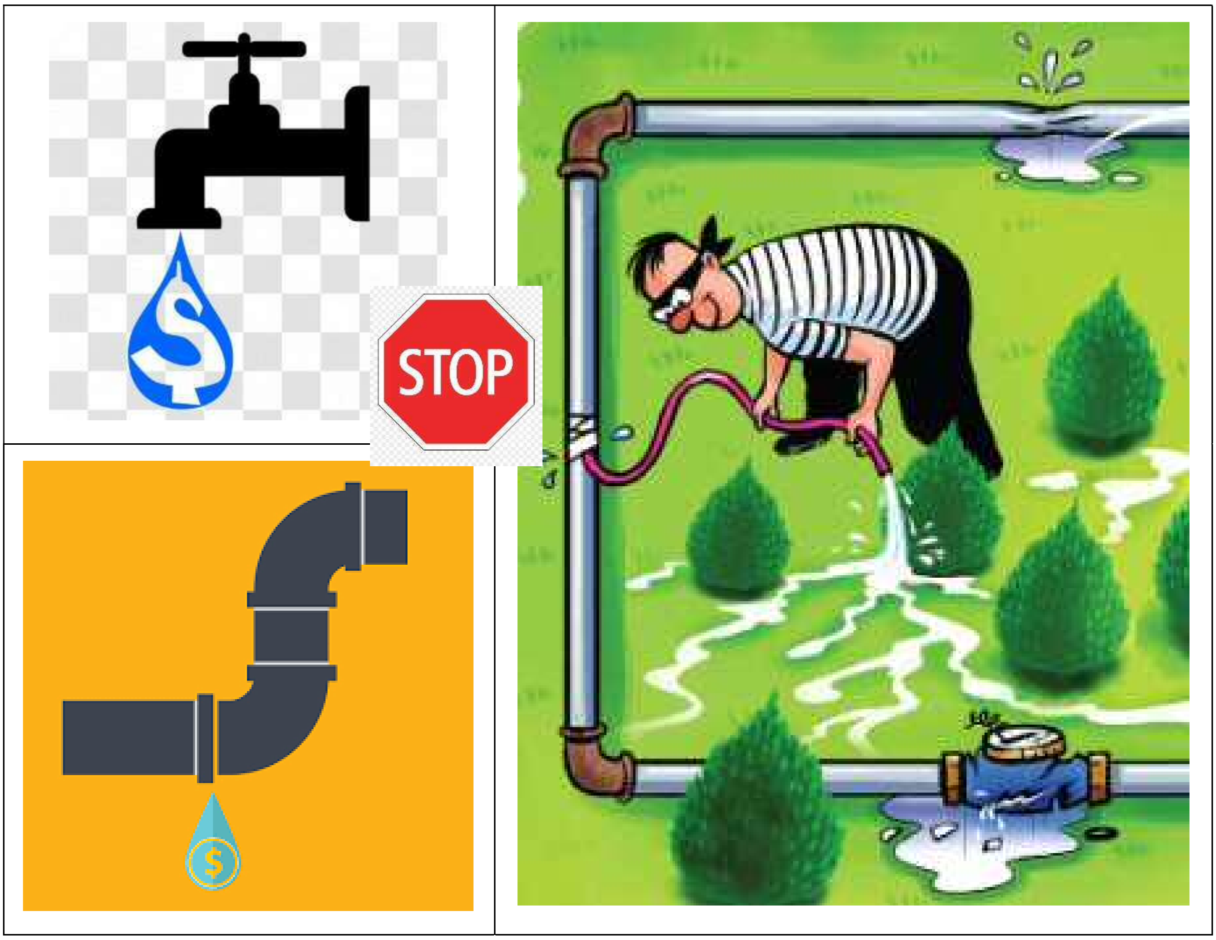
- Keep ready a drainage pump in case the pipeline is not fully drained
- If the chamber lid was tightly closed before opening, allow some time before entering the chamber as dangerous gas might have been accumulated in it
- Since the working space is generally limited inside chambers, select and bring tools which are suitable for such condition

Annex 1.2

Cost-Benefit Analysis of NRW Management Works – English Version

PALESTINIAN WATER AUTHORITY

THE PROJECT FOR STRENGTHENING THE CAPACITY OF WATER SERVICE MANAGEMENT IN JENIN MUNICIPALITY



COST-BENEFIT ANALYSIS OF NRW MANAGEMENT WORKS

AUGUST 2021

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

TEC INTERNATIONAL CO., LTD.
PADECO CO., LTD.

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List of Acronyms

DN:	Nominal Diameter
DMA:	District Metered Area
GIS:	Geographic Information System
GPS:	Global Positioning System
JET:	JICA Expert Team
JICA:	Japan International Cooperation Agency
JM:	Jenin Municipality
NRW:	Non-Revenue Water
PA:	Pilot Area
PPWM:	Pre-Paid Water Meter
SIV:	System Input Volume
UFM:	Ultrasonic Flowmeter

1. BACKGROUND

Non-revenue water countermeasures involve various tasks from simpler and cheaper to more complex and more expensive. All these cost money. On the benefit side, reducing NRW results in physical saving of water by reducing real losses as well as increasing revenue by reducing apparent losses. But the question is, where is the cut-off level of NRW after which NRW reduction costs more than the benefit it produces? To aim to eliminate NRW completely is economically unjustifiable, i.e., the investment required would become much more than the benefits made from NRW reduced.

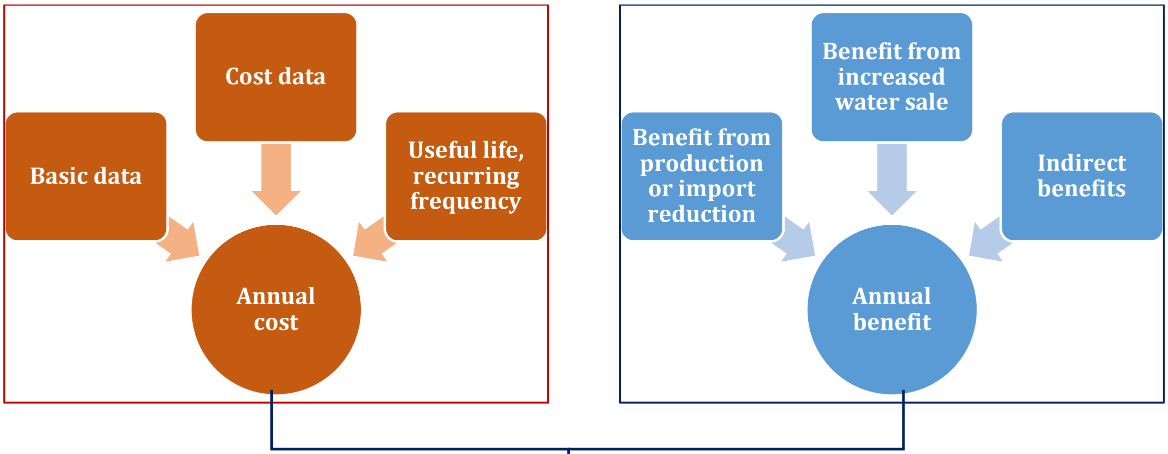
Cost-effectiveness of any countermeasure depends on several factors such as existing level of NRW, actual causes of NRW, availability of qualified human resources and quality materials. In general, when the existing NRW level is very high, such as above 50%, bringing it down to a certain level, say down to 30 to 40%, is relatively easy and can be achieved with less expensive methods such as by quickly repairing visible leaks, reducing/stabilizing pressure, improving metering ratio and meter accuracy, and finding and rectifying illegal connections. Bringing the level further down involves gradually investment-intensive activities such as replacing pipe network and pressure management together with intensive and planned leakage survey and repair.

In this project three pilot areas (PAs) were selected which could be hydraulically isolated. These areas were prepared as district metered areas (DMAs), initial NRW levels were assessed, NRW countermeasures were planned and implemented starting from PA1.

This report has been prepared to outline the NRW countermeasures implemented in the PAs and to evaluate their cost-effectiveness.

2. METHODOLOGY OF COST-BENEFIT ANALYSIS

This section briefly outlines the methodology adopted for this cost-benefit analysis. The concept is illustrated in Figure 1 and explained briefly in the following section.



$$\frac{Annual\ benefit}{Annual\ cost} = BC\ ratio$$

Figure 1: Outline of method for calculating benefit-cost ratio of NRW activities

2.1 Collect basic data of the area

The following basic data was collected:

- ✧ Customer (connection) numbers
- ✧ Pipe network length
- ✧ Average daily/monthly water supply volume
- ✧ Average daily/monthly billed volume
- ✧ Average daily/monthly NRW volume
- ✧ Unit cost of water production (NIS/m^3) (unit cost of supply water)
- ✧ Unit selling price of water (NIS/m^3)

2.2 Collect cost data

The cost components can be divided into one time cost (medium to long-term) and recurring cost. The following cost data was collected:

- ✧ Cost of equipment to be installed permanently such as bulk meters, pressure gauges, data loggers
- ✧ Cost of permanent construction works such as construction of chambers, installation of bulk meters and valves
- ✧ Cost of preparatory activities such as customer database update, pipe network update, customer meter accuracy checking
- ✧ Cost of less frequent tasks such as customer meter replacement

- ✧ Recurring cost with higher frequency (daily, monthly, annual) such as visual leakage survey, illegal connection survey, stop-cock test, step test, underground leak detection survey, leak repair, equipment hire

2.3 Estimate useful life or recurring frequencies and calculate per year cost

For each cost item estimate useful life or recurring frequencies and from these calculate per year cost.

2.4 Calculate benefits

NRW reduction has direct and indirect benefits. We have considered mainly the direct benefits as indirect benefits are more qualitative and exhaustive data and analysis are needed to calculate these.

The direct benefit comes from two ways; by reducing production (thereby saving production cost) or by supplying the additional water saved from reduced NRW. The former is applicable if enough water resources are available, and production can be reduced as a result of reduction in NRW. But this case is not applicable to the situation of Jenin where the demand is higher than the available water resources. Thus, in case of Jenin the direct benefit comes from the second way; by supplying (selling) the saved water additionally to the customers or to the unserved population.

2.5 Calculate cost-benefit ratio

Once the costs and benefits are calculated, the final step is to calculate the benefit-cost ratio by dividing the benefit by cost.

To understand the cost-effectiveness of each NRW countermeasure, the cost and benefit should be calculated separately for each countermeasure. For example, in order to calculate the cost-effectiveness of leak detection and repair, cost for this work and benefit resulted from this work should be calculated separately. To do this, it is necessary to clearly identify how much NRW decreased due to each countermeasure. This is possible if the countermeasures are applied in series, *i.e.*, one after another, not together in parallel. But in reality, it is difficult to avoid the situation where more than one countermeasures are applied together. For example, to save precious water, big visible leaks need to be repaired quickly or found illegal connections need to be rectified quickly while the work of customer meter replacement might be in progress. In such a situation, precise estimate of NRW reduction by each countermeasure is not possible. As an alternative, NRW reduction can be separated into several distinct stages and percentage contribution to NRW reduction by each countermeasure to that stage can be estimated. This approach has been applied in this analysis.

3. FEATURES AND BASELINE NRW LEVEL IN PA1

3.1 Outline of PA1

Pilot area 1 lied at northern part of Jenin Municipality and included three neighborhoods fully and one neighborhood partially. Its outline map is given Figure 2 and pertinent features are given in Table 1 below.

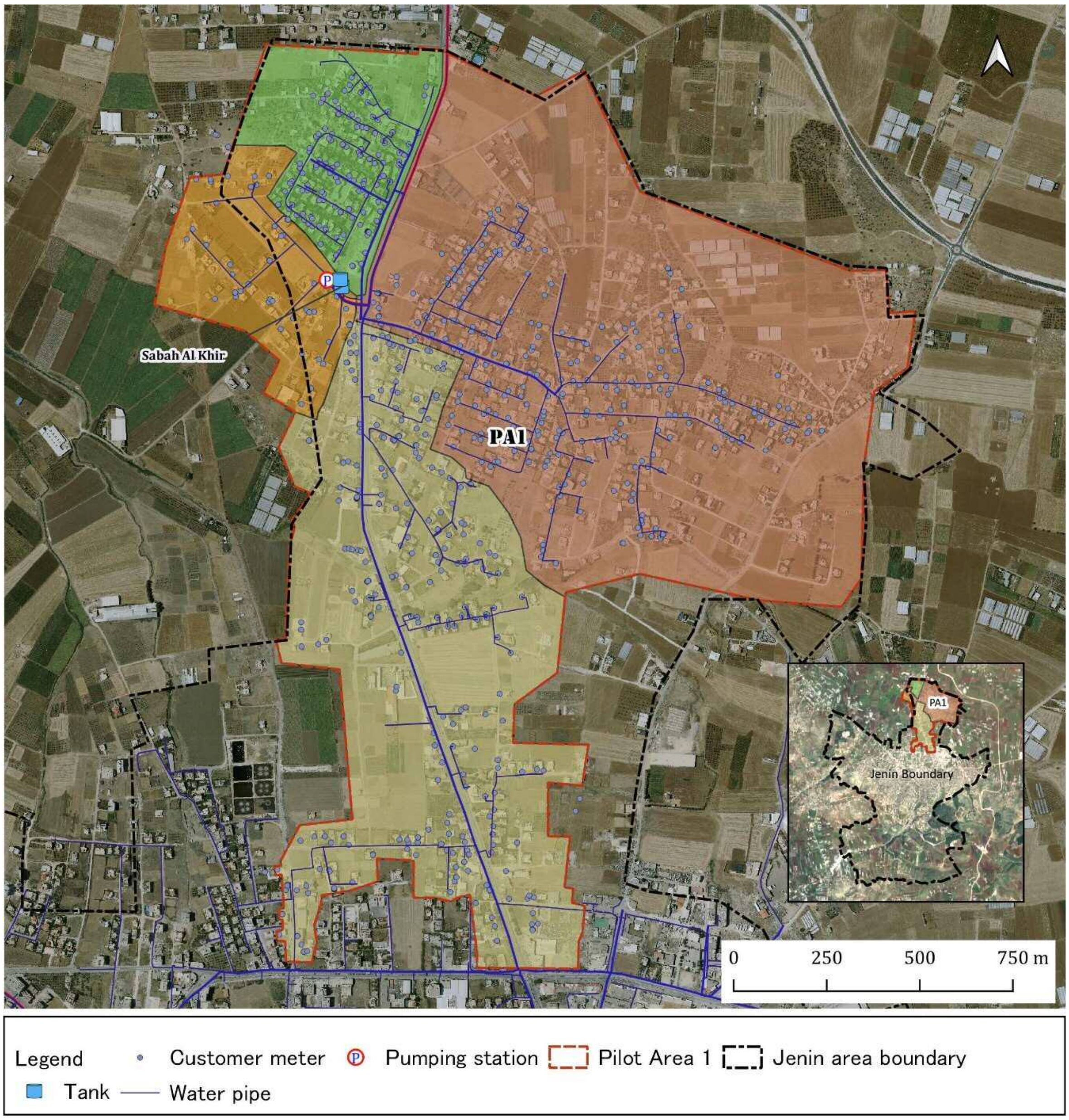


Figure 2: Pilot Area 1 outline showing sub-areas, pipe network, customer meter locations, and Sabah Al Khir pumping station

Table 1: Features of Pilot Area 1

No.	Particular	Description	Remarks
1	Localities	Sabah Al Khir, Kharoubeh, Nazareth Street, Al Basateen (partially)	
2	Area occupied	2.70 km^2	
3	Length of pipe network	17.89 km	25 mm and bigger
4	Number of customers (in 2018)	723 connections	This number has increased to 858 as of Feb. 2021
5	Average monthly surface leak repaired	3.2 nos./month	93 number of leaks repaired in 29 months (Nov 2018 - Mar 2021)

3.2 Supply volume and baseline NRW in PA1

October to December 2018 period was taken as baseline period for NRW as DMA construction work was completed and inflow could be correctly measured by the end of September 2018. Water supply volume, NRW volume and percentage during that period is given in Table 2.

Table 2: Supply volume and NRW in Pilot Area 1 during baseline period

No.	Particular	Description	Remarks
1	Average daily water supply (in Oct.-Dec. 2018 period)	873 m^3/day	Baseline period
2	Average daily billed volume (in Oct.-Dec. 2018 period)	376 m^3/day	Baseline period
3	NRW (in Oct.-Dec. 2018 period)	497 m^3/day (56.9% of supply volume)	Baseline period

4. NRW REDUCTION ACTIVITIES IMPLEMENTED

The following activities were implemented in PA1:

4.1 Customer survey and database update

All households within the PA1 were surveyed and information on water service connection status, alternate water sources, user numbers, size and number of water storage facilities, details of existing meters, and so on was updated/collected. This activity took about two months to finish but when the actual working hours are considered (about 1-3 hours/day) and converted to full day work (6 hrs/d) the total time required for this task was about 10 days.

4.2 Updating of pipe network information

Entire PA1 area was surveyed using pipe locator. Locations of distribution pipelines were determined by the locator and recorded using high precision GPS machine. Using this information, updated pipe network map was prepared in GIS. Location of each customer meter was marked on the map and service connection route from the meter to the distribution pipe was drawn approximately by visual inspection. This process was carried in parallel to customer database survey and took about 10 full days.

4.3 Procurement and installation of flow and pressure measuring devices

Figure 3 shows the locations of flow and pressure measurement in PA1. The equipment installed at each location is summarized in Table 3.

Table 3: Summary of equipment installed at each location of PA1

Location	New chamber	New bulk meter	New pressure tapping and data logger	New valve
1	No	Yes, mechanical (dia. 200 mm)	No	No
2	Yes (pre-cast)	Yes, electromagnetic (dia. 150 mm)	Yes	No
3	Yes (pre-cast)	Yes, mechanical (dia. 50 mm)	Yes	Yes (one)
4	No	Yes, mechanical (dia. 150 mm)	Yes	Yes (one)
5	No	Yes, mechanical (dia. 100 mm)	Yes	Yes (one)
6	Yes (precast)	Yes, electromagnetic (dia. 150 mm)	Yes	Yes (one)

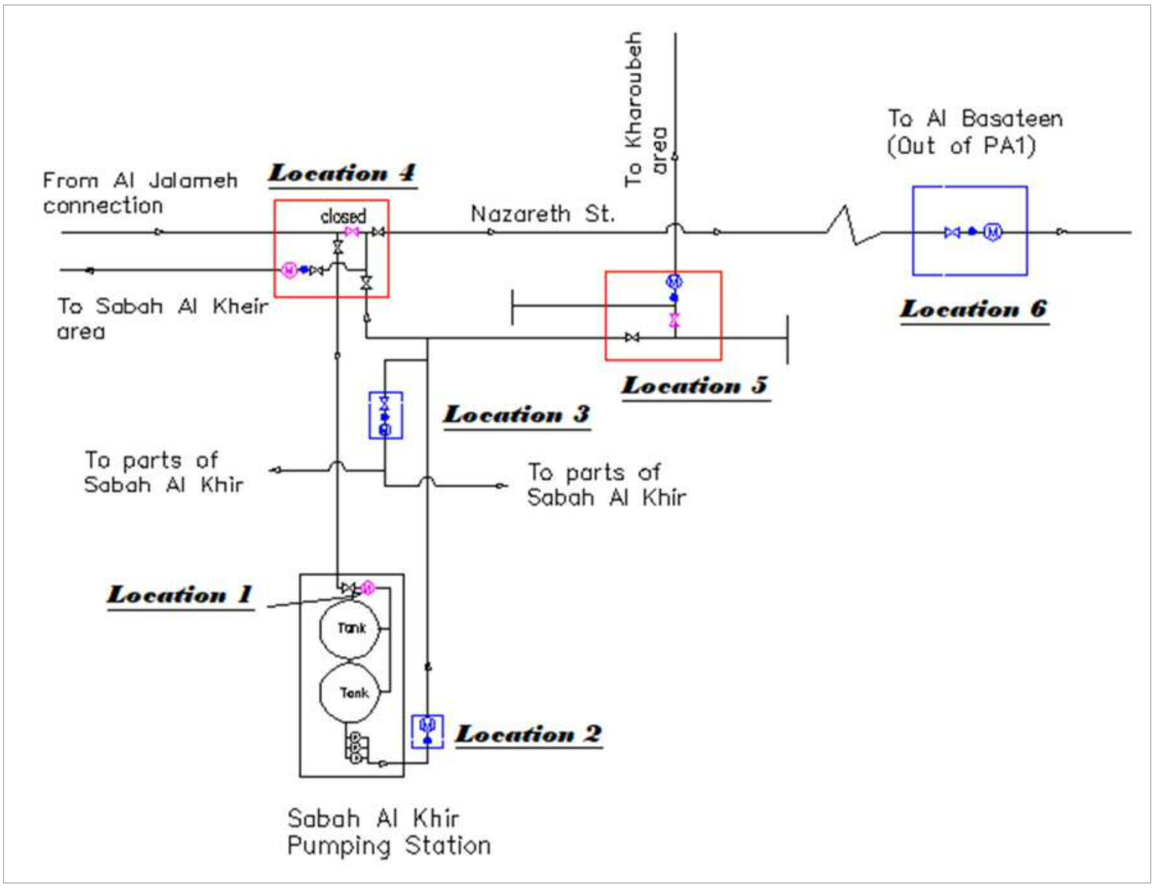


Figure 3: Schematics of flow and pressure measuring devices installation in PA1

4.4 Leak detection survey and leak repair

Leak detection survey was conducted as on-the-job training. The survey covered all the customer households and the entire area covered by distribution network. It found 15 suspected leaks out of which 7 were confirmed and repaired. The leaks were repaired after establishing the baseline NRW level.

4.5 Customer meter accuracy check

Purpose of this task was to find out overall measurement error of existing customer meters. Seventy working (not stopped) customer meters were selected randomly from PA1 and their accuracy was tested in-situ with a portable testing system.

4.6 Customer meter replacement

As of end of this analysis period (August 2020), 684 number out of total 836 existing customer meters in PA1, were replaced with ultrasonic prepaid type meters having the following specifications: DN-20, Permanent flowrate Q_3= 4 m^3/h, Minimum flowrate Q_1=0.01 m^3/h, R =Q_3/Q_1=400, Initial flowrate Q_i=3 L/h, Maximum working pressure =16 bar, Maximum working temperature = 50°C, Accuracy class = Class 1. The remaining customers did not agree to replace their existing mechanical meters for various reasons.

5. COST OF ACTIVITIES

Costs of the above and all related activities are as summarized in Table 4 below.

Table 4: Summary of cost items

S. N.	Items	One time cost (USD)	Useful life/ repetition frequency (years)	Cost per year (USD)	Remarks
1	Bulk meters, valves, fittings, data loggers	35,810	8	4,476	
2	Chamber construction	7,507	15	500	
3	Customer database update survey	1,908	5	382	
4	Network update	660	5	132	
5	Leak detection survey	816	1	816	Repeat every year
6	Leak repair	2,677	1	2,677	Repeat every year
7	Prepaid meters, gateways, fittings	117,522	10	11,752	
8	PPWM installation	7,340	10	734	
9	Illegal connection survey and rectification	252	0.08	3,024	Repeat every month
	Total			**24,493**	

The number and size of leaks repaired from Oct 2018 to May 2021 period is given in Table 5 below.

Table 5: Leak repaired from Oct 2018 to May 2021 period in PA1

Period	Very large	Large	Medium	Small	Unknown	Total
Baseline (Oct-Dec 2018)	0	1	4	2	0	**7**
Jan 2019-Jun 2019	0	4	2	1	0	**7**
Jul 2019-Jan 2020	0	9	2	5	1	**17**
Feb 2020-Aug 2020	3	2	10	6	0	**21**
Sep 2020-Feb 2021	1	0	12	23	0	**36**
Mar 2021-May 2021	0	0	1	4	0	**5**
Total	**4**	**16**	**31**	**41**	**1**	**93**

6. BENEFITS

6.1 Benefits from overall reduction in NRW

Reduction in NRW volume is the main benefit. Figure 4 below shows the trend of NRW in PA1 from the baseline period until all major countermeasures were applied.

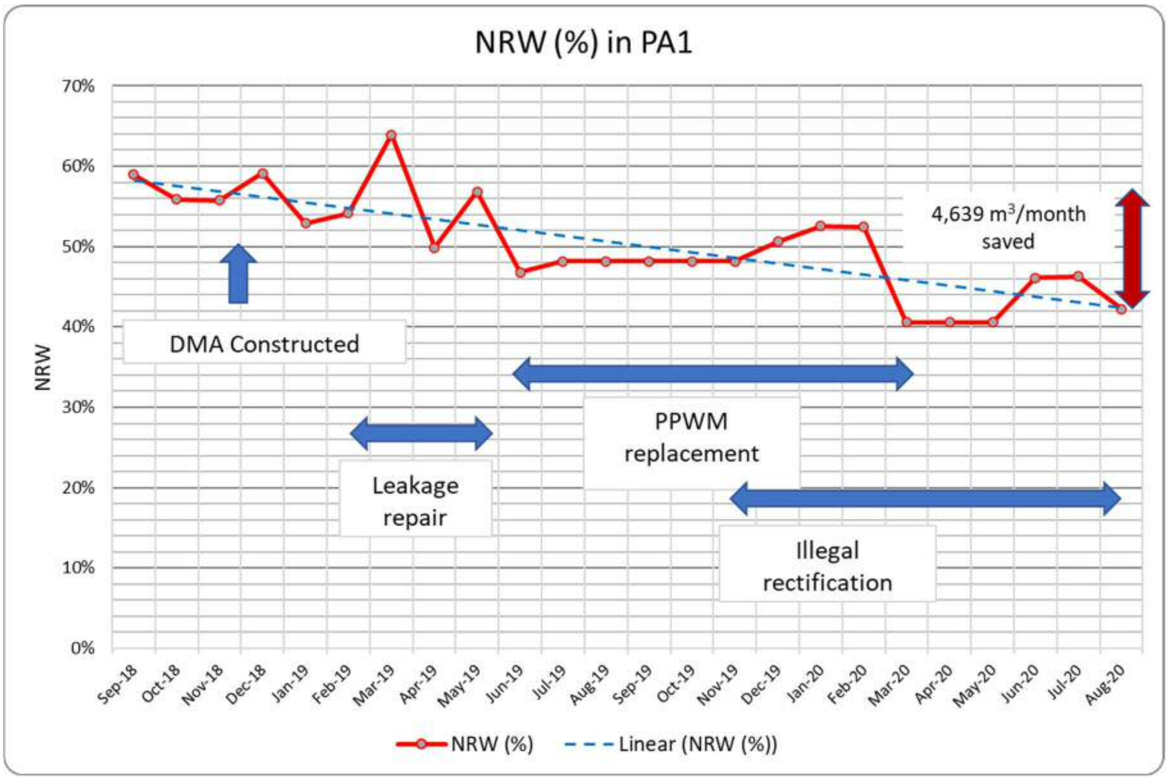


Figure 4: NRW trend in PA1 (2018-2020)

The volume of saved water by reducing NRW consists of both physical losses and apparent losses. If the water production is reduced as a result of reduction in physical loss, then this saving is calculated based on the production cost. But if the saved physical loss is used as an additional source and supplied to customer, then the saving is calculated based on average selling price. Since Jenin's water demand is not satisfied (demand is more than available source) the saved volume from physical losses reduction will also be supplied to customer as an additional source, and thus, the calculation of saving will be based on selling price. The saving from reduction in apparent losses is always on the base of selling price.

6.2 Other intangible benefits

In addition to the direct benefit of saving water, there are several other benefits of NRW reduction such as reduction in chance of water contamination, reduction in inconvenience to public due to unplanned water cut, traffic nuisance from flooded roads etc. But these are difficult to quantify and not considered in this report.

6.3 Benefits of each major NRW countermeasure

In order to calculate benefits of each major NRW countermeasure, the period is divided into four stages. Detail of NRW and major countermeasure in each stage is shown in Table 6 and Table 7 below.

Table 6: Details of NRW in each month during the stages

Stage	Month	SIV (m^3)	Consumption (m^3)	NRW (m^3)	NRW (%)	Av. NRW (m^3/month)
Baseline	Oct-18	28,239	12,464	15,775	55.9%	15,239
	Nov-18	24,708	10,937	13,771	55.7%	
	Dec-18	27,365	11,193	16,172	59.1%	
Stage 1	Jan-19	24,556	11,572	12,984	52.9%	13,452
	Feb-19	24,287	11,140	13,147	54.1%	
	Mar-19	26,528	9,567	16,961	63.9%	
	Apr-19	19,836	9,947	9,889	49.9%	
	May-19	25,819	11,139	14,680	56.9%	
	Jun-19	27,907	14,854	13,053	46.8%	
Stage 2	Jul-19	26,849	13,919	12,930	48.2%	12,523
	Aug-19	26,849	13,919	12,930	48.2%	
	Sep-19	26,849	13,919	12,930	48.2%	
	Oct-19	26,849	13,919	12,930	48.2%	
	Nov-19	26,849	13,919	12,930	48.2%	
	Dec-19	22,115	10,923	11,192	50.6%	
	Jan-20	22,489	10,667	11,822	52.6%	
Stage 3	Feb-20	21,569	10,252	11,317	52.5%	10,600
	Mar-20	22,844	13,574	9,270	40.6%	
	Apr-20	22,844	13,574	9,270	40.6%	
	May-20	22,844	13,574	9,270	40.6%	
	Jun-20	24,491	13,204	11,287	46.1%	
	Jul-20	27,227	14,633	12,594	46.3%	
	Aug-20	26,513	15,321	11,192	42.2%	

Table 7: Major stages of work and main countermeasure

Stage	Duration	Av. monthly NRW (m^3/month)	NRW reduced (m^3/month)	Main countermeasure
0	Baseline (Oct-Dec 2018)	15,239		
1	Jan 2019-Jun 2019	13,452	1,787	Leak repair
2	Jul 2019-Jan 2020	12,523	929	Meter replacement
3	Feb 2020 - Aug 2020	10,600	1,923	Illegal rectification
	Total		**4,639**	

Although major countermeasure of each stage is as shown above, other countermeasures were also applied at the same time with the major countermeasure. Approximately estimated % contribution of each countermeasure to NRW reduction at each stage is shown in Table 8.

Table 8: Assumed % contribution of each major countermeasure on NRW reduction

Stage	Total monthly reduction	Contribution of leak repair	Contribution of meter replacement	Contribution of illegal rectification
0	-	-	-	-
1	100%	**75%**	0%	25%
2	100%	25%	**50%**	25%
3	100%	25%	**50%**	25%

Calculated contribution to NRW volume (m^3/month) reduction by each countermeasure based on the % contribution shown in Table 8 is given in Table 9.

Table 9: Estimated contribution to NRW reduction (m^3/month) by each countermeasure

Stage	Total NRW reduced (m^3/month)	Contribution of leak repair	Contribution of meter replacement	Contribution of illegal rectification
0	-	-	-	-
1	1,787	1,340	0	447
2	929	232	465	232
3	1,923	481	962	481
	4,639	**2,053**	**1,427**	**1,160**

Average selling prices of water in Jenin for year 2016 was NIS 5.12/m^3 (Ref. 2016 annual report). The same value will be used to calculate benefit as there has been no tariff revision since then.

From the above, the benefit of each countermeasure is calculated and summarized in

Table 10.

Table 10: Estimated benefit by each major countermeasure

S.N.	Countermeasure type	NRW saved/ moth (m^3)	NRW saved/ year (m^3)	Benefit/year (USD) [@ 1.551 USD/m^3 (5.12 NIS/m^3)]
1	DMA construction and preparatory works	-	-	-
2	Leak detection and repair	2,053	24,636	38,210
3	Customer meter replacement (with prepaid ultrasonic meter)	1,427	17,124	26,559
4	Illegal connections rectification	1,160	13,920	21,590
	Overall	**4,640**	**55,680**	**86,359**

7. COST EFFECTIVENESS OF NRW COUNTERMEASURES

7.1 Cost-effectiveness of NRW Countermeasures in PA1

The benefit cost ratios are calculated from the costs shown in Table 4 and benefits in

Table 10 and summarized in Table 11 below.

Table 11: Summary of benefit-cost calculation

S.N.	Countermeasure type	Cost items in Table 4	Cost/ year (USD)	Benefit/ year (USD)	Benefit / Cost ratio	Remarks
1	DMA construction and preparatory works	S.N. 1-4	5,490	-	-	
2	Leak detection and repair	S.N. 5-6	3,493	38,210	10.94	Almost all result is due to repairing of surface leakage
3	Customer meter replacement (with prepaid ultrasonic meter)		12,486	26,559	2.13	
	*If the meters were replaced with mechanical volumetric meters**		*(3,465)*	*(26,559)*	*(7.66)*	*To compare with the ultrasonic prepaid type*
4	Illegal connections rectification		3,024	21,590	7.14	
	Overall		**24,493**	**86,359**	**3.53**	

* Cost of mechanical volumetric meter = USD37.2, cost of ultrasonic meter = USD171.4, installation cost same as ultrasonic meter, but no additional fittings are required compared to ultrasonic meter.

The above result shows that in overall NRW reduction works are extremely cost-effective and they should be given priority over other expensive means of new water sources.

Customer meter replacement by PPWM shows the lowest benefit-cost ratio. But it is to be noted that in this analysis only the benefit of NRW reduction has been considered. PPWM has even more important benefit of increasing collection ratio to 100%. If that is also considered, the benefit-cost ratio of meter replacement will be much higher. As also shown in Table 11, if the meters were replaced by conventional mechanical (volumetric type) meters available in the local market, the benefit-cost ratio would have been increased to 7.66 compared to 2.13 for prepaid ultrasonic type meters.

7.2 Cost-effectiveness of source meter checking and replacement in Jenin

If the source meters are inaccurate the measurement of supplied water volume (system input volume or SIV) will be inaccurate. This results into incorrect NRW. Since JM purchases about two-thirds of the water it supplies from private sources and West Bank Water Department, it is necessary to have accurate measurement of source volume, otherwise JM would be paying for wrong volume.

The source meters of private wells were checked by portable ultrasonic flowmeter as a part of regular NRW management activity. Five of the eight private well meters were found to be defective (have errors beyond the permissible range ± 5%). Details of this checking is given in Table 12 and Table 13. Cost-benefit analysis was made considering replacement of the defective meters with mechanical meters. Its result is presented in the following section and Table 14.

Table 12: Detail of source meters checked

ID	Starting date	Measurement duration (hrs)	Quantity recorded in 24-hr period		Measurement Error of the Source Meter (%)	Size of bulk meter (mm)	Remarks
			Well's bulk meter	UFM			
1	20-May-21	24	817.00	795.44	2.7%	75	Error acceptable
2	20-May-21	48	428.00	296.50	44.4%	75	
3	02-Jun-21	24	405.00	390.05	3.8%	50	Error acceptable
4	14-Jun-21	24	818.00	779.40	5.0%	75	Error acceptable
5	14-Jun-21	24	678.00	607.80	11.5%	150	
6	21-Jun-21	48	505.50	362.50	39.4%	75	
7	26-Jul-21	24	592.00	640.52	-7.6%	75	
8	18-Aug-21	96	53.25	168.25	-68.4%	100	

Aggregate error of five meters whose errors are beyond the acceptable range is summarized in Table 13.

Table 13: Aggregate error of five meters having error beyond permissible range

S.N.	Description	Quantity in 24-hr period		Over-reading by existing bulk meters	
		Well's bulk meter	UFM	m^3/day	%
1	Meters having error more than permissible (not within ± 5%) (S.N. 2, 5-8)	2,256.8	2,075.6	181.2	8.7%

From the above, the calculated SIV for NRW calculation of whole Jenin is more than actual by 181.2 m^3/day.

JM can save the water charge equivalent to the purchase cost of 181.2 m^3/day by replacing the 5 defective meters. Even the new meters will have some error but they will likely be both positive and negative and cancel each other. Considering this case, the cost-benefit analysis of testing of 8 and replacing 5 meters by mechanical meters is summarized in Table 14 below.

Table 14: Cost-benefit analysis of source meter testing and replacement

S.N.	Description	Quantity	Unit	Remarks
1	Benefit			
	Apparent loss reduced	181.20	m^3/day	Replacing 5 meters only
	Average purchasing price of water	2.10	NIS/m^3	From 2016 annual report
		0.636	USD/m^3	
	Benefit (saving in water charge payment to private wells) =181.2*0.636	115.28	USD/day	
		42,077.20	USD/year	
2	Cost			
	Cost of checking 8 and replacing 5 meters	11,495.00	USD	
3	Cost recovery period	0.273	Year	
		3.28	Months	

The above result shows that source meters are significant part of error in calculation of NRW and by replacing defective meters (meters having errors beyond acceptable range), JM can recover the cost in about three months.

7.3 Cost-effectiveness of NRW Countermeasures in general

1) Cost-effectiveness of principal countermeasures

In the general context of Jenin, where;

- ✧ the existing NRW level is very high (still more than 50%),
- ✧ illegal connections are widespread,
- ✧ water resources are scared,
- ✧ water supply is intermittent,
- ✧ there is a security concern for nighttime work,
- ✧ supply pressure is extremely high in some localities, and
- ✧ water utility (Jenin Municipality)'s financial situation is weak,

The countermeasures of NRW in the order of decreasing cost-effectiveness may be as listed below:

(1) Conducting daily patrolling for finding surface leakage and quickly repairing,
(2) Implementing measures against illegal connections by regularly analysing customer consumption data and checking customer meters which show zero-consumption,
(3) Checking accuracy of and replacing defective source meters,
(4) Conducting combined stop-cock test and sounding survey in suspicious blocks/branches and repairing leaks quickly,

(5) Testing customer meters and replacing defective customer meters,
(6) Pressure management,
(7) Leak detection survey using conventional acoustic system and timely repair, and
(8) Replacing leak-prone/worn out water network and facilities.

The above measures are graphically depicted below in Figure 5 considering their cost, benefits, and timeframe of implementation.

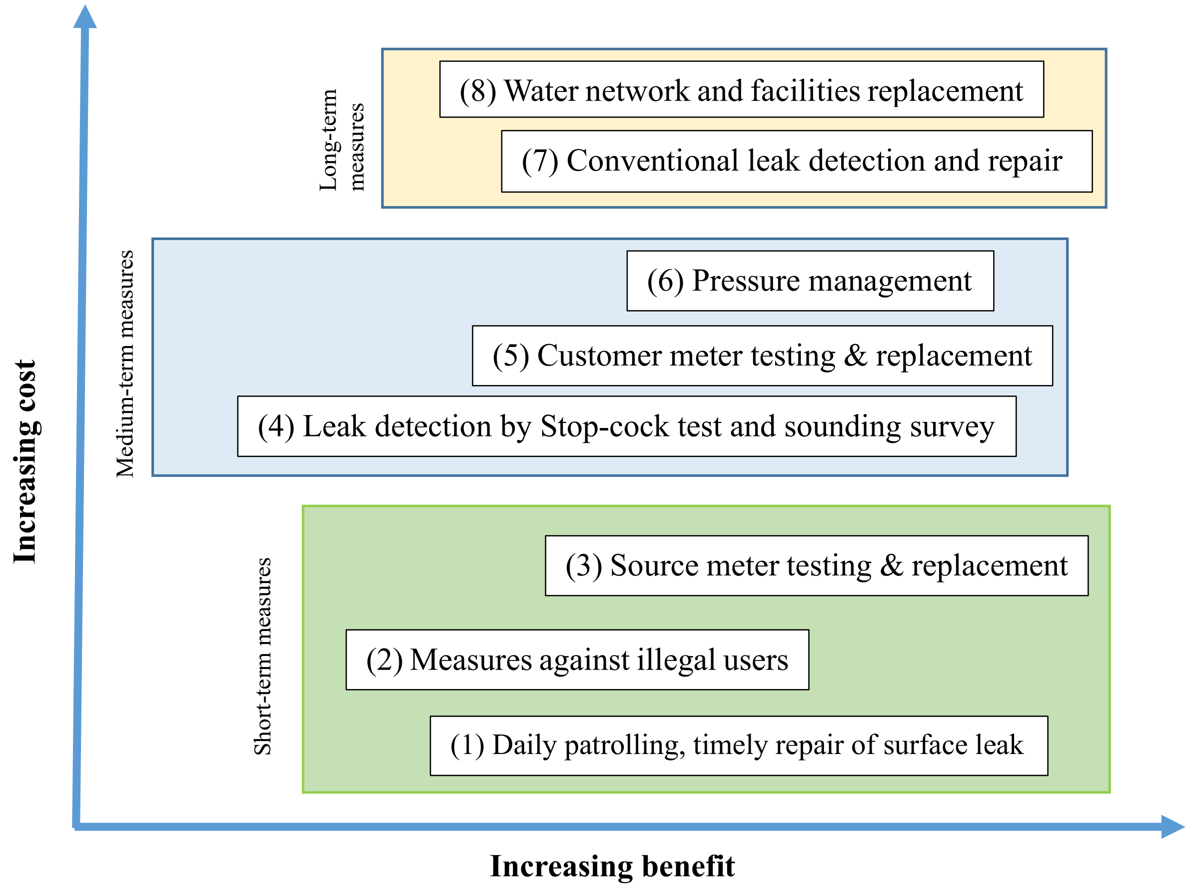


Figure 5: Cost, benefit, and timeframe of potential NRW reduction measures in Jenin

It is to be noted that the cost benefit effectiveness (payback period and BC ratio) is for the range of current NRW level (~50%) in this pilot area. The effectiveness of overall NRW measures and each measure would change as the NRW level decreases. If the current NRW level was in different range; e.g., 20% or less, the effectiveness of overall NRW measures and each measure could have been different.

8. COST-BENEFIT ANALYSIS IN PA3

8.1 Cost of Activities in PA3

The costs are shown in Table 15 below.

Table 15: Cost of activities in PA3

S. N.	Items	One time cost (USD)	Useful life/ repetition frequency (years)	Cost per year (USD)	Remarks
1	Bulk meters, valves, fittings, data loggers	5,735	8	717	
2	Chamber construction	2,104	15	140	
3	Customer database update survey	630	5	126	
4	Network update	632	5	126	
5	Leak detection survey	816	1	816	Repeat the survey every year
6	Leak repair	385	1	385	
7	Prepaid meters, gateways, fittings	88,035	10	8,804	
8	PPWM installation	8,480	10	848	
9	Illegal connection survey and rectification	252	0.08	3,024	Repeat the survey every month
	Total	**107,069**		**14,986**	

8.2 Benefit from NRW Reduction in PA3

The NRW reduction in PA3 compared to baseline NRW in Oct 2019 is as shown below in Table 16 and Figure 6 and Figure 7.

Table 16: NRW in PA3

Month	SIV (m^3)	Consumption (m^3)	NRW (m^3)	NRW (%)	Remarks
Oct-19	20,931	9,375	11,556	55.2%	Baseline value
Jul-20	19,119	9,189	9,930	51.9%	
Aug-20	18,191	8,847	9,343	51.4%	
Sep-20	17,402	8,528	8,874	51.0%	
Oct-20	15,721	7,788	7,932	50.5%	
Nov-20	15,721	7,788	7,932	50.5%	
Dec-20	14,438	6,936	7,502	52.0%	
Jan-21	15,171	7,249	7,922	52.2%	
Feb-21	13,671	6,377	7,294	53.4%	
Mar-21	16,201	7,253	8,948	55.2%	
Apr-21	15,874	8,102	7,772	49.0%	
May-21	16,960	8,927	8,033	47.4%	
Jun-21	15,059	8,020	7,038	46.7%	

Month	SIV (m³)	Consumption (m³)	NRW (m³)	NRW (%)	Remarks
Jul-21	15,059	8,020	7,038	46.7%	
Aug-21	15,012	8,715	6,297	41.9%	
Sep-21	12,992	7,281	5,711	44.0%	

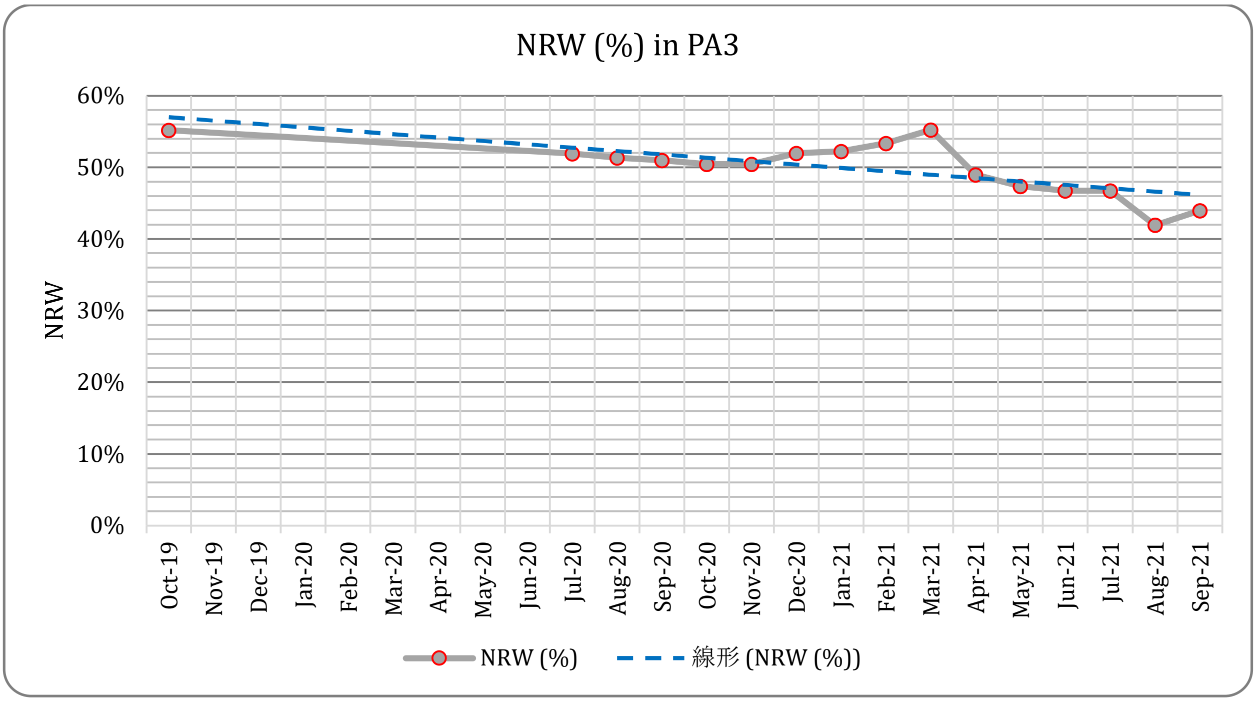


Figure 6: NRW reduction in PA3 (%)

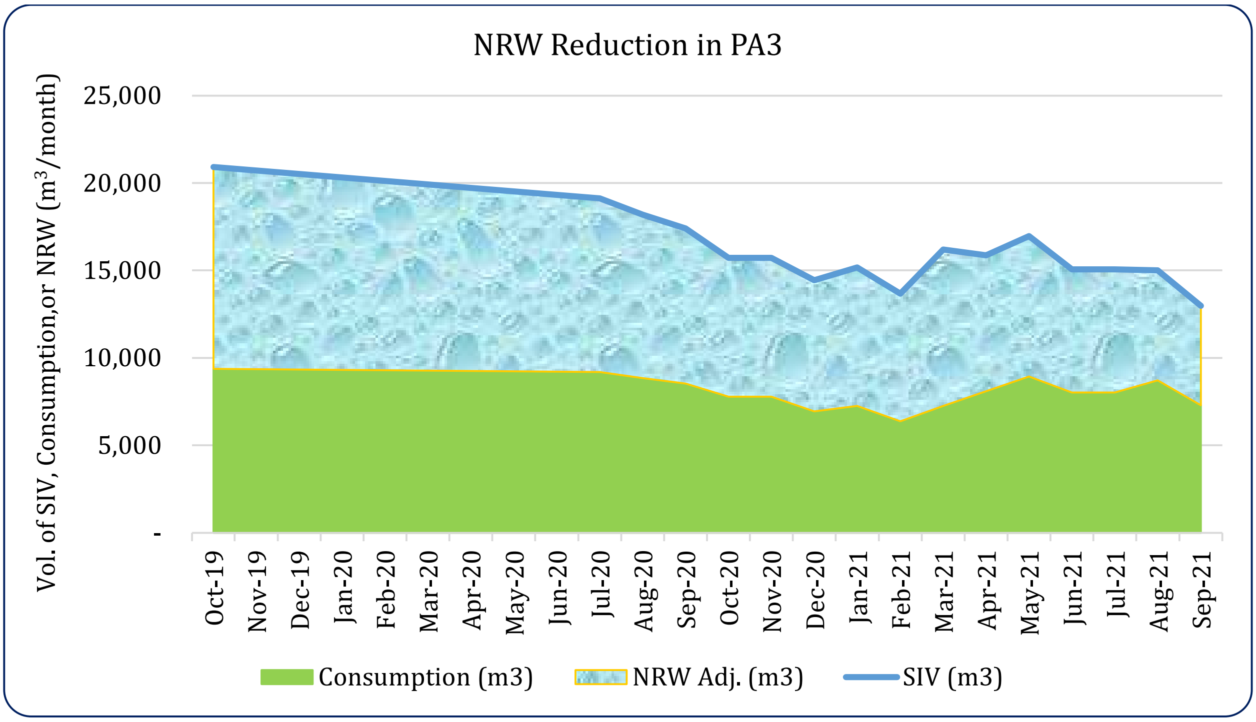


Figure 7: NRW reduction in PA3 (m³/month)

The NRW in PA3 was 11,556 m^3/month in Oct 2019 (baseline period). This has been reduced to 5,711 m^3/month as of Sep 2021. Thus, the NRW volume reduced is 5,845 m^3/month.

The benefit resulting from this reduction in NRW is calculated as shown in Table 17 below.

Table 17: Benefit from NRW reduction in PA3

S. N.	Parameters	Quantity	Unit	Remarks
1	NRW volume reduced	5,845	m^3/month	Baseline (Oct 2019): 11,556 m^3/month Sep 2021: 5,711 m^3/month
		70,140	m^3/year	
	Average selling price of water (NIS/m^3)	5.12		Ref. 2016 Annual report
	NIS-USD conversion rate (1 NIS = 0.303 USD)	0.303		As of 12 Apr 2021
2	Benefit	359,117	NIS/year	
		108,812	USD/year	

8.3 Benefit-cost ratio

From the above values, the benefit-cost ratio comes out to be 108,812/14,986 = 7.26. This gives the cost recovery period of 1.65 months.

The above value is by considering the NRW result of last month (Sep 2021) for which the result is available. But if we take the average of months from Jul 2020 to Sep 2021, the NRW volume reduced will be 11,556 (baseline NRW)-7,838 (average of Jul 2020 to Sep 2021) = 3,718 m^3/month. In that case the benefit would be USD69,215/year and the benefit-cost ratio will be 69,215/14,986=4.61. This will result into a cost recovery period of 2.60 months. This is still an excellent recovery period.

Thus, in conclusion, we can see that the NRW reduction work is extremely cost-effective in the existing context of Jenin. But as noted in the case of PA1, if the current NRW level in this PA was in different range; e.g., 20% or less, the effectiveness of NRW measures (payback period and BC ratio) could have been different.

9. ONGOING COUNTERMEASURES IN PILOT AREAS

NRW reduction is a cyclic process, *i.e.*, if no countermeasures are taken on continuous basis, the once decreased NRW level rebounds. This is due to gradual increase in leakage from existing undetected leaks, occurrence of new leaks, increase in illegal connections, gradual deterioration of meter accuracy, and so on. The NRW level in PA1 once reached down to 40% but it soon increased, due probably to combination of the above factors. The NRW level in PA2 increased compared to baseline level due to connection of a new well source in this area. This well has a very high head pump which caused an increase in supply pressure and reversal of flow direction at the location of a bulk meter. It also probably caused some boundary valves to malfunction. NRW level in PA3 is also high and the reduction is not consistent.

On this background, a workshop was conducted with participation of Jenin Municipality (JM) counterparts and JICA Expert team (JET) which discussed and agreed on a policy to focus on PAs and implement the following specific activities. Currently the counterparts and local JET assistants are actively implementing these activities, and as a result, NRW in PA3 and whole Jenin has started decreasing steadily.

1. Focus on PA1, 2, and 3. Activities on other new DMAs can be taken later.
2. The possible main reasons for high NRW are:
   (a) Leakage (surface and underground)

   (b) Illegal connections,

   (c) Incorrect consumption estimation of non-prepaid meters,

   (d) Leakage due to high pressure (especially near private wells in PA2 and 24-hr area in PA1) and,

   (e) Pipe damage as a result of intermittent supply (repeated closing and opening of valves).

3. Priority cost-effective activities
   (a) Periodical surface leakage patrol together with rapid repair: This measure is low cost and to be continuous activity.

   (b) Finding and rectifying illegal connections: every month check all zero consumption customers. Two or three teams (2 persons in each team) may be needed. If possible, the mayor should be briefed about this very serious issue and his opinion should be considered.

   (c) Correct and complete reading of post-paid meters: all post-paid meters within PA1, 2, and 3 should be read every month. Incorrect estimation or use of zero consumption for unread meters may be causing significant NRW increase. Meters of the suspiciously low consumption or zero consumption customers should be checked visually and if found doubtful, they should be asked to change meters to PPWM. In addition, if consumption history of such customers for last 2-3 years can be prepared, it would help to identify potential illegal water use.

   In addition, replacement of post-paid meter with PPWM shall be enhanced, which avoid meter reading inaccuracy and support zero consumption customer survey.

(d) Continue Step test and Stop-cock methods by small block or at suspicious sections. After this measure, the point of suspicious location will be narrowed down by use of acoustic sounding stick or ground microphone. By this measure, both leakage and illegal connection can be found.

(e) Leakage due to high pressure (especially near private wells in PA2 and 24-hr area in PA1)-during supply time one person should be sent to make a round of the area to check for any surface (visual) leak and if any leak found, it should be repaired with high priority. Not much can be done about pressure management in short term (the remaining time for this project) but temporary measure such as not operating high head pump of the private well during a couple of hours at night can be considered.

Annex 1.3

DMA & Rollout Plan of NRW Reduction – English Version

PALESTINIAN WATER AUTHORITY

THE PROJECT FOR STRENGTHENING THE CAPACITY OF WATER SERVICE MANAGEMENT IN JENIN MUNICIPALITY

DMA & ROLL-OUT PLAN OF NRW REDUCTION

August 2022

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

TEC INTERNATIONAL CO., LTD.

PADECO CO., LTD.

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LIST OF ACRONYMS

CSS	Customer Service Section
CDS	Customer Database Survey
Con	Connection
DMA	District Metered Area (sometimes used to denote a distribution Zone or vice versa)
GIS	Geographical Information System
JM	Jenin Municipality
masl	Metres above sea level
MoLG	Ministry of Local Government
NIS	New Israel Schekel
NRW	Non-Revenue Water
O&M	Operation and Maintenance
OJT	On the Job Training
PA	Pilot Area
PPWM	Prepaid Water Meter
PS	Pumping Station
PWA	Palestinian Water Authority
UFM	Ultrasonic Flow Meter
WWD	Water and Wastewater Department (of JM)

1. BACKGROUND

Non-revenue Water (NRW) reduction is one of the main objectives of this project. In order to build capacity of Jenin Municipality (JM) to manage NRW, three pilot areas were selected, necessary tools and equipment were procured, basic trainings and OJTs for NRW management were provided in the pilot areas. By utilizing the knowledge acquired through the project and with some support of JICA expert team (JET), Water and Wastewater Department (WWD) of JM has started expanding the NRW countermeasures outside the project PAs. Currently two DMAs have been established and preparatory work is progressing in two other DMAs.

By the end of this project the NRW levels in pilot areas have decreased to targeted levels. NRW of the whole Jenin municipality has also decreased by about 5% but the current level is way too high. To reduce the NRW of whole Jenin municipality to a desirable level it is essential to expand the NRW reduction activities in the remaining area of municipality. NRW has the tendency to increase with time, so certain activities are necessary on a continuous basis in the completed areas as well to maintain the achieved levels or reduce them further.

This document provides a plan for rolling out the NRW reduction activities in the remaining areas as well as periodically repeating certain activities in the completed DMAs. This plan draws lessons from the activities implemented in the pilot areas. In preparing this plan consideration has been given to the current progress of DMA implementation and technical and financial capacity of WWD/JM.

2. REVIEW OF PILOT PROJECTS AND LESSONS LEARNED

Three pilot areas were selected in the beginning of the project and activities centered on reduction of NRW and improvement in bill collection ratio were implemented. Salient features of these PAs, activities implemented, results obtained, and lessons learned are briefly outlined in this section.

2.1 Outline of Pilot Areas

The pilot areas were as shown in Figure 2-1.

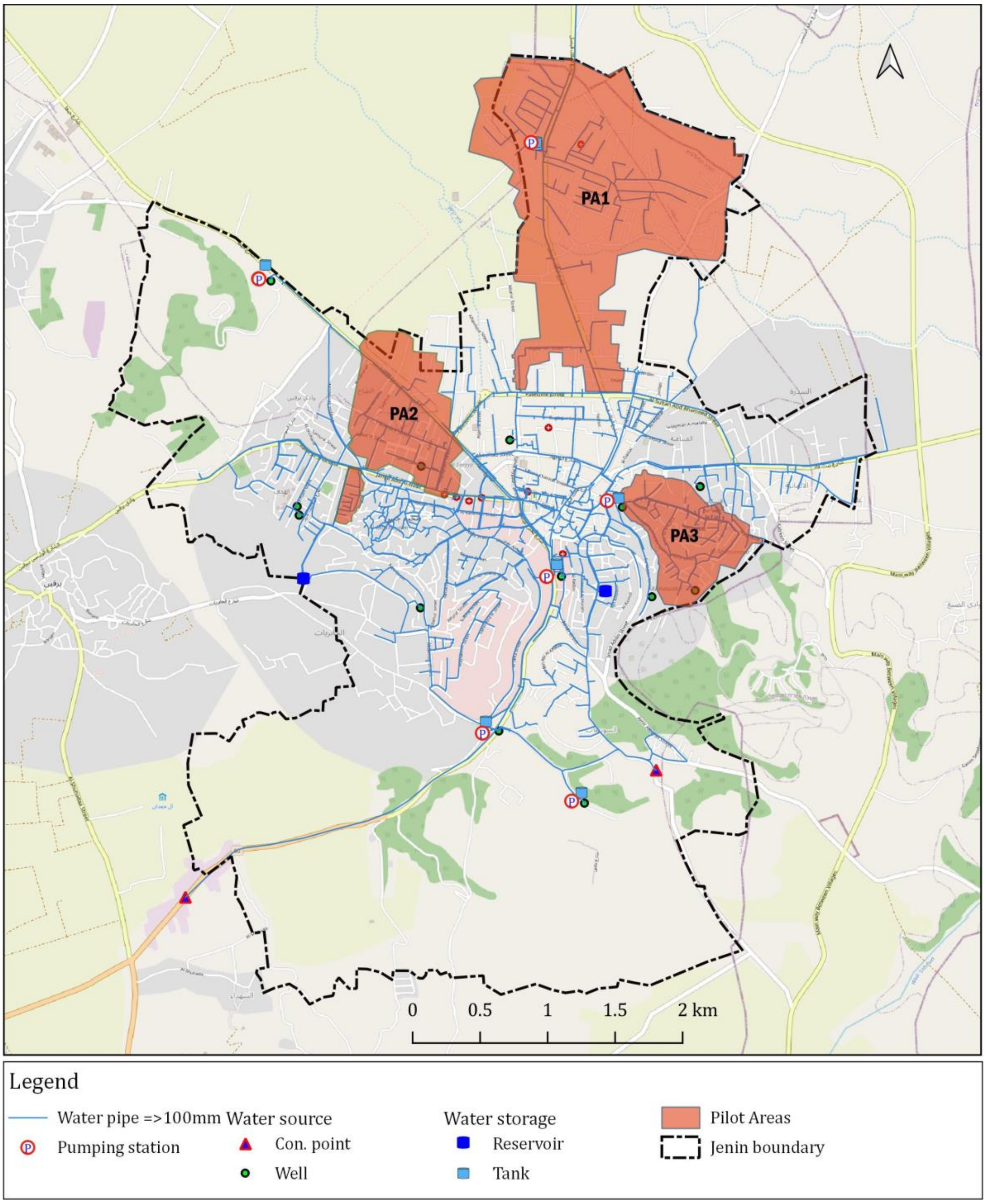


Figure 2-1: Outline of the pilot areas

Table 2-1: Salient features of the Pilot Areas

S. N.	Features	Unit	PA1	PA2	PA3	Total	Remarks
1	Area	km^2	2.72	0.76	0.56	4.04	
2	Number of connections	Nos.	863	671	575	2,109	As of June 2022
3	Length of pipe network (dia. ≥ 25 mm)	km	17.89	14.09	11.32	43.30	
4	Sub-areas/ Sub-DMAs	Nos.	4	2	None	-	
5	Number of bulk meters	Nos.	6	5	2	13	

The three pilot areas covered approximately one-fourth of the Jenin municipality in terms of area, length of pipe network as well as the number of customer connections.

2.2 Implemented Activities

The following activities were implemented in the pilot areas.

Table 2-2: Activities implemented in the Pilot Areas

S. N.	Activities	Unit	PA1	PA2	PA3	Remarks
1	Pressure measurement	Places	10	10	10	
2	Customer database update survey	Properties	1366	907	656	
3	Pipe network confirmation survey (dia. ≥ 50 mm)	km	15.94	11.45	10.15	
4	Chamber construction	Nos.	4	5	1	
5	Procurement and installation of bulk meters for DMA	Nos.	6	5	2	
6	Procurement and installation of dual channel data logger	Nos.	6	4	1	
7	Customer meter accuracy checking	Nos.	70	-	-	Using portable test bench
8	Customer meter replacement by PPWM	Nos.	737	538	533	As of June 2022
9	Leak detection survey	km	15.94	11.45	10.15	
10	Leak repair	Nos.	142	109	45	From 2018.11.16 to 31.08.2022 (45.5 months)
11	Step test	sites	4	0	0	As of Aug 2022
12	Stop-cock method	sites	12	10	4	As of Aug 2022

2.3 Results Achieved

2.3.1 NRW reduction

NRW ratio is one of the key performance indicators of the project. The NRW values of the PAs and entire Jenin city for the baseline, the latest available month (June 2022), and minimum achieved so far are given in the following table.

Table 2-3: NRW situation in PAs and entire Jenin city

Area	Baseline		Latest Available		Minimum Achieved	
	Period	NRW (%)	Period	NRW (%)	Period	NRW (%)
PA1	Oct-Dec 2018	57	June 2022	41.1	Mar~May 2020 May 2021	40.6
PA2	Apr, Jun, Jul 2021	66	June 2022	56.2	Apr 2022	53.9
PA3	Oct 2019	55	June 2022	41.0	Oct 2021	40.1
Whole Jenin	Year 2018	60	June 2022	54.0	June 2022	54.0*

* The NRW in May 2021 is lowest at 42.2% but this value was exceptional caused by reading of many previously unread meters

As indicated by the values in the above table, it is evident that NRW in the pilot areas as well as in entire Jenin city is decreasing, though slowly. The decrease is not always consistent, and it starts raising again if NRW countermeasures are not continued after achieving the lower NRW level. This points to the need of continuous sustained efforts to maintain the NRW at the lowest level.

2.3.2 Collection ratio increase

Another key performance indicator of the project is collection ratio. It has increased remarkably compared to the baseline because of various efforts and replacement of mechanical meters with pre-paid meters. As with NRW, the increase is not always consistent. The baseline, latest, and maximum values achieved so far are shown in the following table.

Table 2-4: Collection ratio (without debt collection) in PAs and entire Jenin city

Area	Baseline		Latest Available		Maximum Achieved	
	Period	Collection Ratio (%)	Period	Collection Ratio (%)	Period	Collection Ratio (%)
PA1	2018	49	July 2022	91.5	Jul 2021	99.6
PA2 (w/o camp)	2018	49	July 2022	70.2	March 2022	77
PA3	2018	49	July 2022	87.6	Feb 2022	100
Whole Jenin	2018	41	July 2022	49.0	Oct 2021	53.8

2.4 Lessons learned and to be incorporated in the DMA & ROP

From the implementation of NRW reduction activities a number of lessons have been learnt. The followings are the lessons relevant to the rollout plan:

1) Significant portion of population (about 40% of residents) do not have municipal water connection and rely on alternative sources of water. These residents live in the same areas where other residents have municipal water connection. Thus, it is necessary to carefully examine each household about its water source during customer database survey (CDS).

2) WWD has a GIS map of pipe network but its accuracy is doubtful. The updating work outside of PAs is still not regular. Thus, substantial effort is required to update and make the pipe network more accurate.

3) The material of distribution network pipe in Jenin is GI or black steel. These are very easily corroded and encrusted. The problems get worse in case of intermittent water supply, and Jenin has this supply system. During leak repair works Jenin's pipe network is found to be heavily corroded and encrusted.

4) The NRW reduction works in pilot areas showed that reducing NRW takes a lot of time and effort. It often requires repetitive works of leakage and illegal connections survey and their rectification.

5) NRW level tends to increase with time. So, maintaining NRW to the lowest level once achieved needs continuous efforts. This is more difficult in case of intermittent supply system, like that of Jenin, because the network is subjected to frequent pressure surges (water hammer) resulting in more pipe breaks.

6) The PPWM system is very important to increase the collection ratio. In addition, this also helped to make water supply more equitable. People become more aware of their water consumption, high consumer reduced their consumption, and the saving was available to others who did not have enough water before. Thus, implementation of PPWM system will be a major factor in successful implementation of this DMA & ROP.

7) Hydraulic isolation of water network (establishing a DMA) is easier in peripheral areas but it becomes more and more difficult as we move towards the city center. There are many reasons for this; pipe network in the city center is often older and unknown, valves are buried, excavation work is difficult due to traffic congestion, and so on. Thus, it is advisable that the DMA implementation start from easier DMAs in peripheral areas and move gradually to more difficult ones to the city center.

3. THE PLAN

3.1 Basic considerations for the DMA & ROP

The following shall be considered in the preparation of this plan:

1) Three pilot areas (PA1, PA2, and PA3) have been completed and NRW countermeasures have been implemented. However, various NRW countermeasures including patrolling for surface leakage detection, investigation of zero-consumption meters for possible illegal connections or problem of meter, monitoring of flow and pressure profiles for abnormal patterns, step test and stop-cock tests of suspicious sections, and investigation for underground leakage/ illegal connections of suspicious sections are needed on regular basis even in these pilot areas to further lower or sustain the achieved level of NRW. Extent of these PAs in the overall zoning plan is shown in Figure 3-1.

2) Preparatory works, DMA establishment, and NRW countermeasures are completed in Al Jinan. This DMA needs monitoring and periodic activities similar to PA1, PA2, and PA3 mentioned above.

3) Preparatory works and DMA establishment have been completed in Al Basateen North. NRW countermeasures need to be started in this.

4) Customer data update survey has been completed in Almaniya. It is about 40% completed in Industrial area.

5) The time required for implementation of various activities is estimated based on the number of household and length of pipe network in each DMA.

6) The cost of items is based on the experience in Pilot Areas.

7) The data of pipe network length, building counts, meter counts and such are taken from the latest available data in GIS. These are indicative only and should be confirmed by surveys.

3.2 Activities included in the DMA & Rollout Plan

The following activities are considered in the DMA & ROP:

1. Clarification and confirmation of new DMA boundary
2. Confirmation of required flowmeters, valves, data loggers etc.
3. Procurement of flowmeters, valves, etc.
4. Pipeline investigation
5. Customer database survey
6. Water pressure measurement
7. Construction of chamber and installation of bulk meter

8. Start of NRW measurement (before measures)
9. Customer awareness and meter replacement
10. Leakage survey (Surface patrolling and underground)
11. Leakage repair
12. Zero consumption meter checking, illegal use survey and rectification
13. NRW evaluation, monitoring, and repetition of Items 10-12 as necessary.

3.3 Detailed Procedure of Executing the Activities

Detailed procedures for the above activities are given in NRW Manual prepared under the project.

3.4 Prioritization of DMAs

The considered time period for implementation of this DMA & ROP is the remaining period of this year (2022) and two more years, i.e., until the end of 2024. With the currently available resources of Jenin Municipality, it will not be possible to cover all the areas of JM within this period. Thus, the DMAs are prioritized. Their implementation should start from the DMA which is easier to isolate or where works have already been progressing. From these prospective, the DMAs have been grouped into three groups; (i) which can be implemented quickly within the remaining period of this year, (ii) to be implemented in year 2023, and (iii) to be implemented in year 2024. The areas not included in any of the above will be out of scope of this DMA & ROP.

Table 3-1: Grouping of DMAs in priority classes and implementation lots

Group 1: Priority 0 (to be implemented in 2022)	Group 2: To be implemented in 2023	Group 3: To be implemented in 2024
1. Jenin camp 2. Industrial area	1. Almaniya 2. North Gate H. Area 3. Basateen North 4. Basateen South	1. Wadi Burqin 2. Wadi Iz Al-din 3. Swetat and Marah Saad

As shown in Figure 5-2 two NRW teams have been proposed within NRW division. The DMAs will be divided and allocated to each team the implementation shall be done in parallel by both teams.

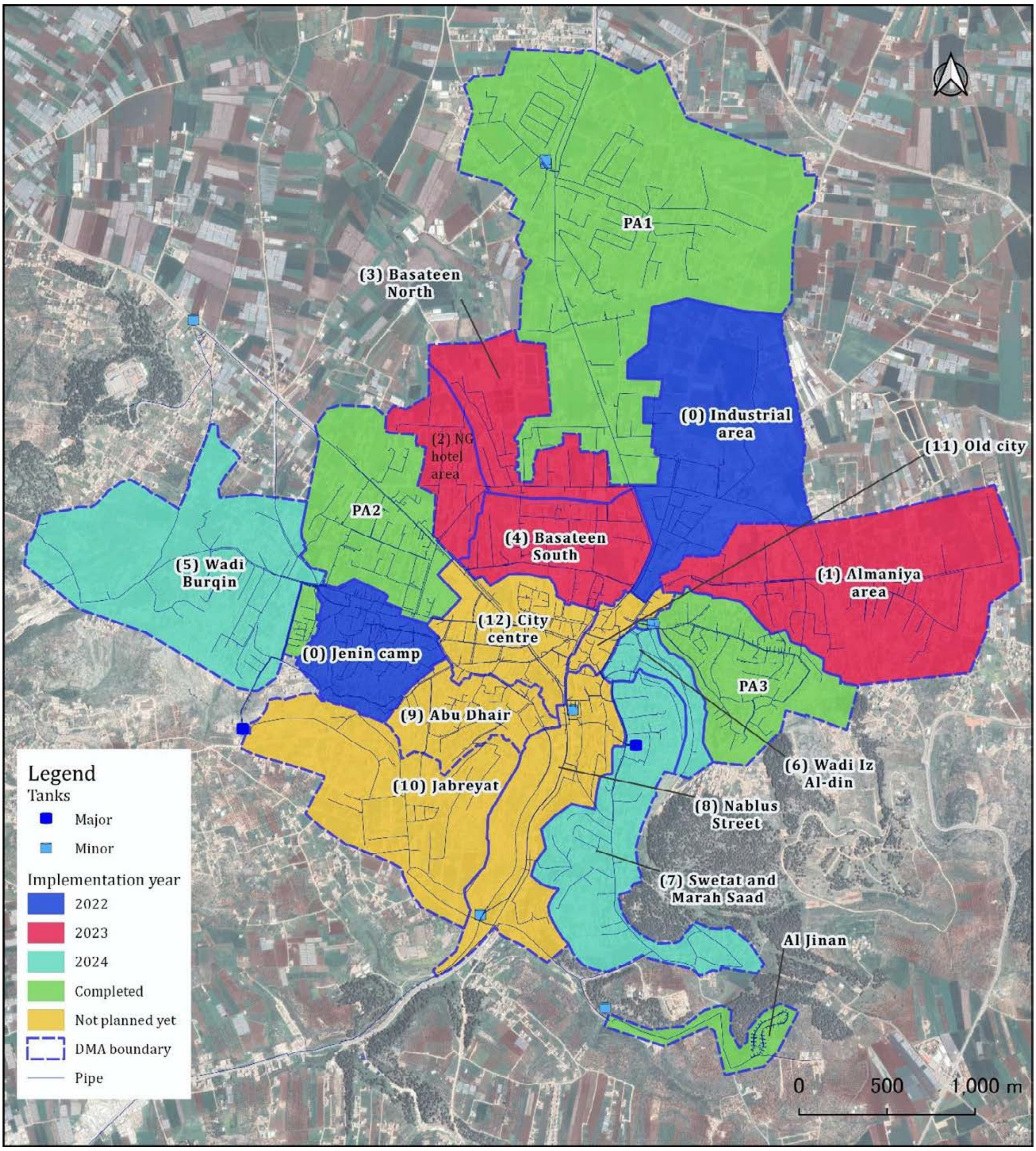
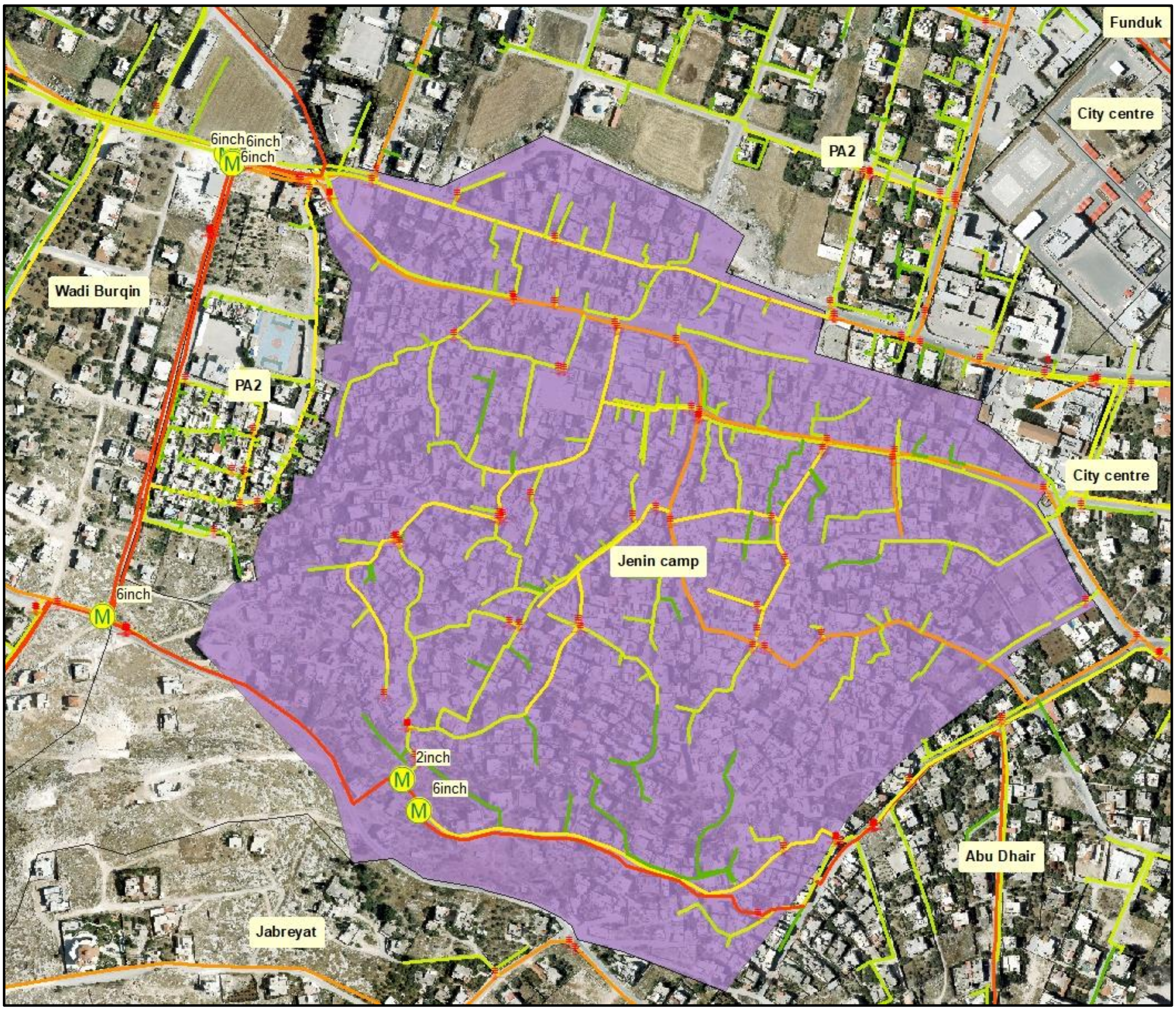


Figure 3-1: Planned DMAs and NRW reduction activities with implementation year

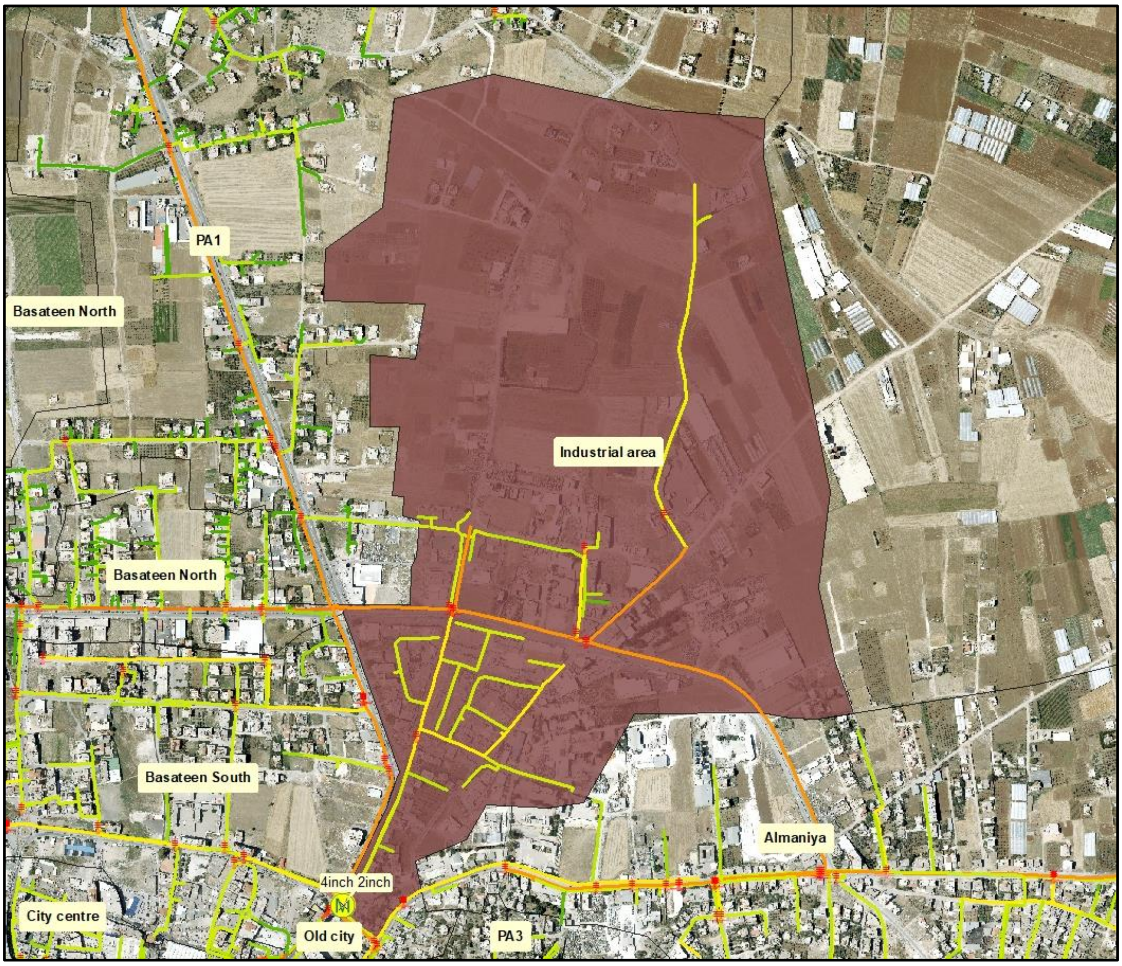
3.5 Details of DMAs

1. Jenin Camp



Number and size of bulk meters required:
3 meters (Día: 150mm), 1 meter (Día: 50 mm)
Likely challenges
1-Checking the boundary valve in the eastern side of Jenin old camp.
2-Not enough space for chamber at some locations.
3-Difficulty to merge two inlet pipelines to one line near Abu Ghada Street to install one meter.

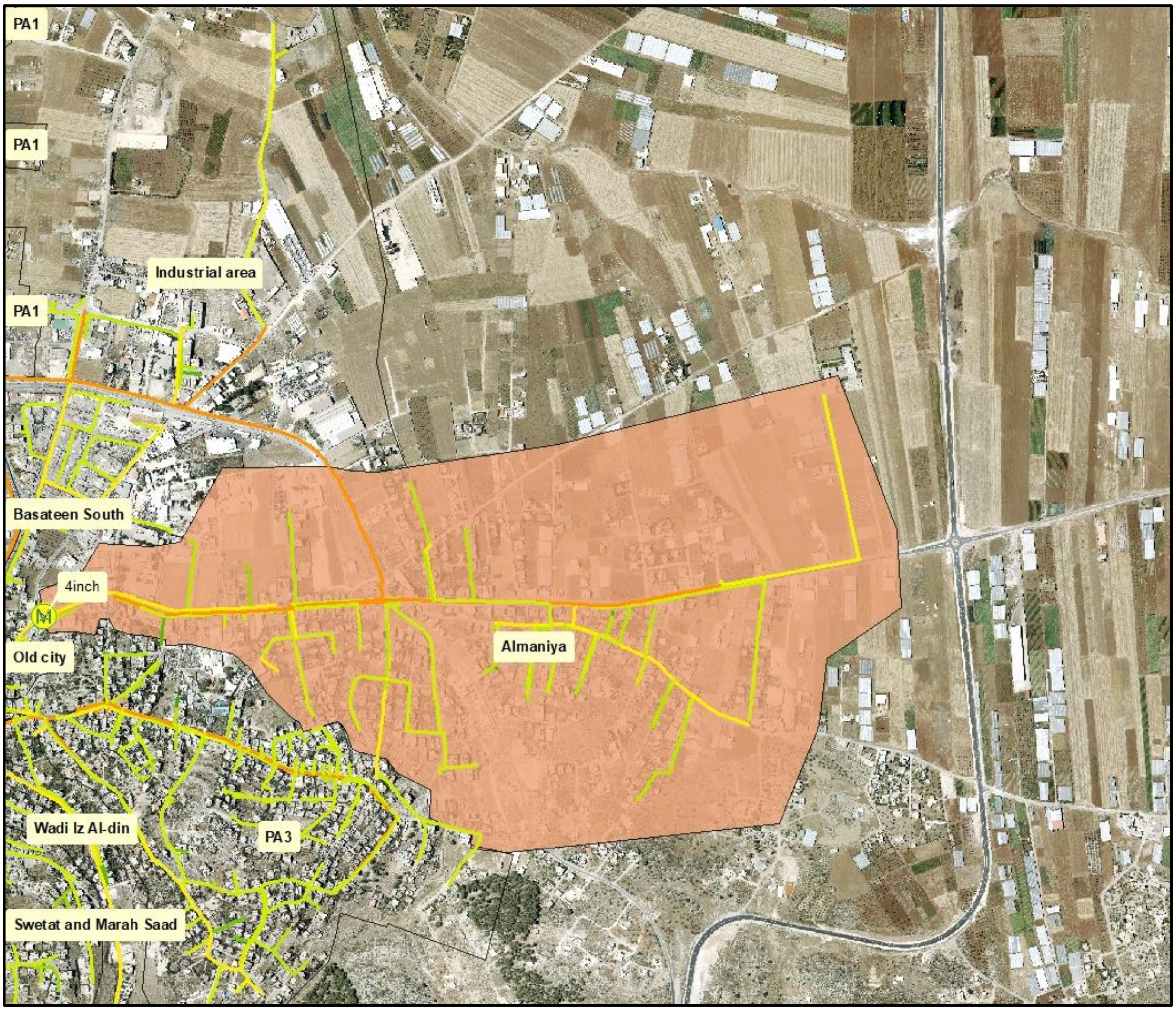
2. Industrial area



Number and size of bulk meters required:
1 meter (dia: 50 mm), 1 meter (dia :100 mm)

Likely challenges:
1-Make sure that boundary valve is working well near Diamond circle.
2-Trying to install one bulk meter instead of two by merging the two inlet pipelines together near Al-Zayed circle.

3. Al-Almanieh

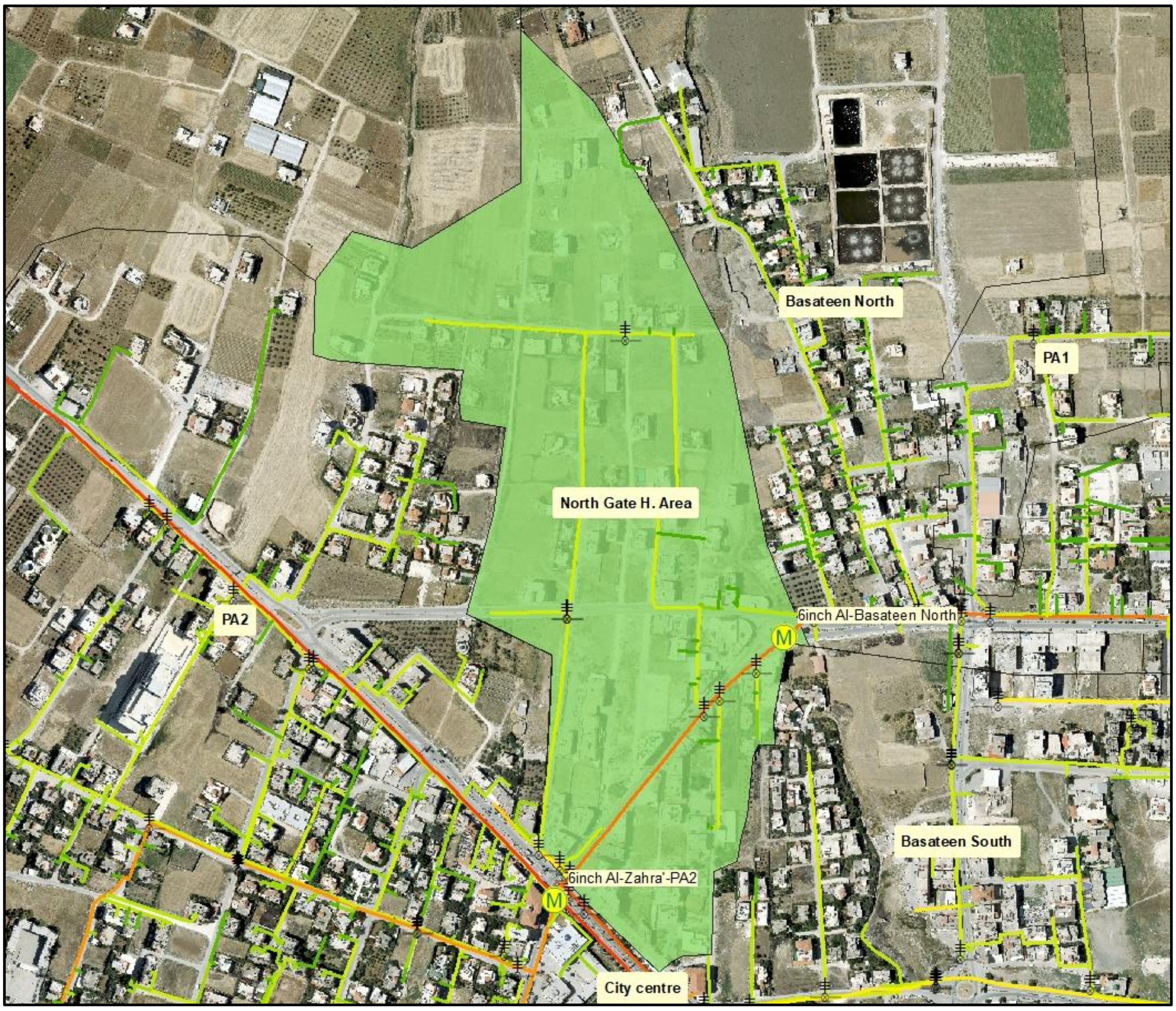


Only 1 bi-directional bulk meter is needed.

Likely challenges:

1- The boundary of DMA is too big and it will need hard work in NRW reduction countermeasures therefore dividing it into two sub-areas and one additional bulk meter might need.

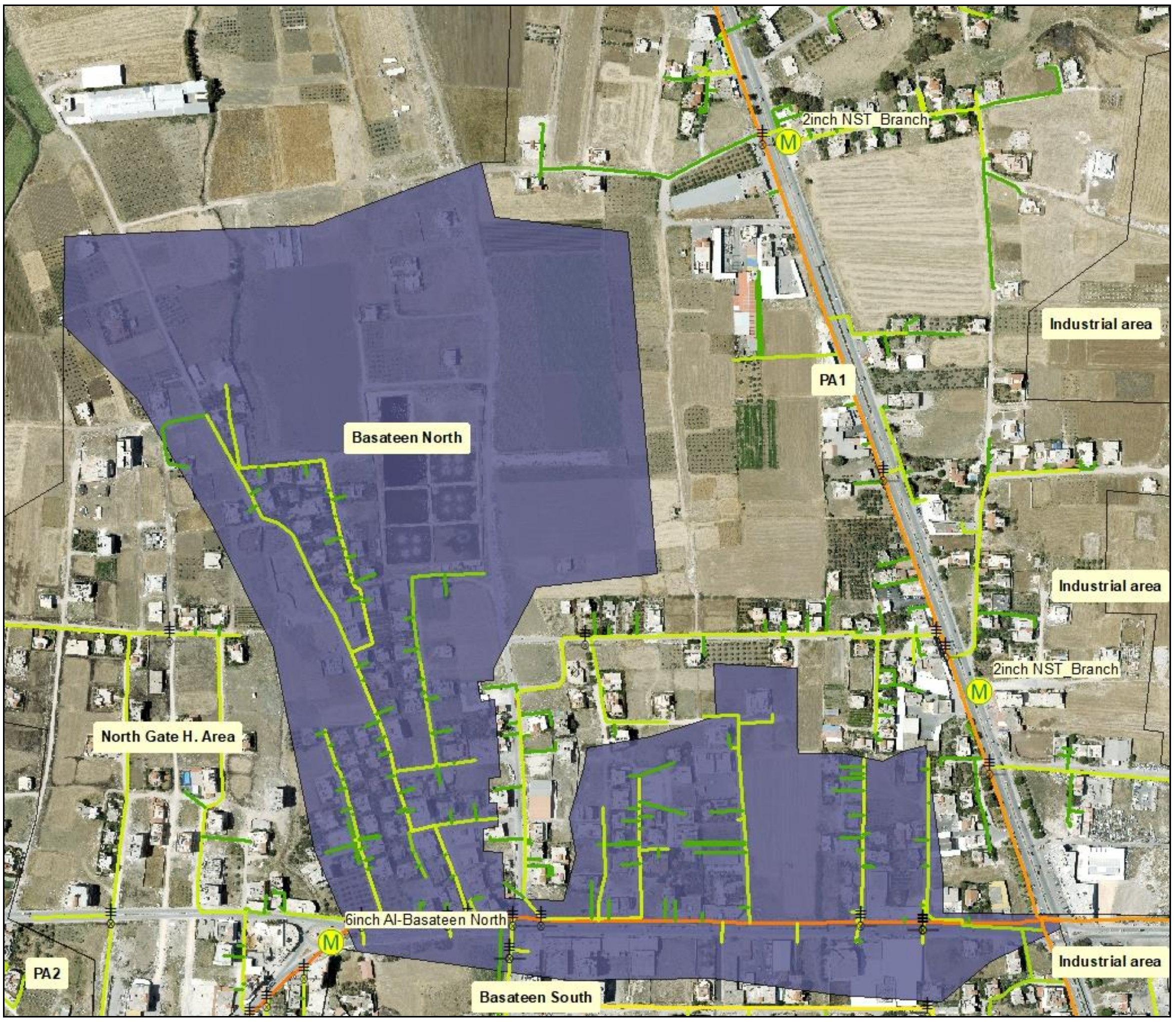
4. North Gate H. Area



The no. of bulk meter needed to calculate the SIV = 2 BMs.

The required BMs are installed already as a DMA bulk meters for other DMAs (one meter as an outlet meter from PA2 and the remaining one as an inlet bulk meter to Al-Basateen north area).

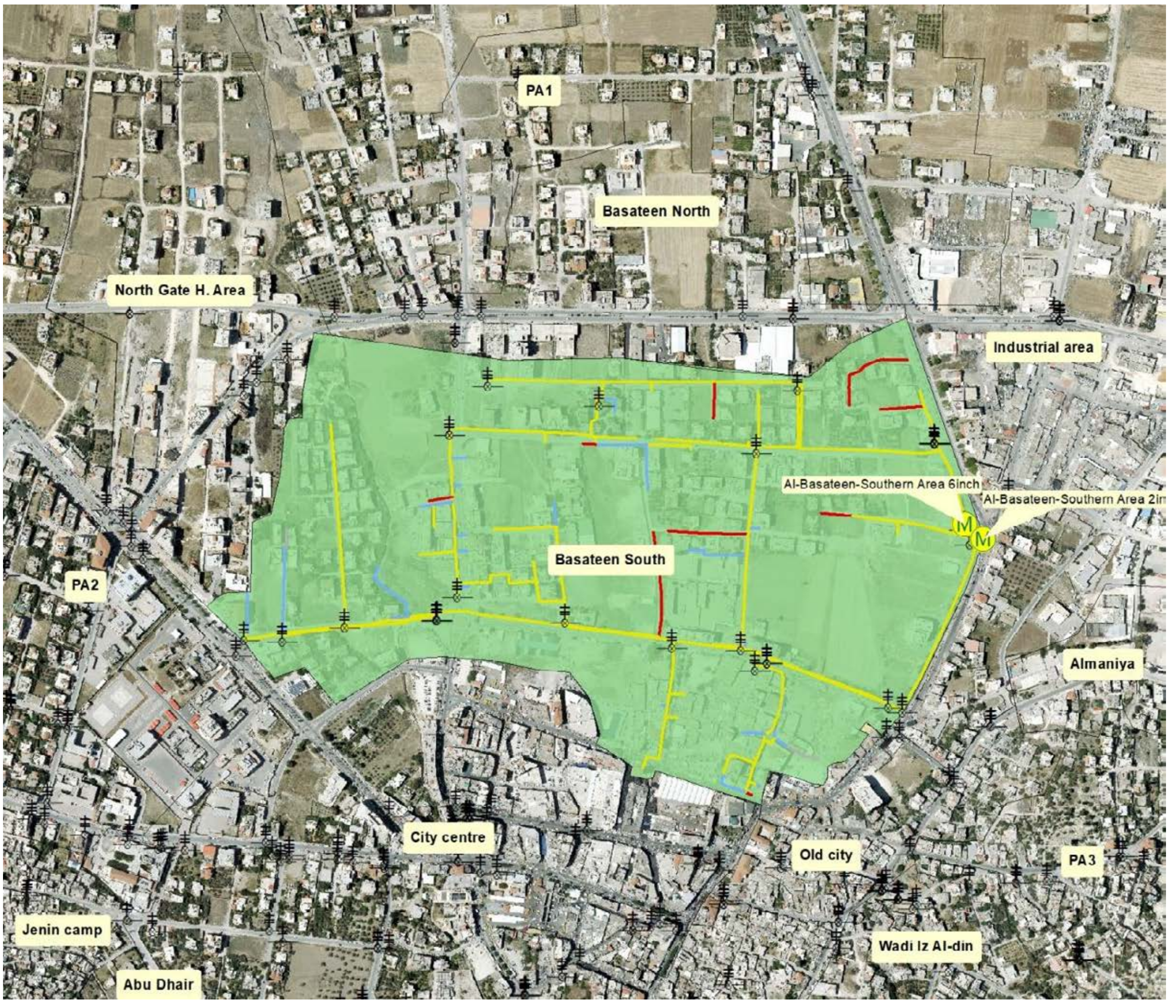
5. Basateen north Area



Number and size of bulk meters required:
1 meter (Dia : 150 mm).

Likely challenges:
1- Checking all boundary valve to make sure it works well.

6. Al-Basateen south



Number and size of bulk meters required:
1 meter (Dia: 50 mm), 1 meter (Dia :150 mm)

Likely challenges:
1-Checking all the boundary valves.

3.6 Costing of Activities

Cost references were taken from the cost compiled for cost-benefit analysis in PAs. The basics of estimating the costs and unit cost of the items are summarized in Table 3-2.

Table 3-2 : Reference for cost estimation of activities

S. N.	Items	Unit basis	Unit Cost (USD)	Remarks
1	Network update	Per km pipe length	33	
2	Customer database update survey	Per No. of household	3	
3	Water pressure measurement	Per No. of location	80	
4	Bulk meter chamber construction and installation			
(i)	Bulk meters, valves, fittings, data loggers (Material cost)	Per No. of Chamber	7,022	
(ii)	Construction of chamber and installation of bulk meter	Per No. of chamber	1,760	
5	NRW measurement	Per time per DMA		As a regular work of NRW section and customer section, no additional cost
6	Customer awareness	Per No. of household		Customer awareness by PR section not costed
7	Customer meter replacement by PPWM			
(i)	Material cost (PPWM, gateways, fittings)	Per No. of meter	159	Being arranged separately
(ii)	Installation cost of PPWM	Per No. of meter	10	Separate plan has been prepared for this
8	Leakage survey (surface patrolling)	Per km of pipeline	4	
9	Leak detection survey (underground)	Per km of pipeline	41	
10	Leak repair			
(i)	Cost of pipe and repair materials	Per No. of leak repaired	249	
(ii)	Manpower and equipment	Per No. of leak repaired	73	
11	Zero-meter reading, illegal connection survey and rectification	Per No. of customer surveyed	0.3	
12	Bulk meter accuracy checking and replacement of defective meters			
(i)	Material cost (Bulk meter)	Per No. of meter replaced	3,490	Replacement of 3 meters every year
(ii)	Replacement	Per No. of meter replaced	47	Replacement of 3 meters every year
(iii)	Accuracy checking	Per No. of meter checked	60	Checking at 2 sites every month

Assumptions made for cost estimate:

1. For cost estimate purpose, on average, three bulk meters are considered for each DMA unless otherwise decided by actual survey;
   150 mm EMF PN 25
   150 mm mechanical PN 25
   100 mm mechanical PN 25
2. Data loggers will be provided for all BMs
3. Strainers will be provided for all mechanical BMs
4. After accuracy checking, replacement of 3 bulk meters will be required every year, one ach of 75, 100, and 150 mm
5. 23 number of leaks found in 20 km pipe network, that means the number of leak locations per km of pipe per one time = 23/20 = 1.15

4. IMPLEMENTATION PLAN

The detailed implementation plan is given in the following two pages.

Implementation plan (1 of 2)

DMA	No.	Activities	Unit	Total	Rem.	Indicative Cost (USD)	Responsible Section in WWD	Remarks
Camp	1	Consutruction of chamber and installation of bulk meter	Nos.	3	3	5,280	Water	
	2	NRW measurement and monitoring	Nos.	1	1	0	NRW / CSS	Every month
Industrial Area	1	Pipeline investigation and network update	km	7.20	7.20	238	Water / NRW	
	2	Customer database survey	Nos.	199	119	357		
	3	Water pressure measurement	Nos.	5	5	400	Water / NRW	
	4	Consutruction of chamber and installation of bulk meter	Nos.	1	1	1,760	Water	
	5	NRW measurement (before measures)	Nos.	1	1	0	NRW	
	6	Customer awareness and meter replacement	Nos.	0	0		PR/CSS	Ref. to separate plan
	7	Leakage survey (Surface patrolling)	km	7.20	7.20	317	NRW	Every quarter
	8	Leakage survey (Underground)	km	7.20	7.20	590		Every 2-year
	9	Leakage repair	Nos.	7	7	4,637	Water	
	10	Zero meter checking, illegal use survey and rectification	Nos.	242	242	436	CSS	Every 6-month
	11	NRW evaluation and monitoring	Nos.	1	1	0	NRW/Water/CSS	Every month
Common for 4 DMAs (Yr 1)	A1	Clarification and confirmation of DMA boundary					Water / NRW	
	B1	Confirmation of required flowmeters, valves, etc.					Water / NRW	
	C1	Procurement of flowmeters, valves, etc. (1st Yr, 4 DMAs)	Nos.	8	5	35,110	Study and Plan.	
Yr 1 (4 DMAs: Almaniya, Basateen North, Basateen South, Funduk)	1	Pipeline investigation and network update	km	25.70	25.70	848	Water / NRW	
	2	Customer database survey	Nos.	1,239	305	915		
	3	Water pressure measurement	Nos.	11	11	880	Water / NRW	
	4	Consutruction of chamber and installation of bulk meter	Nos.	8	5	8,800	Water	
	5	NRW measurement (before measures)	Nos.	4	4	0	NRW	
	6	Customer awareness and meter replacement	Nos.	0	0		PR/CSS	Ref. to separate plan
	7	Leakage survey (Surface patrolling)	km	25.70	25.70	925	NRW	Every quarter
	8	Leakage survey (Underground)	km	25.70	25.70	2,107		
	9	Leakage repair	Nos.	26	26	16,551	Water	
	10	Zero meter checking, illegal use survey and rectification	Nos.	1,121	1,121	1,682	CSS	Every 6-month
	11	NRW evaluation and monitoring	Nos.	4	4	0	NRW/Water/CSS	Every month

Implementation plan 2 of 2)

DMA		Activities	Approx. Quantities Unit	Total	Rem.	Indicative Cost (USD)	Responsible Section in WWD	Remarks
Common for 3 DMAs (Yr. 2)	A2	Clarification and confirmation of DMA boundary					Water / NRW	
	B2	Confirmation of required flowmeters, valves, etc.					Water / NRW	
	C2	Procurement of flowmeters, valves, etc. (2nd Yr, 3 DMAs)	Nos.	9	9	63,198	Study and Plan.	
Yr 2 (3 DMAs; Wadi Burqin, Wadi Iz Al-din, Swetat and Marah Saad)	1	Pipeline investigation and network update	km	28.30	28.30	934	Water / NRW	
	2	Customer database survey	Nos.	1,319	1,319	3,957	CSS / NRW	
	3	Water pressure measurement	Nos.	9	9	720	Water / NRW	
	4	Consutruction of chamber and installation of bulk meter	Nos.	9	9	15,840	Water	
	5	NRW measurement (before measures)	Nos.	3	3	0	NRW	
	6	Customer awareness and meter replacement	Nos.	0	0		PR/CSS	Ref. to separate plan
	7	Leakage survey (Surface patrolling)	km	28.30	28.30	566	NRW	Every quarter
	8	Leakage survey (Underground)	km	28.30	28.30	1,160		
	9	Leakage repair	Nos.	28	28	9,113	Water	
	10	Zero meter checking, illegal use survey and rectification	Nos.	845	845	761	CSS	
	11	NRW evaluation and monitoring	Nos.	3	3	0	NRW/Water/CSS	Every month
PA1, PA2, PA3, 17. Al Jinan	1	Patrolling for surface leakage and repair	km	48.8	48.8	2,733	NRW	Every quarter
	2	Underground leakage survey and repair	km	48.8	48.8	35,429	Water	Every 2-year
	3	Zero consumption meter checking, illegal use rectifica.	Nos.	2,153	2,153	4,521	CSS	Every 6-month
	4	NRW monitoring	Nos.	4	4	0	NRW/Water/CSS	Every month
All	1	Bulk meter accuracy checking	Nos.	1	1	1,080	NRW	Every 2-month

5. PROJECT MANAGEMENT

5.1 Organizational Structure for Implementation

Organization chart of Water and Wastewater Department is shown in Figure 5-1. The NRW Division is one of the three Divisions within the Water Section.

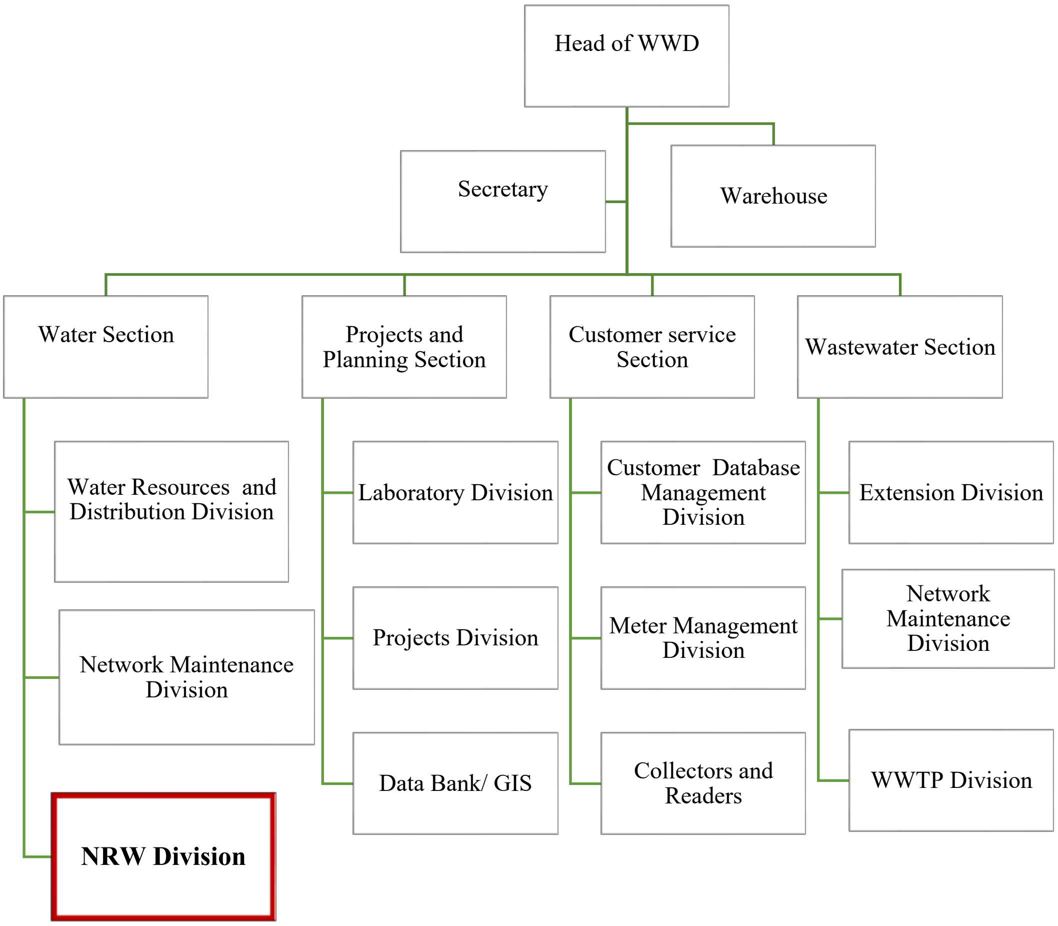


Figure 5-1: Organization chart of Water and Wastewater Department

Currently the NRW division is headed by an engineer. The technicians are common to other divisions in water sections. To implement the rollout plan within the proposed time frame two teams are suggested within the NRW division, each of these teams shall be headed by an engineer and supported by at least two suitably experienced technicians as shown in Figure 5-2.

The engineer who heads the division can also be the leader of one of the teams. The suggested job descriptions of the division head, team leader, and technicians are as given in the following section.

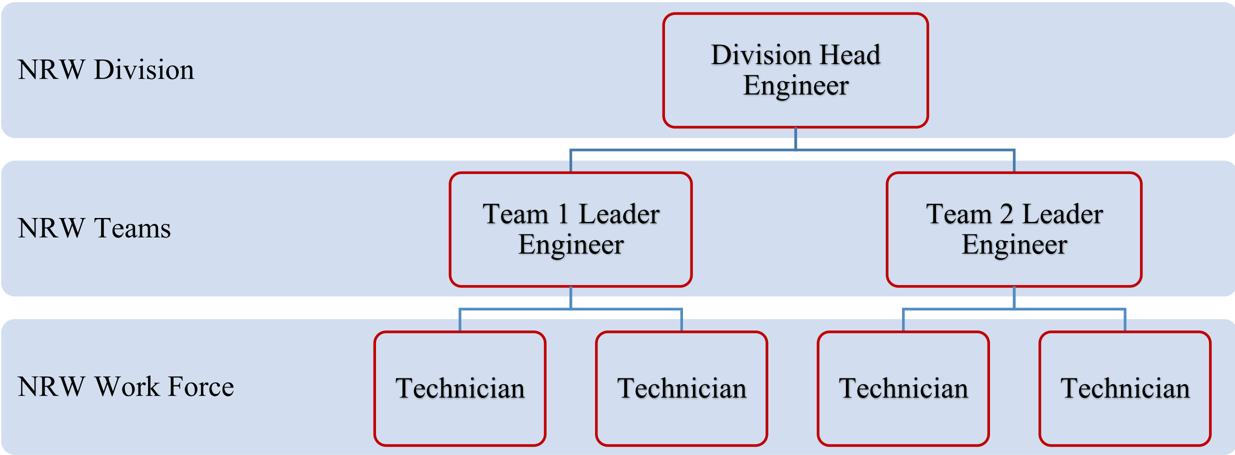


Figure 5-2: Proposed organization for NRW Division

5.2 Interrelation among NRW and other Divisions

Although the NRW division is responsible for overall NRW management activities it will focus on physical loss reduction, for apparent loss reduction it needs to coordinate with other sections and divisions as follows:

- Network Maintenance Division - for timely repair of leaks
- Customer Database Management Division – for getting up-to-date customer data
- Meter Management Division – for timely repair / replacement of faulty meters
- Customer Service Section – for getting monthly customer meter reading data, zero-meter consumption checking information, illegal connection information
- Data Bank / GIS Division – for getting up-to-date pipe network and customer location information

5.3 Job Description (related to DMA & ROP implementation) of Staff Members in NRW Division

(1) Job description of **division head** related to DMA & ROP implementation

S. N.	Main Task	Activities
1	Planning	- From the overall DMA & ROP, extract the list of activities that need to be implemented in the following month, - Prepare the list of required resources (personnel, equipment, transportation, and any other needs) and submit to head of WS / WWD,
2	Monitoring	- Monitor the progress by comparing with the plan on weekly basis,
3	Reporting	- Prepare a summary report of the activities on monthly basis and submit to the head of WWD,
4	Coordinating with	- Coordinate with customer service section for other sections / divisions as necessary,

	other sections/ divisions	- Coordinate with the team leaders to solve any problem or provide support for smooth implementation of activities at the site, - Coordinate with the providers/ suppliers of data loggers, bulk meters, ultrasonic flowmeters etc when there is any issue with these,
5	Monthly water balance and NRW calculation	- Prepare monthly water balance and NRW calculation for DMAs and Jenin from the bulk meter reading, customer meter reading, and WBWD bulk meter reading data.

(2) Job description of team leader (engineer)

S. N.	Main Task	Activities
1	Implementation	- Arrange transportation to and from site, - Arrange logistics such as tools, pipe, fittings necessary for the day's work,
2	Supervision	- Supervise the site work of technicians / third party contractors,
3	Keeping equipment and tools charged and in working condition	- Keep the ultrasonic flowmeters, ground microphone, pipe locators and other equipment in working condition by regularly charging / replacing batteries, - Maintain the provision of accessories such as coupling gel for ultrasonic flowmeter,
4	Reporting	- Prepare a summary report of the activities on monthly basis and submit to the head of NRW division,
5	Bulk meter reading	- On 1st day of each month read all bulk meters of water sources (source meters) and DMAs (DMA meters).
6	Any other	-

(3) Job description of technician

S. N.	Main Task	Activities
1	Implementation	- Carry out the site activities listed in the DMA & ROP that include pipe location, visual leak survey, underground leak survey, pressure measurement, bulk meter reading, - If some activities are outsourced to third party contractors, monitor and supervise their work,
2	Keeping equipment and tools charged and in working condition	- After site work clean the equipment to keep them always neat and clean,
3	Reporting	- Prepare a summary report of the activities on monthly basis and submit to the head of NRW division,
4	Bulk meter reading	- Assist team leader to read bulk meters (source and DMA meters) on 1st day of each month

5.4 Periodic Reporting

The head of NRW division shall collect and compile all progress data and report to the director of WWD every month in a simple to understand format. The director of WWD should share this report to JM for information, feedback, and any support that may be needed from JM.

5.5 Progress Monitoring

Progress of the DMA & ROP shall be monitored against the plan on monthly basis. If any delay happens due to any reason the plan shall be revised and readjusted. The division head shall be responsible for preparing the monthly report.

ANNEX 2

STUDY REPORT AND PLANS - PPWM

Annex 2.1

Case Study of PPWM in Jenin Municipality (Results of Pilot Project) – English Version

THE WEST BANK, PALESTINE

PALESTINIAN WATER AUTHORITY

JENIN MUNICIPALITY

Case Study of Prepaid Water Meter in Jenin

June 2022

Japan International Cooperation Agency (JICA)
TEC International Co., Ltd.
PADECO CO., Ltd.

Case Study of Pilot Project of PPWM in Jenin

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Abbreviation

CDS	Customer database survey
CSS	Customer Service Section
DMA	District metered area
DtD	Door to door
JM	Jenin Municipality
JSC-JWV	Joint Service Council- Jenin Western Village
PA	Pilot area
PPWM	Pre-paid water meters
PR	Public relations
PWA	Palestine Water Authority
WS	Water Section
WWD	Water and Wastewater Department

1. Introduction

1.1. Description of water supply and customers meters' situation in Jenin Municipality

Jenin Municipality (JM) is located in the northern part of the West Bank. It provides an average of **10,000 m^3/day** of water to a population of 60,000 (about 9,500 households). The Water and Wastewater Department (WWD) of the JM has about 60 employees, who are responsible for the water supply and wastewater services in Jenin.

JM produces water from its own wells (Al Saadeh, Al Mechanic, and Balama wells), whereas some water is purchased and supplied from private wells within the Municipal boundary (Farathy, Alwaneh, and Muamar Jarrar, Alsa'di, Abu Sameer, and Abu Hatab wells), and some water is imported from outside (from Israel Mekrot company via Al Jalameh connection and Al Swetat connection) and from West Bank Water Department (WBWD) via Abo Araba connection. Main water supply facilities include wells, pumping stations, transmission mains, reservoirs, tanks, distribution mains, and booster pumping stations as shown in Figure 1-1.

Water supply service in JM is intermittent and cyclical. The supply cycle does not cover a whole week, so supply days are not always the same day of the week. Consequently, most areas receive water once or twice a week for periods ranging from one to two days per week in the summer. In the winter season, the supply time becomes longer as the demand for water decreases. In addition, some people use rainwater for drinking purposes. The water supply is controlled manually by the WWD staff by closing and opening the valves within the pipe network.

JM has a high non-revenue water (NRW) of over 50%[i]. One of the reasons for this high NRW is aging of meters, where the percentage of meters older than 10 years is more than 50%, in addition to other reasons such as the leakage, difficulty to conduct accurate meter reading in some areas and illegal connections. In addition to the high NRW JM also has a problem of very low collection ratio of water revenue (54%[ii]).

The Project for Strengthening the Capacity of Water Service Management in Jenin Municipality targets three pilot areas (PA-1, PA-2 and PA3) as an initial stage to implement a pilot project for NRW measure, and after that it will be applied for the entire city. The number of customers in each of these pilot areas are:
PA-1: 850 customers, PA-2: 560 customers except Refugee camp (103) and PA-3: 560 customers.

In the pilot areas upgrade of customer water meters was considered as one of the measures to reduce NRW. Both, existing mechanical meters and new pre-paid water meters (PPWM) were considered for the replacement. The following considerations were made during the study and implementation.

- To introduce the most suitable customer meter type after a thorough study of the advantages and challenges of both meter types (mechanical and prepaid meters).
- For the introduction of PPWM, particular attention would be paid to financial sustainability and ensuring a system that can respond quickly to repairs and replacements.
- If PPWM is selected, consideration will be given to vulnerable social groups and refugee camp resident households with low ability to pay.

The PPWM system consists of a PPWM, billing system (PC, card reader, UPS, printer, etc.), billing card, and a server for customer database management. The customer goes to the billing station and charges credit to the billing card. The PPWM can ensure a 100% tariff collection rate. Furthermore, it will eliminate the need for the water utility to collect and read the meter. In Palestine, PPWM has already been introduced or underway in several water utilities such as the area under Joint Service Council-Jenin Western Village.

1.2. Reference materials to the case study report

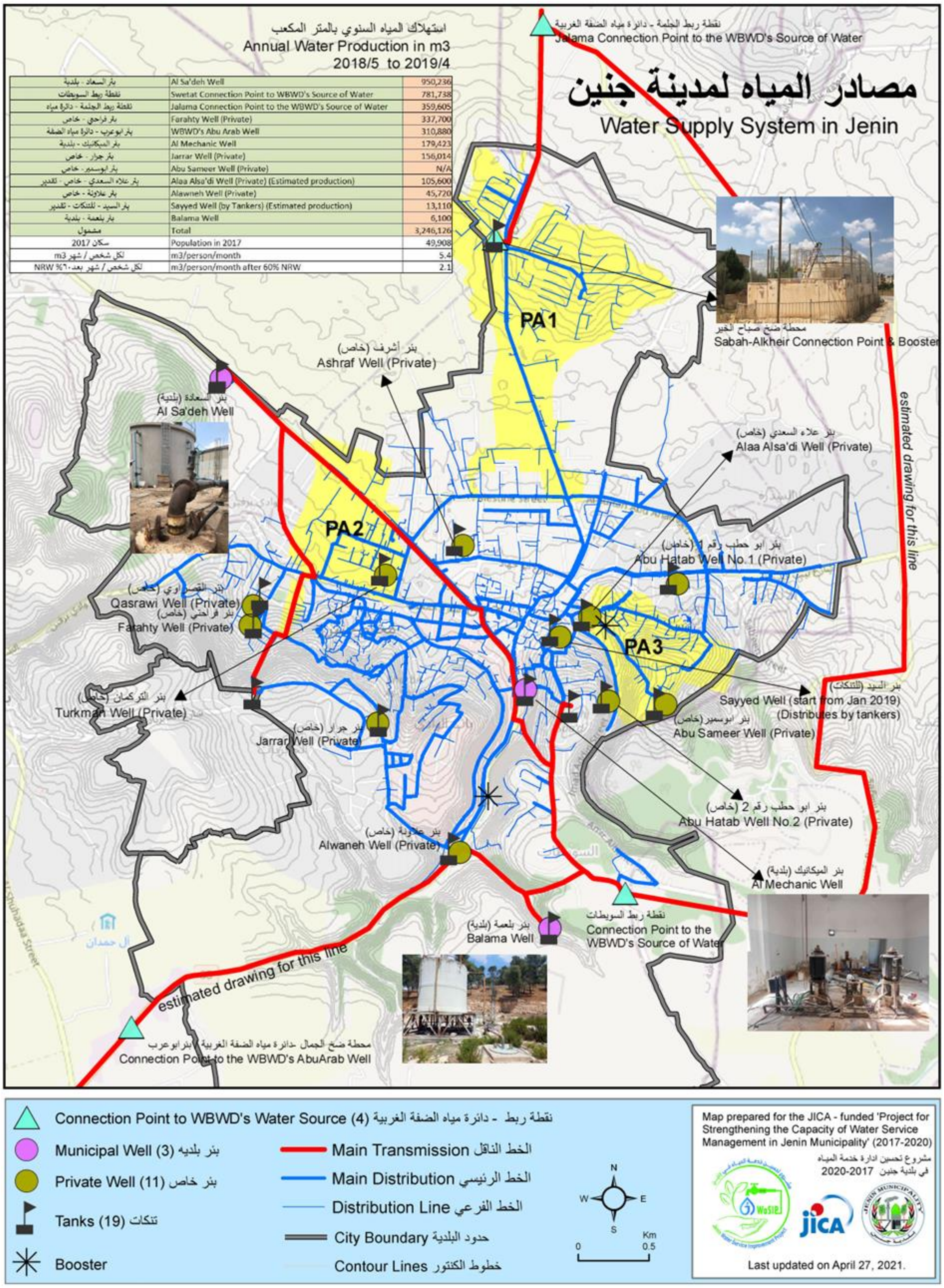
To prepare the case study report of PPWM in JM, the following reports that were prepared in the Project were referred.

1: Baseline Survey Report (Chapter 5 PPWM Study)

2: Outline and Results of Domestic Meter Experiment

3: Sustainability and Strategy Report on PPWM (F/S report)

4: PPWM Implementation Plan



بئر السعاد - بلدية	Al Sa'deh Well	950,236
نقطة ربط السويطات	Swetat Connection Point to WBWD's Source of Water	781,738
نقطة ربط الجلمة - دائرة مياه	Jalama Connection Point to the WBWD's Source of Water	359,605
بئر فراحتي - خاص	Farahty Well (Private)	337,700
بئر ابوعرب - دائرة مياه الضفة	WBWD's Abu Arab Well	310,880
بئر الميكانيك - بلدية	Al Mechanic Well	179,423
بئر جرار - خاص	Jarrar Well (Private)	156,014
بئر ابوسمير - خاص	Abu Sameer Well (Private)	N/A
بئر علاء السعدي - خاص - تقدير	Alaa Alsa'di Well (Private) (Estimated production)	105,600
بئر علاونة - خاص	Alawneh Well (Private)	45,720
بئر السيد - للتنكات - تقدير	Sayyed Well (by Tankers) (Estimated production)	13,110
بئر بلعمة - بلدية	Balama Well	6,100
مشمول	Total	3,246,126
سكان 2017	Population in 2017	49,908
لكل شخص / شهر m3	m3/person/month	5.4
لكل شخص / شهر بعد٦٠% NRW	m3/person/month after 60% NRW	2.1

Source: JICA Expert Team

Figure 1-1: Main Water Supply Facilities in Jenin

1.3. Purpose of prepaid water meter introduction

The main objective of implementing PPWM in JM is to improve the current low tariff collection rate and increase water tariff revenues. In addition, the following objectives were expected:

1. To improve water supply services and provide better services to customers by increasing water tariff revenues.
2. To ensure equity in water supply services by ensuring that all customers pay for water supply services.
3. To reduce water consumption by raising awareness of water conservation among customers who use large amounts of tap water, and to achieve equitable water supply by supplying the reduced amount of water to more customers.

1.4. Procedure of PPWM introduction

PPWM has been introduced through the following procedure:

1. Baseline survey to understand the situation of existing metering, billing, and collection system
2. Case study for PPWM introduction in other water providers in Palestine
3. Social survey on PPWM (Pre-installation survey)
4. Sustainability and strategy report on PPWM (Feasibility study (F/S))
5. Preparation of implementation plan of PPWM introduction
    a) Strategy of introduction of PPWM including selection of Pilot Areas
    b) Improvement of water supply conditions
    c) Setting up of a PPWM system
    d) Operation and maintenance plan
    e) Customer service plan
    f) Public awareness plan
    g) Training plan
    h) Implementation plan
6. Preparation of a check list for required decision by the council to introduce PPWM
7. Procurement of PPWM
8. Conducting door to door (DtD) survey before installation
9. Installation of PPWM system (billing stations, server)
10. Installation of PPWM in each customer
11. Setting and implementation of operation and maintenance and customer service of PPWM
12. Setting of responsibilities and workflow of PPWM installation and operation
13. Post-installation survey (Satisfaction survey)
14. Monitoring and maintenance

1.5. Regulations, institutions, and national policy on PPWM in Palestine

According to Palestine Water Authority (PWA)'s Financial Sustainable Funding Strategy (2014)[iii] for the water sector, PPWM should be introduced if collections do not improve. A number of pilot projects in the use of prepaid meters are ongoing. Building on this experience, a roll-out plan should be prepared for the installation of prepaid meters in relevant areas. However, PPWM is still one of the debatable issues in the water sector in Palestine although it has been recognized by PWA in the Financial Sustainable Funding Strategy for the water sector as one of the tools to achieve this strategy.

In 2010, Palestinian Cabinet approved the installation of PPWMs according to "Technical Requirements and Specifications for Supply and/or Installation of Prepaid Potable Water Meter System" which was updated in 2020 to version 4. In addition to that, in 2014 the Cabinet decided to encourage the installation of PPWMs by including charging PPWMs costs to the PWA for water service providers who want to install and use the PPWM system.

2. Issues on Tariff Collection and Expected Improvement by Prepaid Water Meter

The following table shows the summary of issues of tariff collection.

Table 2-1: Summary of issues of tariff collection

Category of issues	Issues
1. Meter reading	· Customers are negligent: water meter is dirty, hidden between grass · Water meters installed inside home · Location of water meter is in a high level, difficult to read · Customers keep dog around water meter to prevent reader from reading · The meter readers sometimes do not have transportation, especially for going back to the municipality · No supervision or check on readers in the field
2. Billing and collection	· JM does not provide protection to readers and collectors from rude customers · Meter readers are not allowed to read meter sometimes · Objection to invoiced value from customers · Collectors do not have enough will to collect water bill, there is no punishment policy in the municipality and no efficiency · Late submission of reading record by readers · Need a printer to print a large number of invoices · No clear policy for collection from municipality · Collectors under pressure from JM to collect more money · Sometimes the amount paid by customer is not deducted from the accumulated credit balance
3. Illegal connection	· JM does not respond when readers or collectors inform about any cases · There are no technical teams specialized in dealing with illegal connections · Unclear procedure for implementing the already existed regulation about illegal connections · Water meter removed by customers
4. Debt increase and repayment	· Non-payment culture · Not separate debt to be paid by customer through court for the amount owed monthly · Estimated billing without meter reading for some customers (especially if the customer lives outside the city). Problem in old accounting system, when customers get exemption, it is not deducted from customer account
5. Owner	· Ownership of water meter in young people's name, less 20 years · Water meter in the name of dead person · Some water meters in the name of first and second name or third name · Abandoned houses · Buildings under construction which has water meter, in this case the owner should stop the subscription after the construction is finished
6. Human resources	· There are not enough readers and collectors · Lack of enough employees in CSS (Customer Service Section) including technical persons · Not enough maintenance for water network. Complaints on network
7. Collection from refugee camp	· Collection rate in Jenin camp is too low, it is 1% and debts is 7 million NIS, and there are 1362 customers in the camp
8. Water supply condition	· Many residents depend on private wells · Many residents use pumps to draw water from water pipes and send it to water storage tanks
9. Response by municipality	· No quick response on complaints from the related section in the municipality

The following table shows the summary of expected improvement after installation of PPWM.

Table 2-2: Summary of expected improvement after introduction of PPWM

Existing Issues	Improvement after introduction of PPWM
Meter reading	- No reading activity on site. - No reading error and input error. - All meter reading issues can be solved (No more meter reading).
Billing and collection	- No billing and collection activity on site. - Collection rate is almost 100%. - No manual data input and no bill printing is required every month. - Data of meter reading and billing is accurate. No protection of readers and collectors from customers is required. - All billing and collection issues can be solved.
Illegal connection	- PPWM has tamper protection function and can reduce illegal connection. - Once the customer removes the meter, the water consumption data will be zero on the database. - Illegal connection is easy to find using accurate data base.
Debt increase and repayment issues	- Debt does not increase, 100% collection. - PPWM has debt repayment function.
Meter owner	- Customers have to pay water charge according to water consumption. - PPWM does not discriminate owner, pay according to consumption. - If PPWM is damaged, no water supply and no data are coming. Water meter damage is found through data analysis. Data collection can be done by handheld machine (Portable meter reading terminal) or gateway. - Suppose the owner stops using the water meter for any reason. In that case, the data of zero water consumption will be sent to the owner. Cessation of meter usage is discovered through data analysis.
Human resources (staff)	- Introduction of PPWM can reduce manpower. Reading and collecting staff are not required. - Reduced manpower may be assigned to other sections, which lead to more efficient use of human resources.
Collection from refugee camp	- No installation is planned due to political reason.
Water supply condition	- Water consumption may decrease as customers become more aware of use of water and use water wisely since they must pay for entire consumption. Illegal consumption decreases. - Water can be supplied to more customers by reduced water consumption of high use customers. - Consumption limit mode can be used in summer if required, for equitable supply of water.

3. Lessons Learned on PPWM Introduction from Other Water Service Providers in Palestine

In the baseline survey of the Project, the site observation tour and questionnaire study by the Counterparts and JICA Experts was carried out to understand existing PPWM system in 4 water providers in Palestine. The results are included in the Baseline Survey Report. The following are summary of the results.

Table 3-1: Summary of comparison of result of the study for 4 municipalities/providers

Items	Municipalities/Utilities			
	JSC-JWV	JSC-Tubas	Nablus Municipality	Aqraba Municipality
1. Classification of introduction of PPWM	Replacement	New installation and replacement	Replacement in small number of meters	New installation
2. Change of water supply conditions after PPWM introduction	From 1 day/week to 24/7 hours with infrastructure development	24/7days with infrastruture development	Not changed Intermittent supply One day in every 5 days in week	Before, by tanker. After project, normally, 24/7 days
3. NRW ratio	Decreased from 40 % to 13%~16%	Not measured	Not measured	Only minor leakage after PPWM
4. Bill collection efficiency and revenue	Improvement from 40% to 100%	Tamoon district: Improvement from 50% to 95%	Recovered 304,038 NIS out of 4,086,308 NIS debts	Improvement from 60% to 100%
5. Nos. of customer	6,040	8,800	40,000	2,000
6. Nos. of PPWM customer	6,000 (99.3%)	7,000 (79.5%)	1,450 (3.6%)	2,000 (100%)
7. Regular meters	40 (0.7%)	1,800 (20.5%)	38,550 (96.4%)	None
8. Meter owner and installation location	Owned by JSC, installed at private or public premises	Owned by JSC, installed at entrance or outside	Owned by customer	Owned by customer
9. Type of PPWM introduced and warranty/maintenance contract	Mechanical 10 years guarantee with 6 USD/meter/year	Mechanical (Velocity and Volumetric type) 1 year warranty No maintenance contract	Mechanical Made in Nimbo (China): 3 years free maintenance Made in Baylan (Turkey): 1-year free maintenance	Mechanical (Volume) 5-year free maintenance
10. House connection	Installed by JSC	Installed by JSC	-	Installed by municipality
11. Public awareness campaign	Not conducted	Public meeting, relevant institution meeting	Awareness message on the bill	Public meeting
12. Payment method (Vending station)	11 stations, 14 supermarkets	6 stations	1 station at municipality	1 station at municipality
13. Meter problems	Working well with only 1% deficiency, inaccurate meter counting by calcification	They want to use an SDK system [1] to use any PPWM brand for billing and data management. (Currently, each brand requires a separate billing office and data management system).	Over-registration by air problem	Over-registration by air problem

[1] SDK: Software Development Kit. As various manufacturers release their SDKs, they will easily integrate their products with other applications, including third parties. (Different PPWM manufacturers can use the same billing machines, data management servers, and software).

14. Illegal use and penalty	Thief detection function with penalty	Consumed amount is checked to find illegal connection. If it is found, PPWM is installed	Penalty	No penalty because no illegal connection
15. Operation and maintenance	Meter checked every 6 months	Meter readers involve in technical works (multi-functioned)		Monthly consumption check
16. Measures against the socially vulnerable	The law stipulates that water tariff is to be reduced for the socially vulnerable. However, since the MoLG (Ministry of Local Government) has not explicitly identified the socially vulnerable, the calculation function of the PPWM software has not been executed. Also, according to the law, all people must pay for water.	-There are no cases of consideration for the socially vulnerable. -MoSD (Ministry of Social Development) has a list of vulnerable people and suggested that specific discounts could be offered as well as electricity rates.	None in particular	86 cases of care for the socially vulnerable have been reported. There is no water charge for the target population. The city has set aside a budget for this purpose.
17. The cause of success	-No additional cost to the customer (JSC will bear replacement cost). -Customers are more receptive to PPWM due to the 24-hour water supply. -24-hour telephone service to customers, using "WhatsApp." Response time is about 5 minutes or less. -Tap water is cheaper and can be received at any time.		It is still difficult to evaluate the success factors.	-24-hour water supply -Responsive customer service -24-hour phone service to customers -City Hall has a trusting relationship with customers.
18. Recommendations	-The strategy should be to improve water supply, but not to introduce PPWM to increase revenue. -Awareness-raising may not be necessary. People will be against it. If they hesitate to install it, it will not be successful. -PA1 is a good first model because it is a new housing	-PPWM installation and water supply improvement cycle are important. 1. Development of new water sources 2. Expansion of water storage capacity 3. Improvement of water distribution mains 4. Installation of PPWM 5. Management of illegal	-A model area or small test area project for PPWM implementation is good. -Awareness-raising activities are important. Raise awareness among citizens. Radio, Facebook, NGOs were used. -If there is a billing system like a telephone, customers do not need to come to the billing office.	The first step is to renew the old pipe network and improve the water supply situation before implementing PPWM.

	development area. People have high incomes and are well educated there. We should build the first successful case and then expand it to other areas. -To be successful, they need to improve the 24-hour water supply. -The objective is not to install PPWM but to improve water supply conditions. -The difficult part of implementing PPWM in Jenin is the existence of refugee camps.	connections 6. Rehabilitation of facilities 7. NRW management 8. Expansion of water supply facilities -Installation of PPWM starts with influential people (e.g., mayor) and stakeholders. -Monitoring activities of all facilities (from water source to customer meters) need to be integrated.		

In the study, following success factors for PPWM introduction were explained by the water providers.

- Replace customer's existing mechanical water meter with PPWM free of charge
- 24/7 water supply service
- Affordable and good quality water
- 24-hour customer service
- Good and responsive customer service
- Earn trust from customer by good communication

The followings are the recommendations for PPWM introduction made by the water providers.

- PPWM strategy should focus on water supply improvement but not on revenue increase
- Volumetric or ultrasonic PPWM are recommended because of their high accuracy
- Implement a pilot project to gain success experience
- Establishing a water supply improvement cycle:
    1. New water resource development
    2. Expansion of distribution reservoir capacity
    3. Main distribution line improvement
    4. Install PPWM
    5. Illegal use control and monitoring
    6. Renovation of water supply facilities
    7. NRW reduction
    8. Expansion of water supply service
- Start introducing PPWM at residences of some influential people such as Mayor, JSC managers, members of council, board members, water utility employees.
- Cancel old network and replace with new network to improve water supply condition

4. Concerns on Introduction of PPWM by Customers (result of social survey)

4.1. Opinion of Jenin city residents on PPWM

A social survey was conducted to understand opinion of Jenin city residents about the introduction of PPWM in the city. The results of the social survey are summarized as follows.

- 56 % of the residents prefer PPWM and 44% do not.
- In case JM takes a decision to install PPWM, the acceptance of PPWM increases slightly to about 61%, which means a mandatory PPWM will not make a difference in the public acceptance of PPWM.

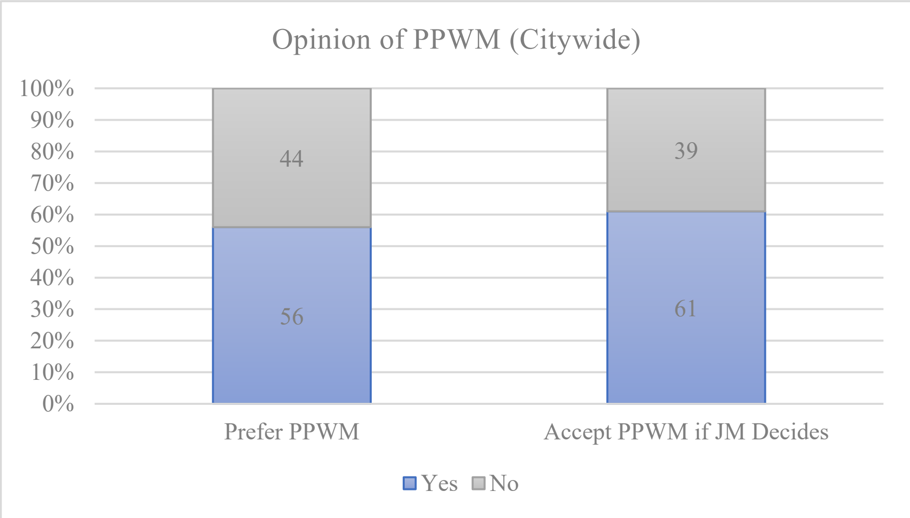


Figure 4-1: Result of social survey on Acceptance of PPWM

In addition, the reasons for accepting or not accepting PPWM were reported as below.

Reasons for accepting PPWM	Reasons for not accepting PPWM
1. Customer pays regularly 2. To get water every day without interruption 3. This system is better 4. Easier for customers and municipality 5. More accurate and depends on how much people consume 6. No need to pay attention for bills every month 7. Water will be available 24/7 8. Better control of consumption	1. Not enough money to charge regularly 2. It costs more money 3. Lack of trust in municipality 4. We already pay water bills in cash, so we do not need this system. 5. This water meter reads more than actual consumption 6. Not suitable for poor people 7. More difficult system 8. Paying every month is better, and the financial status is bad 9. Too much commitment to the municipality (Pay water bills regularly and do not accumulate unpaid bills)

4.2. PPWM satisfaction of current users in other water providers

An interview survey was conducted with PPWM users of other water provider/utilities regarding their satisfaction. The survey targets were as follows.

- West Jenin JSC (9 customers)
- JSC- Tubas (3 customers).

- Aqraba village (3 customers)
- Nablus city (5 customers)

(1) Basic findings: before and after PPWM

The customer percentage with constant access to tap water and weekly water supply by season before and after the installation of PPWM are shown in Figure 4-2 and 4-3, respectively. The change in water supply before and after the installation of PPWM is shown in Figure 4-4. A summary of the results is as follows.

1. Access to water after PPWM has increased both in winter and summer.
2. Access to water by number of days has increased and reached 5-6 days after PPWM.
3. Water consumption decreased after PPWM.

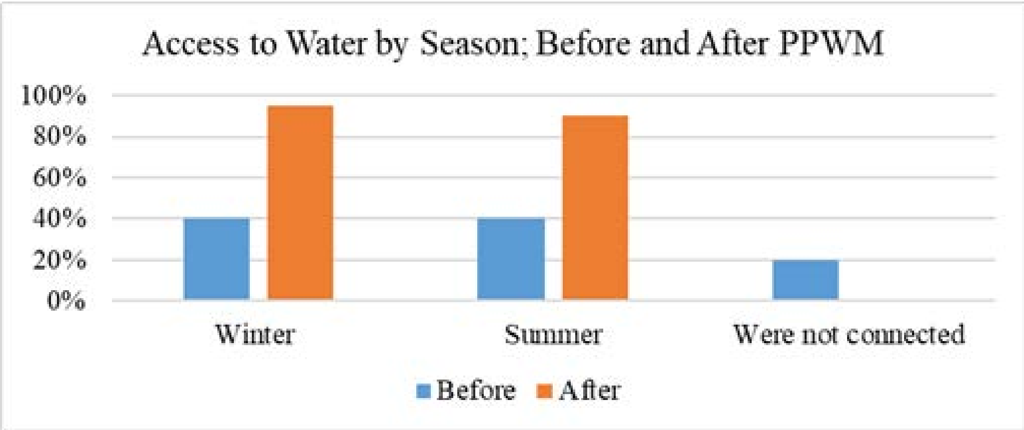


Figure 4-2: Percentage of customers with constant access to tap water by season before and after PPWM installation

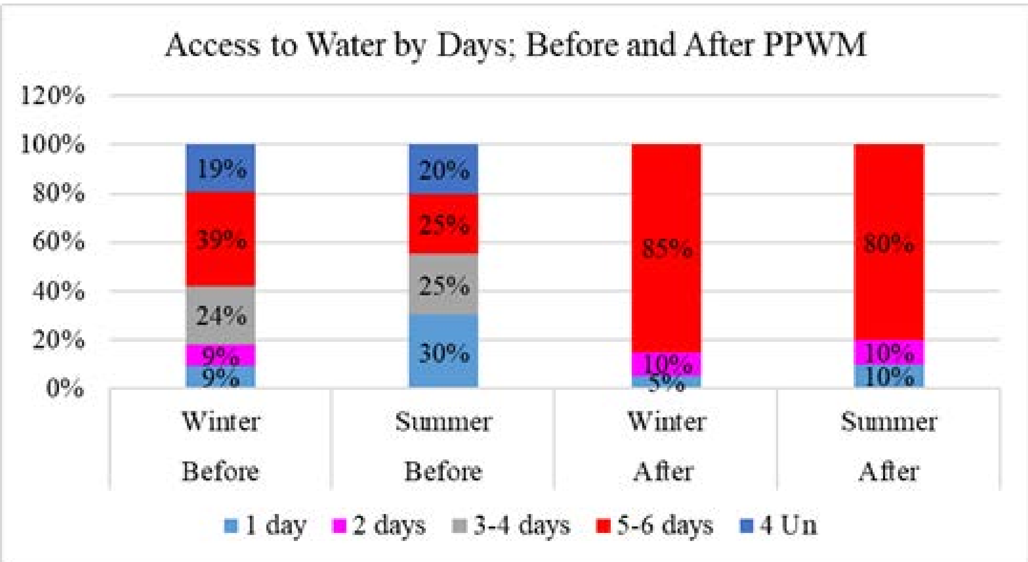


Figure 4-3: Percentage of customers with weekly water supply days by season before and after PPWM installation

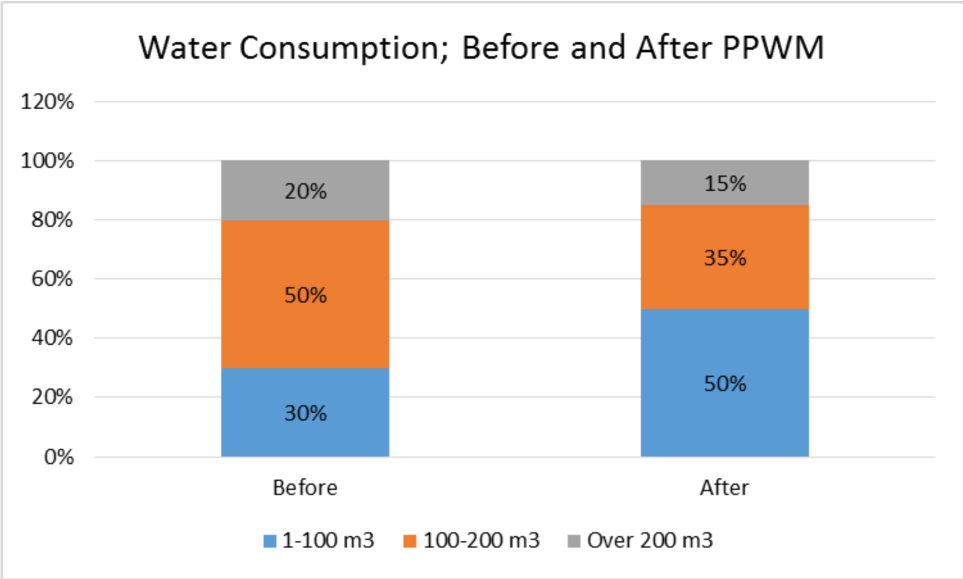


Figure 4-4: Percentage of customers with water supply before and after PPWM installation

(2) Satisfactions

The results of the following questions regarding satisfaction are shown in Figure 4-5.

1. Distance to the vending station
2. Frequency of credit charging
3. Satisfaction with payment
4. Difficulty in using PPWM system
5. Handling of PPWM device
6. Maintenance of PPWM
7. Return to mechanical meters
8. Would you recommend PPWM to others

In general, as seen in the figure below, the users are highly satisfied with the PPWM and recommend to others. The reasons for their satisfaction are as follows.

1. The charge center for PPWM card is close and within 0-1km for most of them. Distance to the charge center has a high impact of the satisfaction.

2. Most of the users charge once a month and it is more convenient to them.

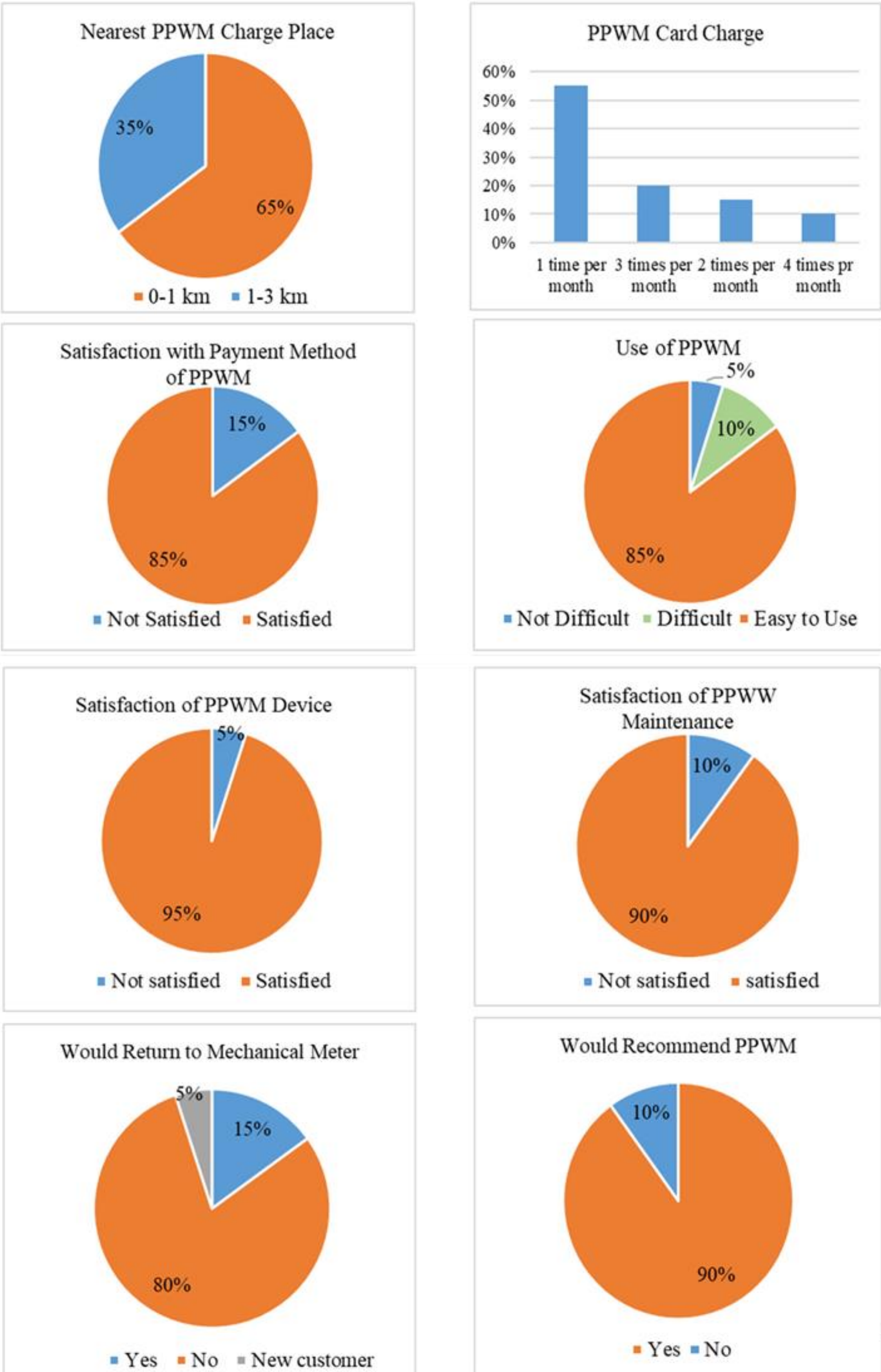


Figure 4-5: Result of social survey of PPWM satisfaction of current users in other water authorities

5. PPWM Implementation Plan

5.1. Feasibility study

5.1.1. Main factors for success

The main factors for the successful implementation of PPWM can be identified from the baseline survey and discussions among the counterparts as follows:

1. Improve customer satisfaction with PPWM device (Usage, etc.)
2. Increase customer satisfaction for water supply services provided by JM after installation of PPWM. The following are required to increase customer satisfaction.
   - Improvement of poor water supply conditions by increased water pressure, extended water supply time, etc.
   - Provision of good customer service (24-hour customer service)
3. Free replacement of existing meters Increase customer awareness on JM water supply service
   - Increase customer awareness on changes (PPWM installation)

5.1.2. Strategy to introduce PPWM

With the input of the counterparts in JM, the following strategy for the implementation of PPWM was developed.

Table 5-1 Strategies for implementing PPWM

Items	Strategy
1. Main success factors	To increase customer satisfaction and increase acceptance of PPWM
2. Policy for introduction	To prepare introduction policy to reduce risk and succeed in PPWM
3. Awareness raising	To increase awareness of water supply service of JM and PPWM
4. Technical	To strengthen technical capacity to back up introduction of PPWM
5. Water tariff and debt recovery	To give financial motivation to participate in PPWM
6. Customer service	To strengthen capacity to manage PPWM system and improve customer service

Following are the components of the strategy for success of PPWM introduction. There are 3 main strategies, in which several components of the strategies are composed. The success probability of PPWM introduction will be increased by implementing this strategy.

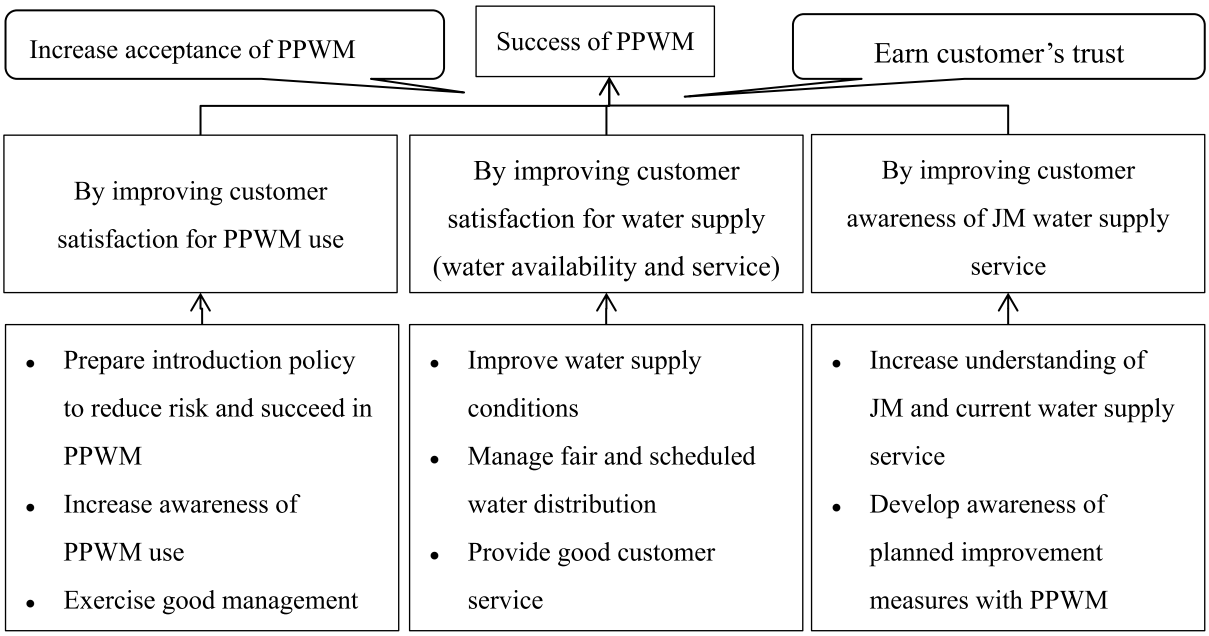


Figure 5-1: Strategy of introduction of PPWM for success

The strategy to introduce PPWM in Pilot Area is as follows.

(1) Introduction of PPWM will be first implemented in the pilot project area as to create a successful model, which could be extended to the other pilot areas and to the other areas of JM in the future.

(2) For this purpose, a suitable area ,PA-1, is selected among the three pilot areas because it has a higher collection ratio, educated and higher income residents. This was supposed to ease the introduction of PPWM.

(3) As an introduction policy, either of the following is adopted. Finally, we adopted b):

a) Introduce PPWM as an option for customers who pay water bills and want to replace their meters and for new customers.

b) PPWM is introduced to all or almost all the customers in the area with intensive awareness raising activities.

(4) In this pilot activities, required organizational set up and training for PPWM will be made in JM.

5.1.3. Advantages and disadvantages for customers and Jenin municipality

Advantage and disadvantage of PPWM for both JM and the customers are summarized in table below.

Table 5-2: Advantage and disadvantage of PPWM for both JM and the customers

	Jenin Municipality	Customers
Advantage	· No need for regular meter reading/bill collection. · Increase in water revenue. · 100% collection ratio. · Collection of part of the previous debt.	· No meter readers at your door. Read the balance on your PPWM by yourself. · Customers can manage the amount of water they use.

	· No reading error and input error. · Higher accuracy of consumption data. · Improvement in water demand management · Reduction in workload and saving in the cost. · Higher customer satisfaction and change in public attitudes toward payment of water charge. · Decrease in wasteful use of water, increase in water availability over time, and supply to more customers. · Increased revenue can be used for improvement of water supply service.	· Customer becomes more conscious about water consumption, resulting in reduction of wasteful use and water bill. · Can reduce water wastage, increase efficient use of water, and supply water to more customers · Payment of water charge by correct meter consumption. · No need to worry about building up water debt. · Pay off your water debt (if any), gradually without economic pressure. · With increased revenues and decreased costs, water rate increases can be postponed. · In many cases, water meter is installed to existing customers by waterworks for free. · Every customer must pay according to consumption, and it treats every customer fairly. · Improvement in water supply service.
Dis-advantage	· High initial cost of PPWM. · Introduction of PPWM might be opposed by un-willing customers.	· If the meter is malfunctioned and the valve closes, the water will not be available. · Non-paying customers must pay (a disadvantage for customers who are not currently paying). · They must pay water charge in advance. · If they don't have enough cash on hand, they won't be able to use the water.

5.1.4. Technical sustainability

(1) Selection of flow meters

Selection of type of flow meters is of the most importance for technical sustainability. The following procedure was taken to select the best type of PPWM to ensure technical sustainability.

- The performance of existing water meters in Palestine was studied.
- Ultrasonic meter together with mechanical meter (volumetric and velocity type) was tested in actual use and checked its validity.

In Palestine, mechanical meters have been mainly used. In the Project, ultrasonic water meters were also considered for examination and evaluation, considering the impact of air intrusion in water distribution pipes. An overview of the measurement principle of each type is given below.

- Mechanical type (velocity): This type measures the velocity of the flowing water with a built-in impeller and converts it into a flow rate.
- Mechanical type (volumetric): Measures the volume of the flowing water using a built-in cup and converts it into a flow rate.
- Ultrasonic type: Transmits and receives ultrasonic waves in the water flow and converts the difference in travel time of the ultrasonic waves into a flow rate. There are no mechanical parts in the part of the water meter where the water flows.

The evaluation results of the three types of water meters are shown in the following table. As a result, the ultrasonic type was selected.

Table 5-3 Overview of evaluation of three types of water meters

Item	Meter type		
	Flow rate type	Volumetric	Ultrasonic type
Advantage	· Easy to maintain	· Can be mounted in any position · Low minimum flow rate	· Does not measure air · Low rated minimum flow rate · No mechanical/moving parts · More accurate and longer life
Issue	· Intermittent water supply counts air · Can only be installed in horizontal positions · Machine parts in the flow may be damaged · High rated minimum flow rate and low sensitivity at low flow rates	· Due to intermittent water supply, meter counts air · Silt water, rust, particles, or calcification clogs the meter and stops working correctly, resulting in shorter life	· There is minimal experience with ultrasonic flowmeters using prepaid units. · More expensive than traditional meters
Life span	· Generally, if the water quality of raw water is good, it is more than 7 years · Short life for machine parts and accurate measurements	· Generally, if the water quality of raw water is good, it is more than 7 years · Silty water (particles) and calcification make meter short life or require frequent maintenance	· Generally, more than 7 years · Long life as no mechanical or moving parts · 10 years of battery life
Adoption results	· There are many installations · The existing ones are aging · The number of installations deceases due to air intrusion problems and lower accuracy at low flow rates.	· Many application results	· Few application results · Ultrasonic PPWM was tested with JSC-JWV
PPWM device price (Estimates)	· About 120-130USD	· About 120-130USD	· About 140-150USD
Customer Perspectives	· Negative preconceptions that the meters count air intrusion and count more than the actual water consumption.	· Negative preconceptions that the meters count air intrusion and count more than the actual amount of water consumed.	· May be claimed to be minimal experience
Results of demonstration experiments on water meters (See Box1)	· When the inside of the pipe was not full, meter counted even when air/air mixed water flowed through the pipe. However, since the amount is less than the ultrasonic type, the problem of air may be negligible in Jenin City. · The rated minimum flow rate of the meters used in this experiment was large (less accurate at low flow rates). Thus, the recorded flow rate was lower than the other two types.	· Two of the existing volumetric meters no longer work. Foreign matter may have been clogged. · Counting is continued even if the inside of the pipe is not full or when air/air mixed water flows through the pipe. However, since the amount is almost the same as the ultrasonic type that does not count air, the problem of air may be negligible in Jenin City.	· Visually, it was confirmed that if the inside of the pipe was not full, it stopped (does not work) when air/air mixed water flows. · In Jenin City, there was no significant difference in the flow rates of the volumetric and ultrasonic flow rates, even with intermittent water supply.
Evaluation	· Low flow accuracy · Mechanical parts may be damaged. · The accuracy decreases by aging. · Air intrusion may not affect the counting of water consumption, but the air may be counted even if it is too low. However, because there is a	· Particle problems are serious · Air intrusion may not affect the measured value, but even if it is too low, the air may be counted. However, because there is a perception of counting air, it is difficult to remove it.	· Good performance (low minimum flow rate) · Air and air mixed water are not measured. · Long life is due to the no mechanical parts. · Meter is hard to be clogged by mixed objects and sand particles, and can be used as a household meter during

Item	Meter type		
	Flow rate type	Volumetric	Ultrasonic type
	perception of counting air, it is difficult to remove it.		intermittent water supply or when there may be contamination such as rust, sand, and calcium in the water.
Judgment			adopted

Box1 : Demonstration experiment of water meter

(1) Meter type and location

In order to evaluate the functioning of the meters, a comparison experiment was conducted between three types of new water meters and existing meter at 11 locations in Jenin City. All three types of new meters had the same permanent flow rate. The following meters with different minimum flow rates and starting flow rates were used in the experiment. The existing meters vary in type and characteristics depending on customers.

Table 5-4 Characteristics of the flow meter used

Type	Starting flow rate	Minimum flow rate (Q1)	Permanent rate (Q3)
Ultrasonic	2 L/h	5 L/h	2,500 L/h
Volumetric	2 L/h	6.25 L/h	2,500 L/h
Velocity	Not known	25 L/h	2,500 L/h
Existing meter	Some velocity, some volumetric		

The arrangement of the meters installed for experiment is shown below.

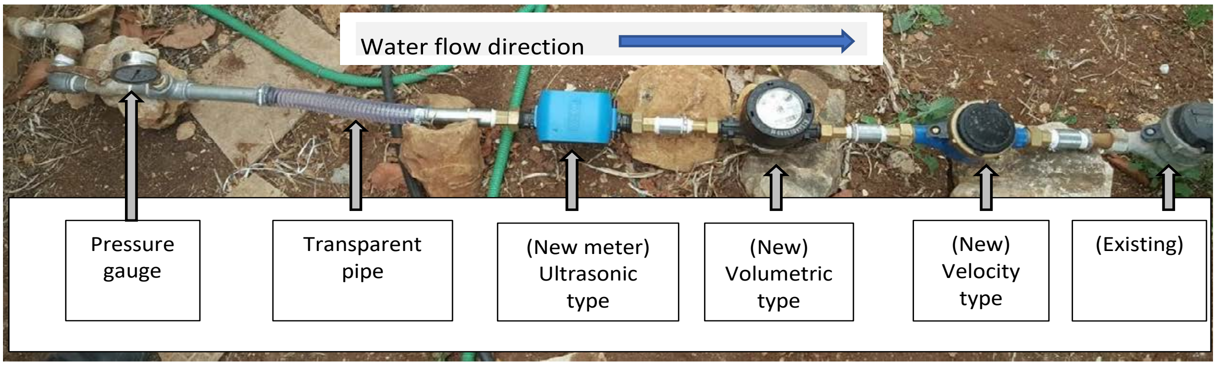
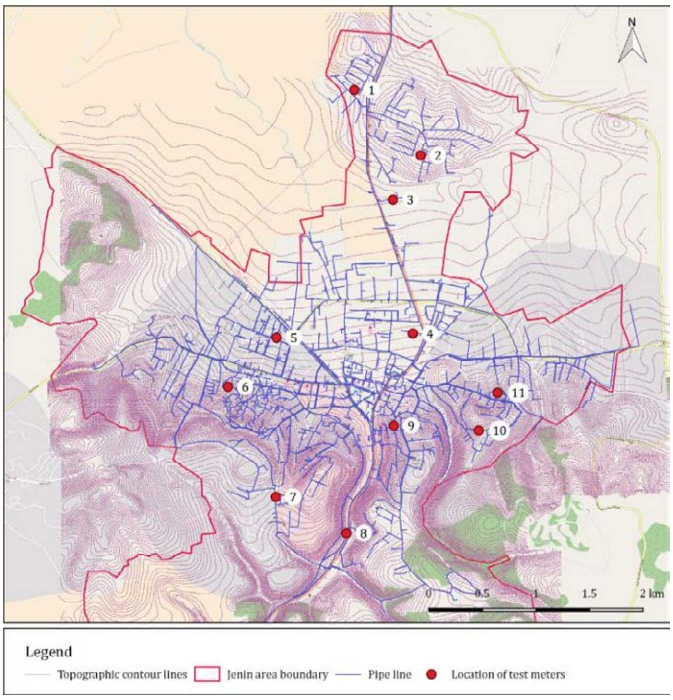


Figure 5-2 Typical arrangement of installation of meters in experiment



ID	Terrain	Water supply time (hours/week)	Existing meter	
			Type	Years of installation
1	Flat	48	Vel	>15
2	Flat	48	Vel, Class B	>15
3	Flat、Lowland	76	Vel, Class B	ND
4	Flat	90	Vel, Class B	ND
5	Flat	24	Vel, Class B	>15
6	Middle	24	Vel, Class B	3
7	Hilltop	48	Vel, Class B	10
8	Valley	48	ND	>15
9	Middle	24	Vol, R=200	4
10	Hilltop	Very short period, low pressure	Vol, R=200	-
11	Middle	24	Vel	23

Vel.: Flow rate, Vol.: Volume, ND: No data

Figure 5-3 Location of experimental water meters and data on water supply, etc.

(2) Results

The experiment results with four different water meters at 11 different locations are shown in the following table. The cumulative measured values for all the meters are shown in comparison to the values of volumetric type. The cumulative measured flow rate of the water meter at location 5 is also shown in Figure 5-4 for reference.

Table 5-5 Ratio of the measured cumulative flow rate of each meter by location to the measured value of the new volumetric type

Meter location number	May 2018 - July 2018 (3 months)				May 2018 - July 2019 (15 months)				Remarks
	Ultrasonic (US) %	Volume (m^3)	Flow rate (VEL) %	Existing (EX) %	Ultrasonic (US) %	Volume (m^3)	Flow rate (VEL) %	Existing (EX) %	
1	-1.0%	71.8	-3.0%	0.7%	-1.0%	181.2	-7.1%	-1.9%	
2	-0.3%	74.0	-3.1%	3.7%	0.1%	285.6	-3.4%	2.2%	
3	7.5%	126.5	2.4%	-14.0%	-	-	-	-	
4	-3.2%	33.7	-7.9%	-69.2%	-	-	-	-	Dia. 25mm
5	-1.3%	80.0	-2.2%	-0.5%	-1.0%	412.1	-1.8%	-3.2%	
6	-2.5%	53.4	-2.6%	-5.3%	-1.8%	257.2	-1.4%	-4.3%	
7	-0.8%	80.2	-0.6%	-1.0%	-1.2%	360.6	-1.1%	-1.5%	
8	5.4%	33.4	-13.3%	-16.1%	6.8%	205.8	-15.0%	-22.7%	
9	-1.3%	33.6	-12.3%	0.7%	-1.0%	169.8	-8.9%	-0.2%	
10	-80.7%	9.3	-6.1%	-81.0%	-	-	-	-	Extremely low water supply pressure
11	1.0%	28.4	-6.7%	-20.1%	1.4%	134.5	-8.1%	-29.3%	

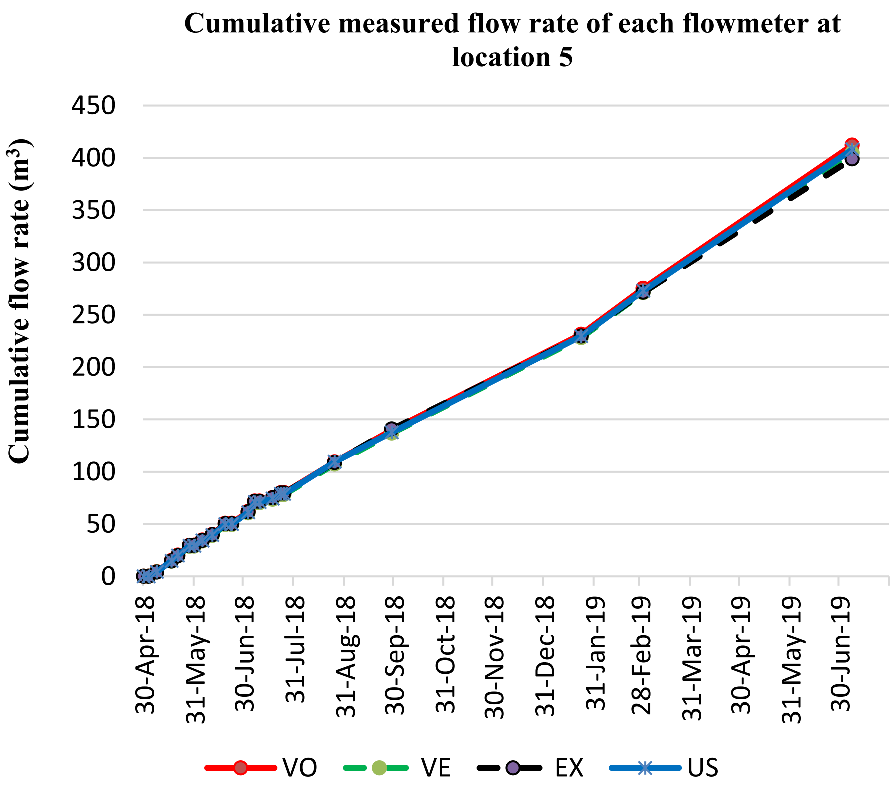


Figure 5-4 Cumulative measurement water volume of water meters at location 5

The existing meter at location 3 and 4 showed 14% 69% underflow, respectively. However, its diameter (25mm) was too large compared to the customers consumption, which may have affected the accuracy of the measurement. Location 10 was located at the top of a hill. The supply period was very short, irregular, and with very low water pressure, resulting in continuous bubbles in the water. There was a significant difference between the ultrasonic and volumetric readings at this location, attributable to the water supply conditions described above.

Observation during the water supply confirmed that the ultrasonic meter stopped reading when the water contained air bubbles. Except for the results of sites 3, 4, and 10, the total volumes recorded by both the volumetric and ultrasonic meters were in close agreement. However, when individual sites were considered, the ultrasonic meter recorded less at five of the eight sites and more than the volumetric at three sites. The velocity meter recorded less cumulative water volume compared to the volumetric and ultrasonic meters.

In general, mechanical meters (velocity and volumetric) continue to count even when air is present. In contrast, ultrasonic meters do not measure when bubbles are present in the water. It should increase mechanical readings but decrease ultrasonic readings in water systems with rationing (intermittent) water supply. This study showed that both the volumetric and ultrasonic meters gave almost the same measurement results, even with intermittent supply, if the supply was stable and sufficiently pressurized at the time of supply. However, the measurements of both types were significantly different when the location was at the top of a hill, and the water supply was very low pressure and unstable.

(2) Operation and Maintenance (O&M)

The following are recommendations for required operation and maintenance of PPWM system for technical sustainability, but most of them are not only limited to PPWM but also needed for regular meter system.

a) Operational setup
  - to ensure quick response to customer complaints (both meter systems)
  - to check, repair and replace meters (both meter systems)
  - to find illegal connection (both meter systems)
  - to manage database (both meter system)
  - to manage vending stations and programs
b) Establishment of a maintenance organization for PPWM
c) Training of staff members who are involved with the new system (i.e. meter installation, system management and customer database of the PPWM)
d) Training for data analysis of PPWM to check the consumption trend and abnormal values
e) Sharing role with PPWM supplier, especially in maintenance of PPWM

The following is an example of maintenance of PPWM in JSC-JWV:

- In general, the PPWM deficiency rate is about 1%. Sometimes the sensors get broken.
- Replacement policy: Replacement of PPWM is free because JSC has such agreement with a maintenance company.
- 2 batteries are inside. The life-time will be 10 years but if they charge money more frequently the life-time will be reduced (8 years or so).
- No regular calibration. When it is broken it will be checked by a maintenance company in Ajja.
- Out of 6,000 meters, 10~12 meter/month needed repair.
- Spares parts stocked in JSC-JWV are battery, caps, etc.

The following are maintenance practices of PPWM in the maintenance center of a PPWM company in Ajja village, Jenin Governorate:

- Seven municipalities are serviced by the maintenance center
- They have three sections (water prepaid meters, electricity prepaid meters and IT (software)
- Technical staff: 8 members
- Only broken meters are collected from providers for repair
- On average, 10 meters per day are repaired.

		
P-10: Testing measurement accuracy of PPWM in meter test bench	P-11: Operation equipment of test bench	P-12: Maintenance of Prepaid system part

Photo 5-1: Maintenance center of a PPWM company in Ajja village

5.1.5. Financial sustainability analysis

The financial sustainability of the implementation of PPWM was checked through a financial cost-benefit analysis based on 2017 tariff revenues.

(1) Basic data

As basic data, billing, and revenue data and PPWM costs and personnel costs in 2017 are presented below.

Table 5-6 Billing and revenue data in 2017

Item	Customer	Total billing amount	Revenue amount	Unpaid amount	Collection rate
(NIS)	Number	NIS/year	NIS/year	NIS/year	%
Total in 2017	10,220	7,393,416	2,820,888	4,572,528	38.2
Refugee camp	1,409	1,104,650	205,259	899,391	18.6
Areas other than refugee camps	8,811	6,288,766	2,615,629	3,673,137	41.6
(USD)	Number	USD/year	USD/year	USD/year	%
Total in 2017	10,220	2,121,910	809,595	1,312,316	38.2
Refugee camp	1,409	317,035	58,909	258,125	18.6
Areas other than refugee camps	8,811	1,804,876	750,686	1,054,190	41.6

Exchange rate：NIS = 0.287US $

Table 5-7 PPWM cost and personnel cost data

Item	Unit	Cost
PPWM device price (including meter box and installation) Installation cost: 5USD/meter (assumed)	USD/meter	170
PPWM accessories (server, software, handheld)	USD/set	10,000
PPWM accessories (5 charging machines)	USD	10,000 （USD2000 per set）
Maintenance costs for PPWM meters	USD/meter/year	5
Average salary of Jenin City employees	NIS/month	2,780

Exchange rate：NIS = 0.287US $

(2) Cost-benefit analysis

1) Financial benefits and cost

Financial feasibility was analyzed by a cost-benefit ratio (BCR), net present value (NPV), internal rate of return (IRR), and payback period for initial cost (PBP). The following costs and benefits were used in the analysis. The PBP is the number of years required to recover the initial cost through increased revenue.

Table 5-8 Financial cost and benefit calculation methods

Item	Content	Calculation method
Financial benefits	Additional revenue and reduced costs from PPWM introduction	- Increase in revenue (100% collection rate of billed amount when PPWM is used) (Note: This does not include the collection of past unpaid bills) - Reduction in personnel costs (meter readers and collectors, etc.) ➢Of the 16 existing meter readers and collectors, 8 will be reduced, and the remaining 8 will become meter maintainers ➢Reduction in the number of rate auditors and sub-cashiers
Financial costs	Additional cost of PPWM	- Initial introduction cost (PPWM system cost) - PPWM operation and maintenance costs

Reduced personnel costs (financial benefits):

The personnel costs that could be reduced by the introduction of PPWM are as follows.

- ●Meter readers and collectors：8 people* 2,780 NIS/person/month* 12 months = 266,880 NIS/year
- ●Auditor and sub-cashers：2 people* 2,780 NIS/person/month* 12 months = 66,720 NIS/year
- ●Total：333,600 NIS/year

Increased revenue (financial benefits):

Revenue increase in 2017:

Total bill in 2017（7,393,000 NIS） - Total collection in 2017（2,820,000 NIS）= **4,573,000 NIS/year**

2) Assumption

The assumption of the financial cost-benefit calculation is shown below.

- Collection rate: 100% after PPWM introduction
- Estimated project duration: 8 years of PPWM system use
- Initial cost: to be borne by Jenin city (PPWM will be replaced by Jenin city free of charge)
- Reduction of water consumption per customer: Water consumption will be reduced by 10% after PPWM system

- No maintenance cost for PPWM system for 3 years warranty period
- Discount rate for NPV: 10%

3） Analysis case

The following two cases were analyzed.

Case	Content
1	Replace all customer meters with PPWM
2	Replace meters for PPWM for all customers except refugee camps

4） Summary of results

In both cases, the net present value and internal rate of return are very high because of significant revenue increase expected, and a short payback period. Therefore, both cases have high financial sustainability. In addition, other water utilities are using the unpaid bill collection program that PPWM has. When JM uses this function, unpaid bills are collected, generating additional revenue. The calculation sheet is attached at the end of this section. It should be noted that a portion of the increased revenue will need to be used to replace or improve the PPWM in the future.

Table 5-9 Financial sustainability analysis for PPWM implementation

Case	Content	Annual financial benefits - cost (USD) 5 years after the start	Average annual economic benefit cost (USD) 8-year average	Internal rate of return (IRR)	Initial cost recovery period (PBP) (year)	Discount (10%) benefit/cost ratio (BCR)	Total net present value (NPV) (USD) over 8 years
1	Replace all customer meters with PPWM	943,638	565,790	53%	1.86	1.44	2,377,960
2	Replace meters for PPWM for all customers except refugee camps	725,697	416,068	46%	2.09	1.19	1,695,237

Appendix: Financial cost-benefit calculation sheet

Meter replacement of all customers with PPWM — USD — Consumption decrease -10%

Sq No.	Year	Financial Cost with PPWM			Financial Benefit with PPWM			Benefit -Cost	Financial Benefit by reduced water consumption (10%)		Benefit -Cost by reduced water consumption (10%)
		Initial cost	O&M	Total	Personnel saving	Increased revenue from unpaid customers	Total		Increased revenue from unpaid customers	Decreased revenue from current paying customer	
1	2020	878,700		878,700	0	0	0	-878,700	0		-878,700
2	2021	878,700		878,700	95,743	656,158	751,901	-126,799	686,285	141,044	-333,459
3	2022			0	95,743	1,312,316	1,408,059	1,408,059	1,276,827	282,089	994,738
4	2023		25,550	25,550	95,743	1,312,316	1,408,059	1,382,509	1,276,827	282,089	969,188
5	2024		51,100	51,100	95,743	1,312,316	1,408,059	1,356,959	1,276,827	282,089	943,638
6	2025		51,100	51,100	95,743	1,312,316	1,408,059	1,356,959	1,276,827	282,089	943,638
7	2026		51,100	51,100	95,743	1,312,316	1,408,059	1,356,959	1,276,827	282,089	943,638
8	2027		51,100	51,100	95,743	1,312,316	1,408,059	1,356,959	1,276,827	282,089	943,638
total		1,757,400	229,950	1,987,350	670,202	8,530,051	9,200,253	7,212,903	8,347,248	1,833,577	4,526,321
NPV	10%discount			1,653,102				4,036,455			2,377,960
IRR								79%			53%
Payback period (year)								1.25			1.86
BCR								2.44			1.44

0.1

Meter replacement of all customers except refugee camp with PPWM — USD — Consumption decrease -10%

Sq No.	Year	Financial Cost with PPWM			Financial Benefit with PPWM			Benefit -Cost	Financial Benefit by reduced water consumption (10%)		Benefit -Cost by reduced water consumption (10%)
		Initial cost	O&M	Total	Personnel saving	Increased revenue	Total		Increased revenue from unpaid customers	Decreased revenue from current paying customer	
1	2020	758,935		758,935			0	-758,935	0		-758,935
2	2021	758,935		758,935	82,543	527,095	609,639	-149,296	556,929	130,781	-332,787
3	2022			0	82,543	1,054,190	1,136,734	1,136,734	1,031,315	261,563	769,752
4	2023		22,028	22,028	82,543	1,054,190	1,136,734	1,114,706	1,031,315	261,563	747,724
5	2024		44,055	44,055	82,543	1,054,190	1,136,734	1,092,679	1,031,315	261,563	725,697
6	2025		44,055	44,055	82,543	1,054,190	1,136,734	1,092,679	1,031,315	261,563	725,697
7	2026		44,055	44,055	82,543	1,054,190	1,136,734	1,092,679	1,031,315	261,563	725,697
8	2027		44,055	44,055	82,543	1,054,190	1,136,734	1,092,679	1,031,315	261,563	725,697
total		1,517,870	198,248	1,716,118	577,804	6,852,237	7,430,041	5,713,923			3,328,541
NPV	10%discount			1,427,587				3,167,794			1,695,237
IRR								73%			46%
Payback period (year)								1.34			2.09
BCR								2.22			1.19

(3) Increase in PPWM through revolving fund of 1,850 PPWM generated from JICA grant procurement

If 1,850 PPWMs are installed and the bill collection rate improved to 100 % from 55 % in the pilot area, it is estimated that **170,532** USD/year is additionally collected.

If half (85,266 USD/year) of the additional revenue can be utilized, about 502 PPWM s can be purchased in the next year. Every year, the number of additional PPWM can be increased with increase in revenue. With the additional increased revenue, mathematically, about 7 years are required to replace almost all existing meters with PPWM. If all additional revenue is utilized for purchase of PPWM, about 4 years are required to replace all existing meters with PPWM.

Table 5-10: Trial calculation of use of 1850 PPWM obtained from JICA grant as revolving fund

year	Case 1: half of the additional revenue		Case 2: all additional revenue	
	Annual increase of PPWM	Total number of PPWM	Annual increase of PPWM	Total number of PPWM
JICA PPWM installation	1,850	1,850	1,850	1,850
1st year	502	2,352	1,003	2,853
2nd year	635	2,986	1,541	4,394
3rd year	806	3,793	2,373	6,766

4th year	1,024	4,817	3,654	10,420
5th year	1,301	6,117		
6th year	1,652	7,769		
7th year	2,098	9,867		

5.1.6. Social sustainability

(1) Risks

The following risks or challenges are identified through the PPWM study of other water providers in Palestine. These could socially disturb the success of JM in its PPWM system.

1. Introduction of PPWM without any service improvement may provoke a protest among customers. In particular, the customers who are hesitant to pay bills would perhaps oppose and object PPWM if they not convinced about the benefits of PPWM.
2. The PPWM gives more accurate reading, and the new bill amount may be more than the previous bills, thus customer may resist prepaid water meter.
3. Low-income families would be affected by prepaid system.
4. If there is no improvement of water supply service in PA1 it may be difficult to implement PPWMs in the other areas.

(2) Recommendations for social consideration

- Customer's satisfaction on water supply (water availability and service) should be improved together with introduction of PPWM, which eases acceptance of PPWM.
- Conduct public awareness and involvement activities before and after PPWM system for better understanding of the public.
- Priority of installation is required, such as avoiding the area with low water availability and refugee camp.
- The affordability of the advance payment for low-income families must be considered.

5.1.7. Confirmation of political will and backup

- The municipal councilors in JM have decided to introduce PPWM since 2017.
- If fund is available, JM has a will to introduce PPWM anytime.
- If pilot projects of introduction of PPWM by JICA succeed, they will extend it to the other areas.
- The municipality also plans to purchase PPWM for new customers.

6. Procurement of PPWM System

6.1. Products and features

Prepaid water meters system includes prepaid water meter, charging card, vending station (PC computer, card reader, UPS, printer …etc.), handheld unit, software, PPWM box and gateway system.

(1) PPWM device: The device includes the user interface for the loading of credit and other data. The PPWM device must be protected to prevent tamper.

Photo 6-1: PPWM with charging card

(2) Vending station: Vending stations shall be established at accessible points for customers' convenience for extended hours. A vending station per 1,000 customers is suggested by the supplier. The equipment necessary for vending station will be PC system including software, the device for charging credit, etc., and one staff shall be deployed at this station. Vending station can be outsourced to supermarkets or to companies which offer credit charging services like Palpay Company in Palestine. Convenient and hassle-free payment methods; properly located charging centers (vending stations) with extended service hours and friendly/knowledgeable staff are established. The software will be used on a standard computer with an attached card reader.

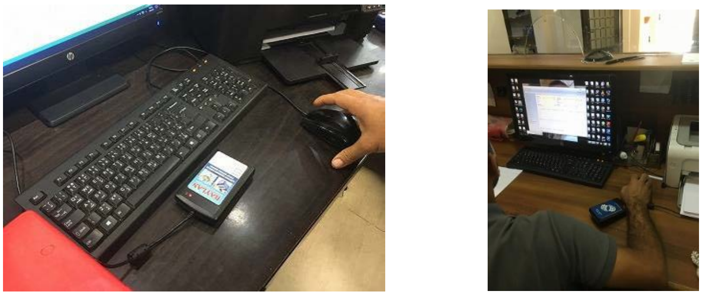


Photo 6-2: Sample of vending station

(3) Software: The prepaid water meters system of specific service provider shall be uniquely coded via a database code or identifier linked to the prepaid water meters, so that meters and token from one area cannot be used in another area. It was integrated with the current accounting software of JM

(Alshamel) to transfer the financial information of PPWM customers from PPWM server to the current database in financial department server.

(4) Handheld unit: Handheld unit allows access to water meter via authority card directly to read data. Handheld unit enables reading tokens, creating special purpose cards including time, authorization, maintenance, open, close, control (Info)...etc.

Photo 6-3Handheld unit

(5) PPWM plastic box: For protection purposes, the PPWM is installed inside the box. JICA Expert Team and JM suggested installing a plastic box customized for JM, as shown in Photo 6-4. The existing metal box has a lid that must be opened wide to allow card touch, which requires a large space for installation, making it impossible to install in a small space. The design of the plastic box has been changed to include a small window for card touch so that it can be installed in a small space. The metal box could affect the signal transmission between the PPWM and the gateway system.

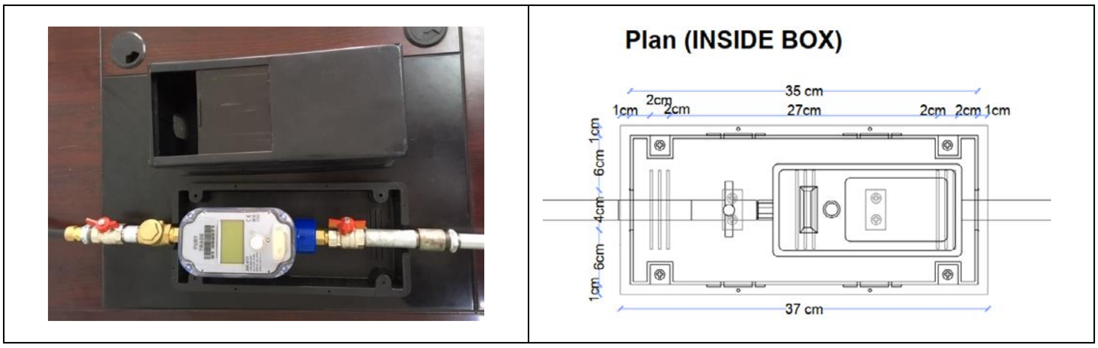


Photo 6-4: PPWM box

(6) Integration with municipality financial software: The PPWM software is integrated with the accounting and financial software of JM, by which prepaid meter system will be concurrently operated with accounting and financial software. The PPWM data such as credits is continuously transferred to the JM accounting software. The following are purposes / benefits of integration.

- Speed up accounting, save manual entry time, cost, human errors, miss typing, and additional employees or employee's time. Without integration, daily all the charging records of PPWM transaction should be entered manually to accounting and financial software (Alshamel).
- Illegal transaction /Security (No frauds /misuse of money protect data from change or being copied or viewed by un-authorized persons). It prevents any illegal use of PPWM charging money.
- Guarantee that financial transactions of all sources are entered to the financial system and get real treasury and bank balances.
- Get real time financial transactions.

(7) Gateway system: In order to streamline and enhance the monitoring process of the PPWM, a gateway system using LoRa technology was adopted, which allows administrators to completely monitor the PPWM remotely, generate reports, and provide technical instructions as needed. The overall system layout of the PPWM and gateway system is shown in the following figure.

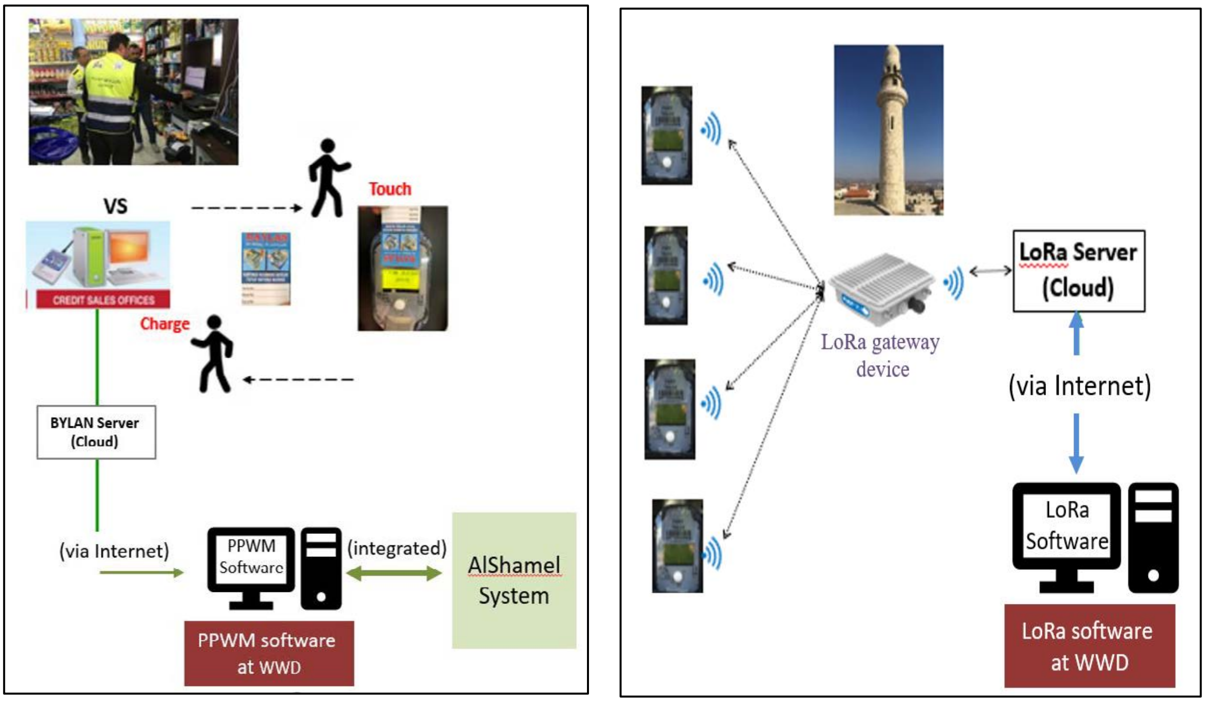


Figure 6-1: PPWM System (left) and LoRa Gateway System (right)

(8) Guarantee

The warranty period of PPWM by Fury Trade is 3 years from the date of delivery. Fury Trade will promptly inspect the equipment and repair or replace it free of charge after receiving notice of failure from JM.

6.2. Specifications of PPWM system in Jenin project

(1) The PPWM device: The required specification of ultrasonic PPWM is shown below considering the availability of PPWM in Palestine.

a) Diameter: 3/4 inch (ND20mm)

b) Q3 (Permanent flow rate) =2.5 ~ 4.0 m3/h and Q1 (Minimum flow rate) ≤ 0.016 m3/h.

(2) Vending station: hardware equipment and software. It includes PC, LCD Screen, printer, card (tag) reader, stand by card (tag) reader unit and UPS, on-line software, router, etc.

(3) Software and server: BAYLAN PPWM software, Server management software and hardware server suitable for the application are required. It also includes a suitable UPS, on-line software, router, etc.

- Technical specifications: HPE computer with 8 core processor 32 GB memory 1 TB hard disk including license for Windows & SQL 2016 standard license for 8 core & Unlimited Cals.

(4) Handheld unit: Model: Symbol, Workabout pro4, Platform: PXA270 624 MHz Processor

- 1 GB Flash ROM, 256 MB RAM, Operating System: Microsoft Windows CE 5.

(5) PPWM plastic box: Rigid plastic box.

(6) Gateway system:

Items	Specifications and standards	
Gateway Device	Communication	LoRaWAN 1.0 and 1.01 Compliant
	Antenna Connetors	"N" type RJ-45 for female POE
	Max Transmitter Power Output	27 dBM
	External LoRa Antenna	3.0 dB additional gain
	External H5 or LTE Antenna	2.15 dB additional gain
	PoE Spilitter (Inside IP67 enclosure)	48 Volt PoE at 25 Watts
	Operating temperature	-40 to +70 cent degree
	Storage temperature	-40 to +85 cent degree
	Accessories	Lightning arrestor, outdoor cable, antenna, etc. necessary for operation shall be included in.
	Model	Ethernet mLinux programable
Device Box	• Box shall be enough capacity for storing Gateway device with the antenna in this box. • Box shall be made of wooden or fiberglass materials. • Box shall be strong enough for installing at outdoor site.	

6.3. Procured items of PPWM system in Jenin project

In September 2018, a tender for the PPWM system was conducted by JICA Palestine Office according to the PWA technical specification and guidelines, and two companies, Fury Trade and Electromed, responded. After evaluation, the bid was won by Fury Trade, which responded with Baylan water meters. The procured PPWM system is shown below. After that, JM has procured 1,500 PPWMs by its own fund.

Table 6-1: Procured Items of PPWM system

No.	Items and Specifications	Quantity procured by JICA	Quantity procured by JM
1	Prepaid water meter (DN20), PN 16 bar, Ultrasonic type	1,850	1500
2	Check valves (DN20mm), PN 16 bar	1,850	1500
3	Ball valves (DN20 mm), PN 16 bar	3,700	3000
4	Rigid plastic box for installing PPWM, valves, fittings	1,850	1500
5	Complete vending station with hardware equipment and software	4 sets	6 (Only card reader and

			license)
7	Server management software and hardware	1	0
8	Installation including commissioning for Server management	1	0
9	Handheld Unit (field verifier)	3	0
10	Gateway	3	0

7. Installation of PPWM

7.1. PPWM installation plan in the pilot project areas of Jenin city

An installation schedule and workflow chart has been prepared to install the PPWMs in the three pilot areas.

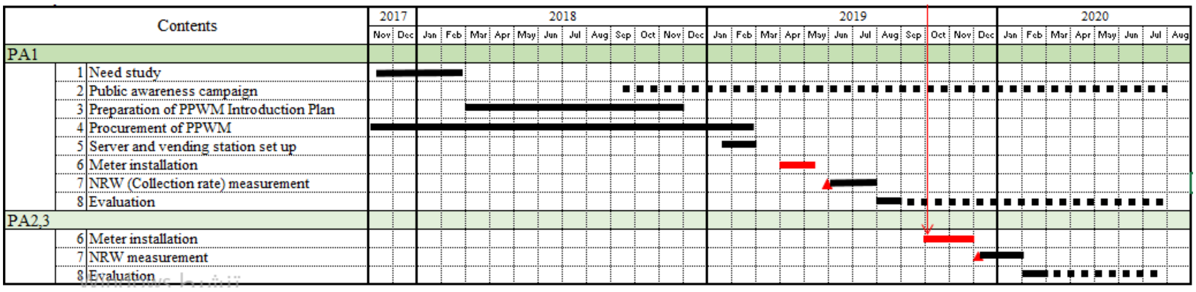


Figure 7-1: PPWM's Installation plan

7.2. Roles of the involved departments and sections

Installation of PPWM for entire city is a teamwork and involves many departments and sections. Although some departments may play smaller roles, they have important impact for success of the project.

Table below shows the related departments at JM which play different roles by providing specific services. The Water and Wastewater Department (WWD) plays the most important role in execution of the project by involvement of mainly its Customer Service Section with assistance of the Water Section, the GIS unit and the PR department of JM.

Table 7-1: Organizations Involved in PPWM Implementation

Organization	Major involvement
Water and Wastewater Department	Customer Service Section, Water Section, Collection Unit
GIS Unit	Preparation of GIS database and installation maps
Public Relation Department	Public awareness and door to door visits before PPWM installation, Satisfaction survey
IT Department	Technical issues with PPWM software and servers, VS
Financial Department	Customer payments database, financial reports
Public Citizen Center	Service applications on DMAS system
Legal Unit	Process for illegal users, enforce penalties
Human Resources Department	Hire of new staff if needed
City Council	Provide support for the team when needed
Mayor’s office	Provide support for the team when needed

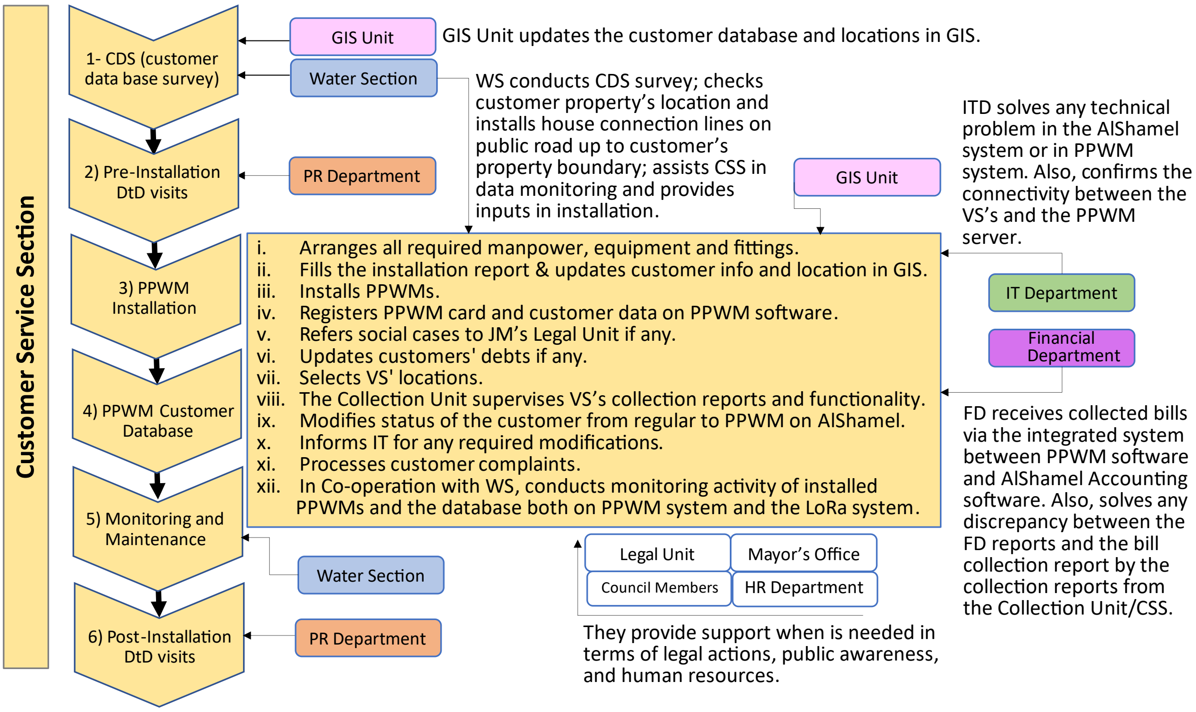


Figure 7-2: PPWM's Workflow and Tasks by Involved Section

7.3. PPWM installation team formation

(1) CDS team

A CDS (Customer Data Survey) team was already formed to collect customer information in the pilot area (DMA) of the NRW management pilot project. The customer data from the CDS team was used as basic information for the installation of PPWM.

(2) PR team

A PR (Public Relations) team was formed to visit customers before installation to explain PPWM and confirm their consent to installation (door to door (DtD) survey). The PR team is also responsible for customer satisfaction surveys after installation. Within the team, three teams were formed as follows.

Table 7-2: Details of the organization of the PR team and the time frame and tasks required for the door-to-door survey

Members		Customers per day	Other tasks
Team 1	1) JM PR Staff: 2 persons	About 10 customers (10am to 14pm)	Initial training, filling out forms on the field, taking photos, pinpoint absent/disagreed customers for re-visits
Team 2	1) JM PR Staff: 2 persons	About 10 customers (10am to 14pm)	Initial training, filling out forms on the field, taking photos, pinpoint

			absent/disagreed customers for re-visits
Data entry	Assistant PR	18- 24 customer data entry daily (8am to 4pm)	Data entry in GIS, scanning, photo filing, tabulating data

(3) Installation supervision team

An installation supervision team was formed to install PPWM at customers visited by the PR team and agreed to the installation. The installation will be carried out either directly by the Water Section (WS) or on a subcontracted basis. The installation supervision team will consist of two technicians. It will perform the following recording tasks during the water meter replacement process.

a) Document the last meter reading of the existing meter immediately prior to replacement as customer information.

b) After filling out and signing the final meter reading form, take the following photos.

   Photo 1: Existing water meter

   Photo 2: Existing water meter showing the surroundings

   Photo 3: Installed PPWM

   Photo 4: Installed PPWM showing the surroundings

c) The filled-out form and the photos are electronically filed for each customer's house ID.

7.4. PPWM installation

The installation started from PA1 in April 2019. At first, the installation was done by WS technicians. After that, WWD installed the meters through an outsourced contractor to speed up the installation process. After completion of PA-1 the installation in PA-2 and PA3 was done by another outsourced contractor. 1,792 PPWM were installed in the three pilot areas (PA-1, PA-2 and PA3) as of 15-Feb-2021.

Photo 7-1: PPWM installation

PPWM installation in the pilot areas was successful without major rejection movement. After this success story, JM procured PPWM by its own fund and started installation of PPWM in other areas in the city based on the following policy:

1) New customer: PPWM is installed for all new customers. JM has increased the new connection fee to 1,150 NIS, including the cost of PPWM installation; JM installs PPWM, and the

Municipality will be the owner of the meter.

2) Damaged mechanical meter: The replacement option is decided by site inspection. All damaged meters will be replaced by PPWM and change the customer's contract, and JM will be the owner.
3) Set up 7 new DMA and follow the same procedure as the JICA project, including CDS, DtD visits, PPWM installation, and necessary data entry.
   Note: PPWM will be free for the current customers for replacement of existing meter.

To date, JM installed 1,187 in areas other than three pilot areas and in total 3,119 PPWM have been installed in the entire city as shown in the following table.

Table 7-3: PPWM installation summary - All city 15-Feb-2021

Area	Installed PPWM
Pilot areas	
PA1	732
PA2	534
PA3	526
Sub-total	1,792
New DMA	
Al-Jinan DMA	44
Al-Basateen DMA	96
Sub-total	140
Other areas in the city	1,187
Total	3,119

7.5. Gateways and vending stations installation

7.5.1. Gateways installation

To monitor PPWM remotely and prepare the required reports for analysis purposes and data management, three gateways were installed in JM in November 2019.

Photo 7-2: Gateway device

7.5.2. Vending station installation

After installation of the first three vending stations and in conjunction of increment in the number of installed PPWM, JM decided to install more vending stations in the city.

To facilitate the control and management of vending stations, JM contracted with Palpay Company (Service Company for card charging issues and bill payments). By contracting with Palpay company, JM will be able to increase the vending stations easily with lower cost. Eight vending stations were installed by Palpay Company in June 2020 to bring the total number of vending stations in the city to 10. To date, average monthly charges of PPWM exceed 200,000 NIS by all vending stations.

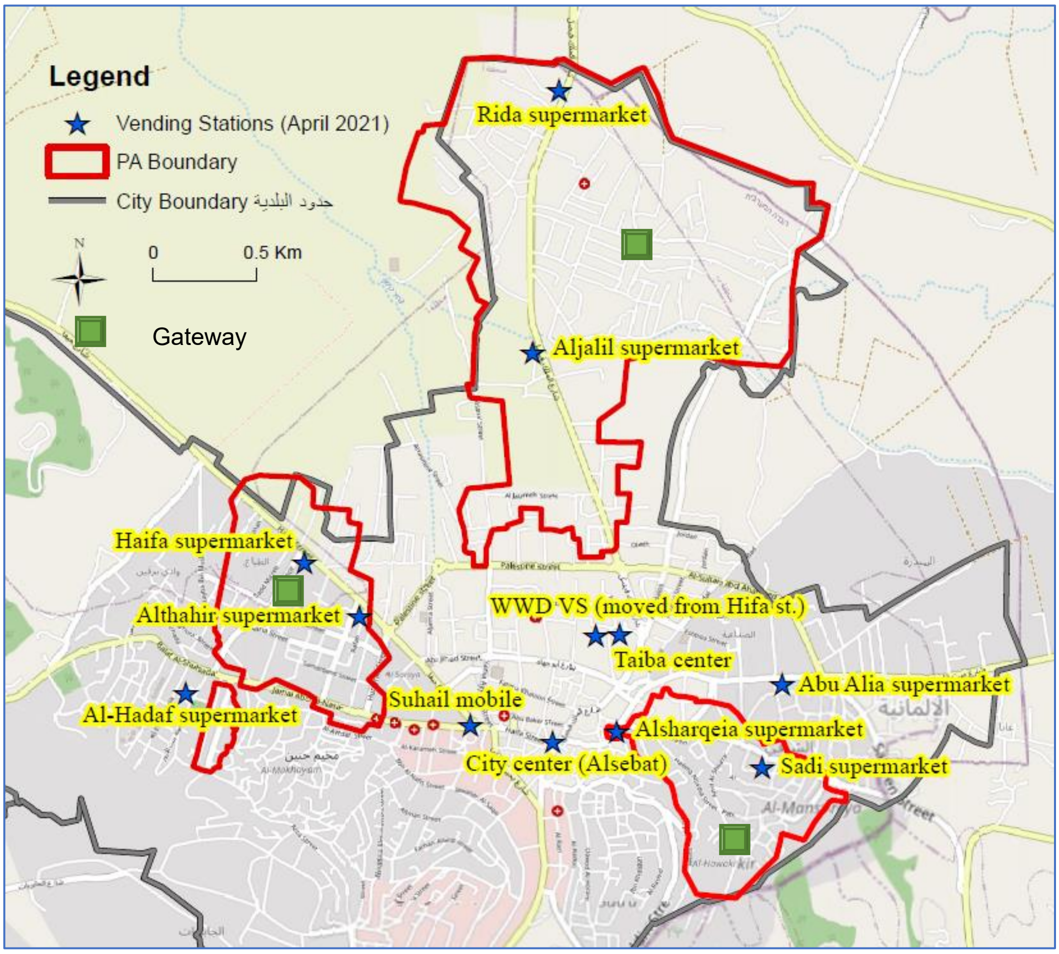


Figure 7-3: Vending stations (★) and gateways (■) in Jenin city

7.5.3. Water tariff

The water tariffs (post-paid and pre-paid) in JM are shown below. The minimum charge was eliminated in the pre-paid system, and it is also an incentive to replace to PPWM.

Table 7-4 Water tariff in Jenin Municipality (Post-paid)

Category		Tariff	Remarks
Minimum tariff (fixed)		17.36 NIS/month	Equivalent to the tariff for minimum water consumption (4 m^3)
Metered rates	0-50m^3	4.34 NIS/m^3	Bills are issued once a month
	Over 50m^3	6.2 NIS/m^3	
Maintenance costs for network		6.2 NIS/month	

Table 7-5 Water tariff in Jenin Municipality (Pre-paid)

Category		Tariff	Remarks
Metered rates	0-50m^3	4.34 NIS/m^3	Advance payment
	Over 50m^3	6.2 NIS/m^3	
Maintenance costs for network		6.2 NIS/month	

8. Operation and Maintenance of PPWM

8.1. PPWM operation organization

Customer Service Section (CSS) has formed teams to operate and maintain PPWM. These teams follow up and monitor PPWM to implement appropriate measures. The following workforce is currently engaged in JM for the operation and maintenance of PPWM.

Table 8-1: PPWM operation and maintenance organization in JM

No.	Job title	Number of employees	Section	Duties
1	PPWM maintenance	2 Technician (full time)	CSS	• PPWM maintenance which includes: - Replacement of the battery - If the prepaid meter fails, remove the meter and replace it with a standby PPWM and send the damaged meter to outsourced maintenance center for repair. When the meter is fixed the technician reinstalls it again. • Periodical inspection of meter every 1 to 6 months. • Checking meters with abnormal value (on site) for possible illegal connections
2	Vending station clerk	City official (outsource)	CSS/Outsourcing	• Credit charging process and remittance of sales credit to the Municipality
3	Database/program management	1 (full-time)	CSS	• Working in database and sever management. - Application, registration, disconnection, etc. - Reporting - Program management • Monitoring and following up the vending stations • Checking of monthly consumption, find abnormal values, ad report to Customer Service Section.
4	Handling customers complaints	2 Technicians and 1 IT (full time)	CSS	• Respond and solve complaints quickly. • Provide good service with good communication with customers.

8.2. Progress of CSS activities after PPWM installation

The following table shows the progress of CSS activities from Nov 2019 to Feb 2021.

Table 8-2 Progress of CSS Activities (November 2019 - February2021)

Activity	Current progress
Handling customer complaint	878 Complaints
Regular inspection of PPWM	615 PPWM
Maintained PPWM by warrantee	91 PPWM

The following are the summary of content of major complaints which were received and solved by CSS:

1. PPWM valve was still closed.
2. Card charging issues / Card does not match with the PPWM number.
3. Accuracy of PPWM: Some customers requested to check the accuracy of their PPWM.
4. Product defect.
5. In the early stages of the COVID-19 pandemic, there was a demand to activate the fire mode and use water due to the inability to charge credit outside.
6. Water leakage inside.

Note: If there is no credit, or the storage tank is empty, and a fire breaks out, the fire mode can be activated. It keeps the valve open and allow water to be used for 180 minutes in an emergency. The water used during the fire mode will be deducted from the next credits charged.

9. Results and effects of PPWM introduction

9.1. Implementation strategy and details

The implementation strategy of PPWM and its details are summarized below. See the following sections for the results of the implementation.

Table 9-1 Implementation strategy and details of PPWM

Item	Strategy	Implementation details
1. Major success factor	Increase customer satisfaction and improve willingness to accept PPWM	The satisfaction has been improved through the implementation of the following 3 to 6 items. Furthermore, the water supply situation was improved.
2. Implementation policy	Prepare implementation policies to reduce the risk of failure of PPWM introduction and ensure success	The first implementation was carried out in PA1, where residents were considered to easily accept PPWM, and a successful example was made.
3. Raising awareness	Raise awareness of the water supply service in Municipality and PPWM	Raised awareness among citizens by holding public meetings, disseminating information through social media, and visiting DtD to explain PPWM individually
4. Technology	Enhance technical capabilities to back up PPWM implementation	Enhanced by training by the PPWM supplier and on-the-job training by the JICA expert team. Visited the maintenance center of the PPWM company to observe the maintenance of PPWM. Three types of water meters were tested for measurement, and the most suitable water meter (ultrasonic type) was introduced. Gateway was installed to remotely check the meter status and acquire meter management control capability.
5. Water tariff and debt collection	Give customers financial incentives to participate in PPWM	Minimum charges were eliminated from water rates for PPWM.
6. Customer service	Enhance the management capabilities of PPWM systems and improve customer service	As described in Section 9.3 below, the PPWM management organization system was established, and customer service was improved through the implementation of PPWM.

9.2. Water supply improvement

Water supply improvement, one of the implementation strategies, is summarized below for each PA. In addition, a water distribution hydraulic model of the PA was created, and the piping details to be improved (route, diameter, and extension) were calculated. However, the water distribution pipe replacement project could not be implemented due to a lack of budget.

Area	Water improvement policy	Effect
PA1	The opening and closing position of the valve was changed to allow water to reach the areas with poor water supply. The Al-Basateen area, supplied with water from the PA1 water source, was changed to a water source from another area.	Some areas with poor water supply due to valve operation have been improved. The water source change has increased the amount of water source available for distribution to PA1 and improved the water supply service.
PA2	Contracted with one private well contractor in PA2 and connected the private well to the city water supply. Repaired the damaged boundary valve in PA2 and secured the water source volume for PA2.	Water supply pressure and supply volume increased due to the addition of a private well. In June 2021, the water distribution volume in PA2 was about 1100m^3/day. Of this, about 600m^3/day is distributed from contracted wells.
PA3	Contracted with one private well contractor within PA3 to connect the private well to the city's water supply.	The water supply was not available in the high elevation area, but now it is available in the whole area. In February 2021, the water distribution volume in PA3 was about 560 m^3/day, of

		which about 300 m^3/day was distributed from contracted private wells.
City-wide	Contracted with four private well contractors, including the PAs, to connect private wells to the city water supply. The Al-Saadeh city-owned well was upgraded. However, the effect of the improvement was not sufficient.	Water allocation increased from an average of 8,640 m^3/day in 2018 to 9,943 m^3/day in 2020. The increase is about 1,303 m^3/day.

9.3. Establishment of new responsibilities and procedure for PPWM in Jenin Municipality

It is important for JM to understand the PPWM installation progress and to identify the responsibilities for the involved departments and sections in the PPWM installation process. The following is the sequence of steps and workflow that are understood from the discussion with the related sections in JM:

(1) Customer Service Section (WWD)

The first step of the PPWM installation/replacement for the existing meters starts from this section as follows:

1) Decides the installation area and prepares the necessary information and conducts the DtD visits with PR Department for customer acceptance of PPWM installation 1 to 2 weeks before the installation period. Re-visits any rejecting customers when needed.
2) Prepares the GIS map of customer locations and other information such as water meter number, name, etc. collected by the Customer Database Survey (CDS) into GIS system.
3) Prepares the customer database on the PPWM software in advance and will make sure that the data is correct by crosschecking the PPWM database before the customer charges his PPWM. About 20-30 meters are supposed to be registered daily according to the installation teams and productivity experience during the pilot project period.
4) Identifies the PPWM and its charging card under the specific names of customers before the installation. This is because the PPWM should be ready to be charged immediately after installation.
5) Change the status of the customer in the Alshamel software to PPWM user immediately after PPWM installation. This feature was added by modifying the Alshamel program. As a result of this change, billing will stop, and PPWM customers will be removed from the meter reading list.
6) Updates customer financial status automatically by the integration between the Al Shamel Accounting software and the PPWM software.
7) Supervises the PPWM installation together with Water Section. Conducts the final water meter reading before replacing with PPWM. Confirms the customer satisfaction and documents the complaint if necessary, by the PR staff of the team.
8) CSS in cooperation with the PR department, conducts and supervises customer awareness of the PPWM system especially the first time PPWM customers prior to the installation, and provides them with all necessary information and PPWM booklets -individually and using tools such as social media and JM website.
9) CSS (GIS assistant) receives the installation reports from the installation team and archives/updates the customer database in GIS.

10) Processes any complaints from the other sections and units such as the Collection Unit or the Water Section if there is any problem in the database which affect the vending functionality or issues with the installation itself. Also, CSS processes complaints from customers if there is any difficulty in using the PPWM or any issues with the PPWM malfunction/damage, and consumption, etc. CSS will do with its staff any required maintenance/replacement for the malfunctioned PPWM as possible as they can, or they will coordinate to send the PPWM to the supplier for maintenance.
11) Issues any required reports from the PPWM software or Alshamel upon request.
12) CSS assigns monitoring staff for periodically monitoring of the PPWM customer database for any observed abnormality in credit charges or long period of zero/low consumption and solves the discovered issues in cooperation with the assigned monitoring staff of the Water Section. Updates the database, as necessary (LoRa System, PPWM software, AlShamel)
13) CSS-WS monitoring team coordinates and conducts random check and/or periodic check of the installed PPWM and takes the necessary actions to solve any issues.
14) Sends SMS reminder for debt payment.

The Collection Unit of CSS is the unit responsible for receiving the cash money from the water bill collector. As for the PPWM related activities, the Collection Unit is responsible for functions of the Vending Stations as follows:

1) Confirms that VS's functionality is in good situation, and they are able to vend to customers.
2) Contacts daily with the Vending Station points (i. e. contracted supermarkets) and collects the water charging reports.
3) Reports to the CSS if any technical problem occurs in the vending stations.

(2) Water Section (WWD)

The water section is responsible for installing the house connection after registration process being completed by the CSS.

1) Completes the Customer Database Survey (CDS) prior to the installation period to collect the following information:
    a) Building owner's name,
    b) Building code number,
    c) Number of households and family,
    d) Registration status in customer database,
    e) Water meter number, route of house connection, Utilized pipe material and diameter,
    f) XY coordinates of the water meter location and branched points XY,
    g) Usage of private network,
    h) Number and volume of water tanks,
    i) Building photo.

2) Assists the GIS Unit for digitizing of the customer location maps and the house connection line maps. Provides input if any modification required for the house connection line or meter location on the site and on the map.
3) Assists CSS in filling the installation report of the house connection file of the customer with all required details and deliver it to CSS for feedback.
4) Assigns monitoring staff to cooperate with the CSS's monitoring staff on PPWM database observations for abnormality of credit charges, zero/low consumptions, battery issues, and solves any discovered issues by coordinating with CSS and prepares the report.
5) The same CSS-WS cooperation monitoring staff will also coordinate and conduct random check and/or periodic PPWM checks and follow up with the necessary actions from WS.

(3) GIS Unit
1) Prepares the CDS and DtD maps for targeted area selected by WWD and CSS.
2) Prepares the GIS database and the installation maps for targeted areas selected by WWD and CSS.
3) Updates customer status and PPWM location on GIS database after the installation.
4) Updates customer information and status (Frozen, disconnected, illegal) in cooperation with CSS.
5) Issues any required reports from GIS database to head of CSS upon request.

(4) Public Relation Department
In addition to carrying out PR activities to promote PPWM in entire city by use of social media and JM website and production of PR materials, interviews and short movie productions, the following major public awareness activities play a significant role in success of the PPWM acceptance by customers if conducted prior to the installation period of the installation area:

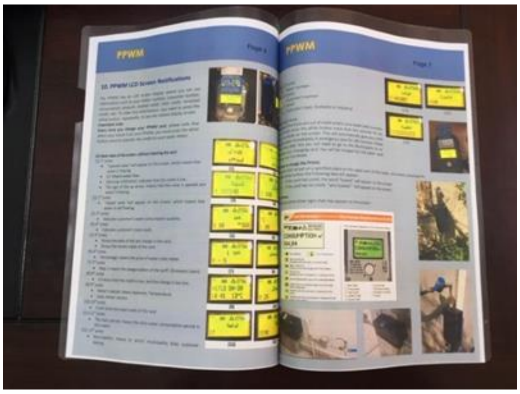
1) Pre-Installation Door-To-Door (DtD) visits

These visits include visiting every customer 1 or 2 weeks prior to the installation with the purpose of receiving the customer's consent on installation of PPWM. The customer will be well explained and informed about 1) PPWM and its benefits, 2) type of the selected PPWM and the reasons, 3) how to use the PPWM, 4) where to charge the PPWM card, and 5) how the installation would work and what day they should expect the installation team. A PPWM booklet with all of the necessary information will be also handed to the customer and the PR staff make sure that the customers understood the PPWM and all their questions are answered before the installation day. Customers who refused to be installed, will be recorded for a re-visit with higher level of management of JM.

The following steps can be used as a reference when conducting the pre-installation DtD visits.

i. Set up the area of visit.
ii. Extract customer information from the AlShamel database for the selected area.
iii. Set up team members, means of transportation, and visiting time: weekdays mornings are more suitable when it is expected that customers are present at home.
iv. Prepare accompanied documents: 1) hardcopy map of the visiting area using GIS map, 2) PR materials such as PPWM booklet and VS time/schedule, and 3) a hardcopy of list of the customers including their name, water meter number, and subscription number.

In the booklet customers can read about:



- PPWM in Jenin
- PPWM Benefits
- Type of PPWM in PA Areas and How It Works
- Water Fee and Credit Charges
- Where to Purchase Credit for Your PPWM Smart Card (charging your card)
- Customers Responsibility on Their PPWM
- How to Maintain the PPWM from Damages or Misuse
- Where to Report If any Damages are noticed in the PPWM or Misfunction
- Installation Timetable
- PPWM Screen Notifications

Additional information:

- Location of Tested PPWMs in Pilot Areas
- Results of Accuracy Test of Three Types of Water Meters
- Other Activities by the Project

2) Re-visit of rejecting customers

The second visit's purpose is to convince those customers who reject installation of PPWM in their property. According to experience form the pilot project areas, most of these customers finally accept the installation. It is important that higher level of management and key people such as the mayor, head of the WWD, key community people, or council members accompany the PR team for the second visits for a more successful result.

3) Post-Installation visits

Visits in order to ensure positive experience of the PPWM customers and address any issues they may have. Measure their satisfaction level and share with the city citizens for the purpose of public awareness.

4) Neighborhood meetings and meetings with community leaders

These neighborhood meetings are also very significant in group discussions prior to the installation period. It is effective when it is well planned and key members of the community such as mosque imam, and community leaders are also attending. Attendance of higher-level management of the JM is essential in these neighborhood meetings.

5) Public awareness during installation and operation

The activities focus on the proper use of the PPWM, procedures for the related service applications, new service procedures, complaints system, etc.

- Prepare and distribute instruction sheet on how-to use PPWM.
- Prepare and distribute information sheet about misusing the service.
- Facilitate installation's team by allowing entry to the house.
- Receive any complaint by customers and send it to Head of CSS.
- Periodic information about the progress of the installation project on JM’s website and Facebook for the citizen’s awareness
- Periodic FB posts on benefits of PPWMs
- Production of PPWM short movies i. e. interview with PPWM customers to share their experience with the residents. The movies can be shared on FB, YouTube, and JM website.
- Production of PR materials such as flyers, pamphlets, etc.

(5) IT Department

The IT section in JM is mainly responsible for the technical issues related to the PPWM system.

1) Conducts installation for the VSs, Server, Internet, and solves any issues.
2) Confirms the connectivity between the VS’s and the PPWM server.
3) Solves any technical (IT) problems in the PPWM system by coordinating with the PPWM supplier.
4) Solves any technical (IT) problem in the Alshamel system by coordinating with the AlShamel software supplier.
5) Ensures functionality of the Integration between Alshamel and PPWM software and provides training to the CSS employees in this regard.

(6) Financial Department

Confirms the financial data on Alshamel software on a monthly basis and ensures that the money transfer movements are correct via integration between PPWM & Alshamel software. Cooperates with CSS and the Collection Unit.

(7) Citizen Service Center

1) Receives new customers' applications for PPWM water subscription.
2) Receives subscription fees and transfers the application to CSS to install the PPWM.
3) Follows up with customers complaints on PPWM if any.

(8) Legal Unit

1) Follows up with CSS service for any rejected cases to install the PPWM especially if the customer has cumulative debt.
2) Transfers rejected customers information to the Mayor's office to take necessary actions such as sending an installation notification or transfer customer file to the Court.
3) Follows up any illegal case after PPWM installation.

(9) Human Resource Department

Follow up with WWD and CSS to assign new staff for PPWM installation if required.

(10) Mayor Office and Council Members Office

1) Supervises and instructs WWD and CSS for PPWM installation process, in general.
2) Provides all possible support to speed up and success of the PPWM installation whether financial or organizational.
3) Follows up the rejected cases with CSS and takes the required actions to install the PPWM for these cases.

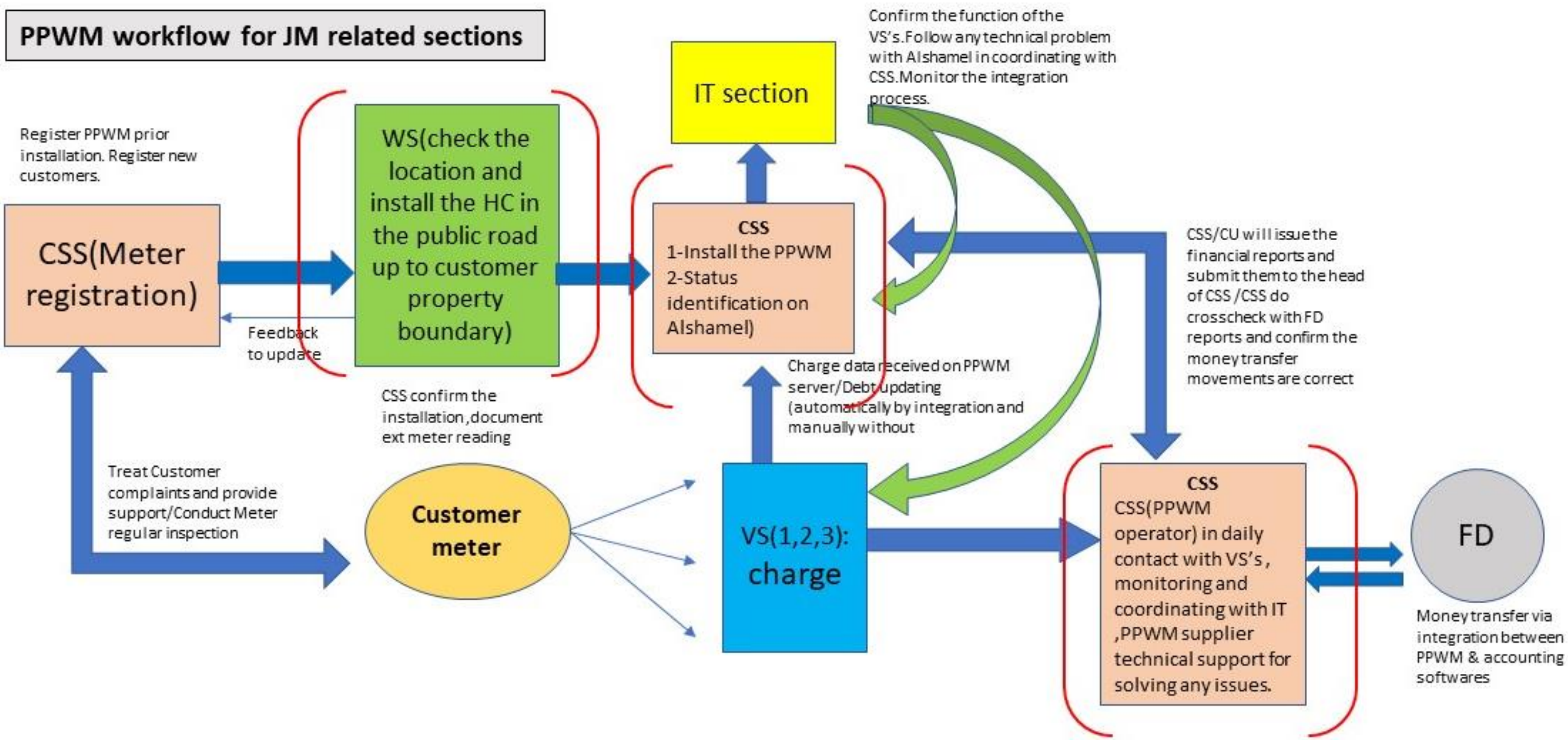


Figure 9-1: PPWM Workflow for JM related Section

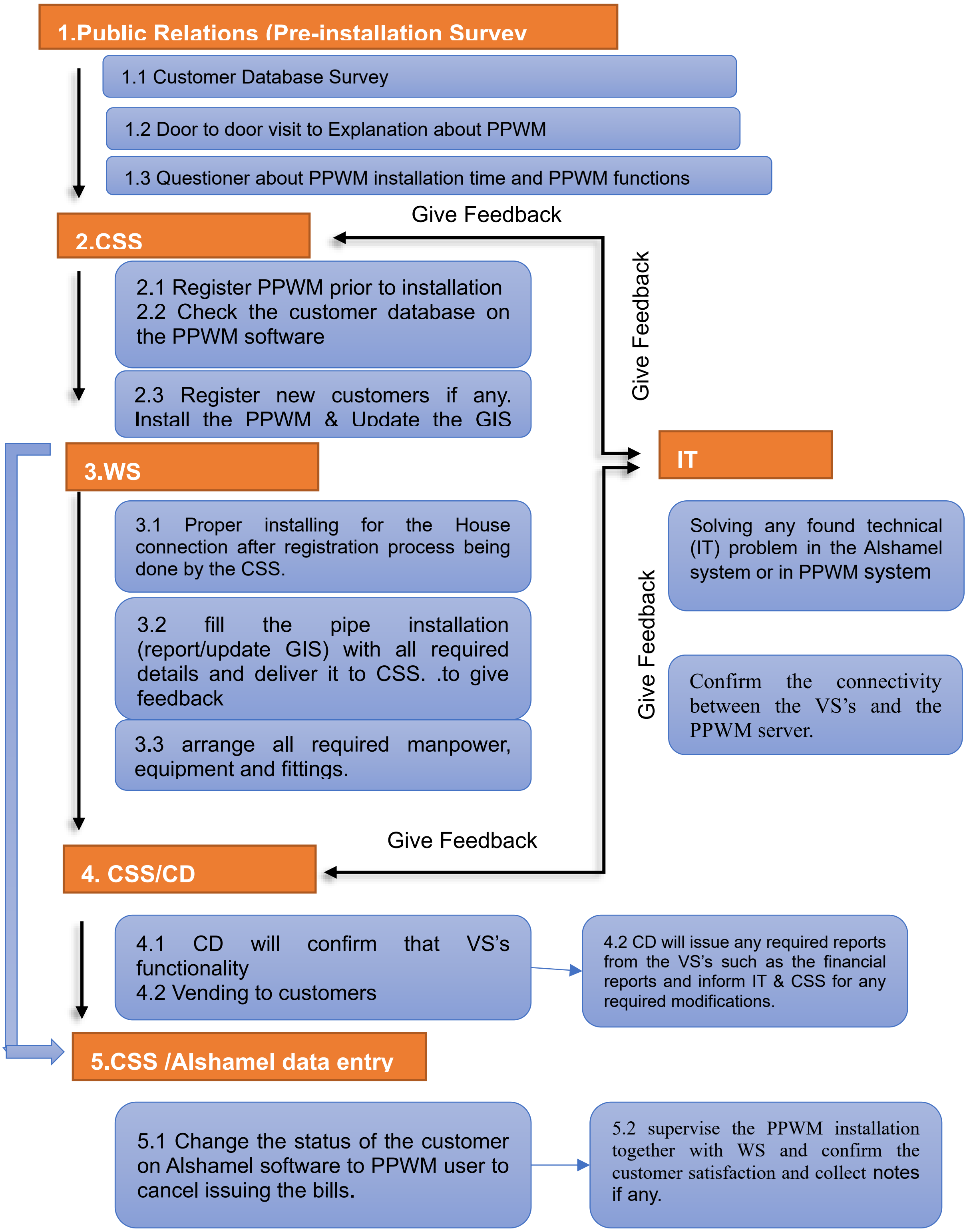


Figure 9-2: Sequence of PPWM installation steps:

9.4. Tariff billing and tariff collection rates

PPWM installation significantly improved the collection ratio of pilot project areas, as shown in the following figures and summary table. In addition, PA2 has a large number of customers from refugee camps and public institutions. The tariff collection rate is low for these customers because PPWM has not been installed. If these customers are excluded, the collection rate is about 90%. There is also missing data in January 2020, but this is the month when the Mobile Billing System (MBS) started to be used, so the data was not available.

Table 9-2 Tariff collection rate in pilot area (Only current month's tariff, not including collection of unpaid bills)

Area	Before installation	After installation
PA1	About 50%	About 90%
PA2	20-50%	50-80%
PA3	20-50%	80-95%

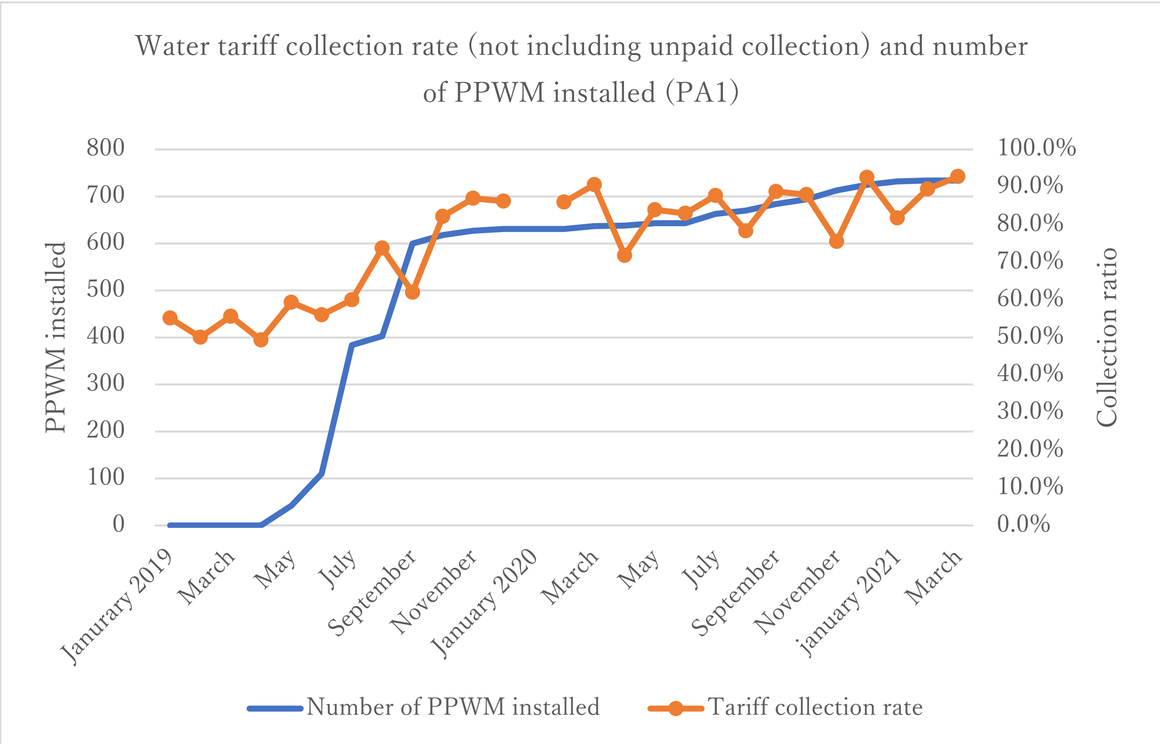
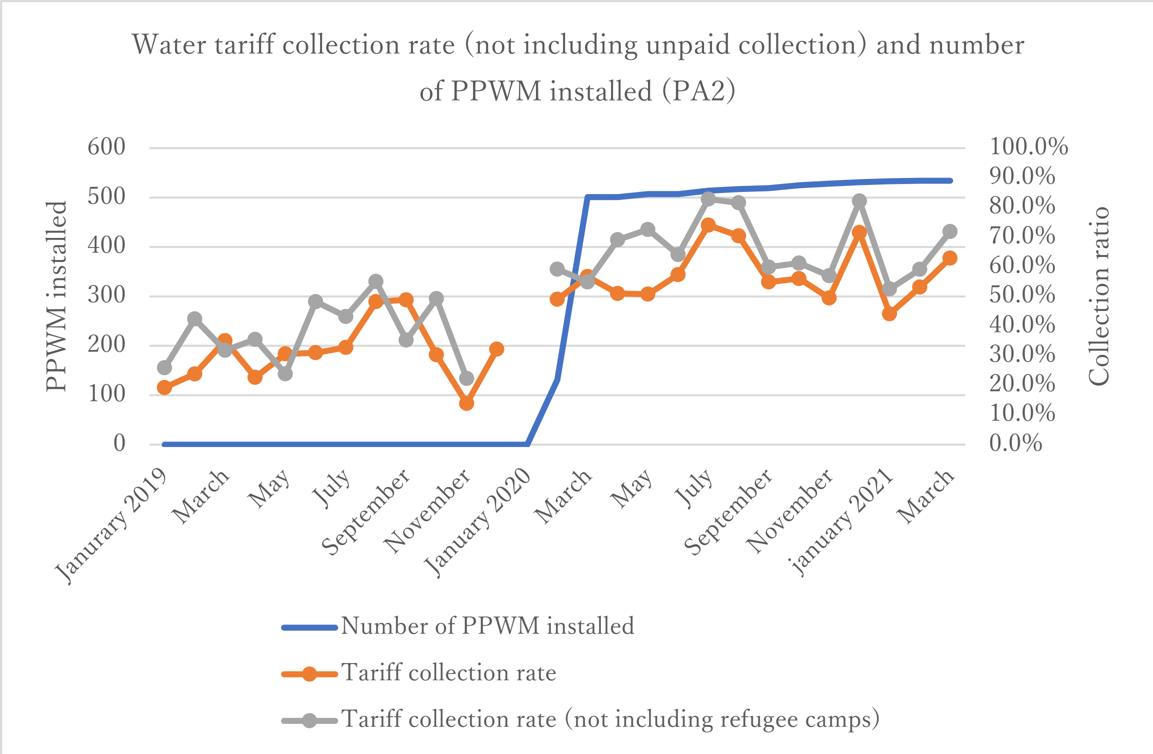
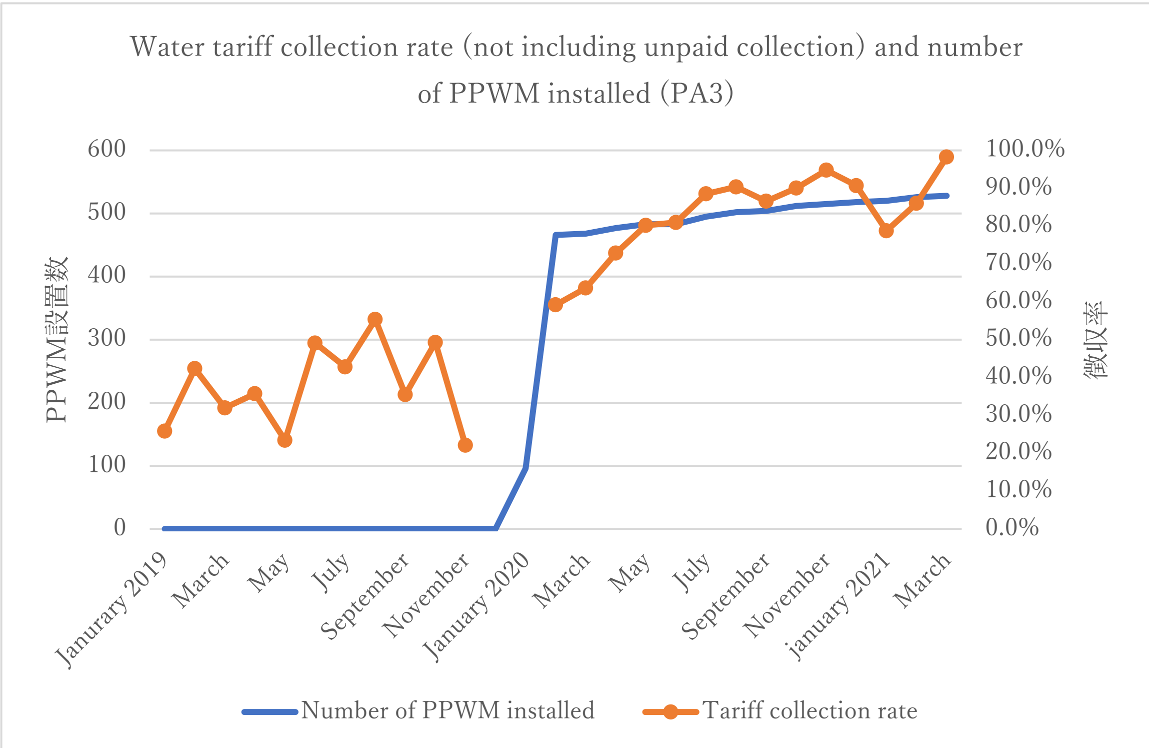


Figure 9-3 Improvement of tariff collection rate and amount in PA1



Note: Installation started in February 2020

Figure 9-4 Monthly tariff collection rate in PA2



Note: Installation started in January 2020

Figure 9-5 Monthly tariff collection rate in PA3

9.5. Analysis of customer data before and after PPWM installation

9.5.1. Change in customer water consumption

Based on Alshamel's post-paid customer data and prepaid data of the same customers, we analyzed the monthly water consumption data of all 603 customers in PA1. Monthly water consumption data were compiled for the period when post-paid water meters were used (October 2018 to March 2019) and the period after PPWM were installed (March to September 2019). The following table shows the statistics. Note that the water consumption of the post-paid meters represents the billed water consumption.

The average water consumption for all customers and per customer was 9,602 m^3/month and 15.9 m^3/capita/month during post-payment metering and 9,142 m^3/month and 15.2 m^3/capita/month after installing PPWM, which is almost the same. In the case of post-paid meters, the number of customers with zero water consumption was 54, which decreased to 8 after being installed with PPWM.

Table 9-3 Comparison of water consumption before and after PPWM installation

Item	Water consumption (before introduction) (m^3/month)	Water consumption (after introduction) (m^3/month)
Total	9,602	9,142
Monthly average/customer	15.9	15.2
Maximum	167	88
Number of 0 values	50	24

A comparison of the customer's average water consumption before and after the installation of PPWM is shown in the following figure. The blue bar graph shows the monthly average water consumption of customers in each group by arranging the customers in descending order of water consumption (from largest to smallest) when they were using post-paid water meters and dividing the total number of customers into groups of 60 customers each. The red bar graph shows how much the same customer group consumed on average per month after the installation of the PPWM. It shows that even though the total water consumption of all customers is the same, the water consumption of each customer group has changed significantly. While many customers use large amounts of water during post-paid metering, many customers use little or no water at all. On the other hand, after the same group of customers switched from post-paid meters to PPWM, customers who used large amounts of water reduced their consumption, while customers who used minimal or no water increased their consumption. It indicates that high water users' reduction in water consumption has been transferred to customers who previously did not have access to sufficient water. These customers who no longer have access to sufficient water are thought to have lived in hydraulically disadvantaged areas by the pipe network.

From the above, it can be said that the introduction of PPWM has equalized the water consumption of each customer, and PPWM plays a role in promoting equitable use of water.

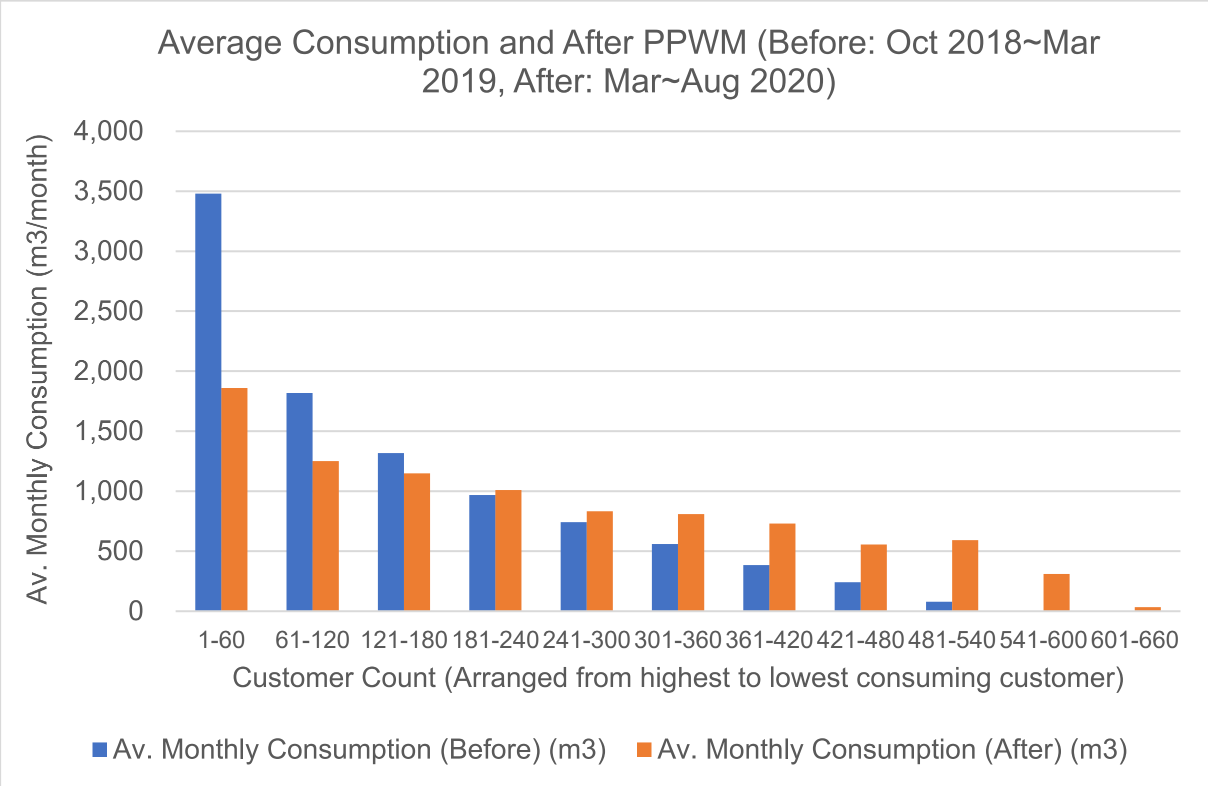


Figure 9-6 Average water consumption of customers before and after installation of PPWM for each customer group

9.5.2. Change in monthly payments by customers

The data statistics of water bills collected and billed after installation of PPWM for the same period for the same customers with water consumption by the post-paid method are shown in the following table. The average water billing amount for all customers is NIS 55,004 before installation, of which the amount collected is NIS 22,102. After installation, the total credit billed amount (collected amount) increased to 50,389 NIS. The total credit billed amount after installation is almost equal to the total tariff billed amount before installation. The amount collected/credit charged per customer increased significantly from 36.7 NIS to 83.6 NIS before and after the installation. In the case of post-paid meters, the number of customers with zero amount collected was 195. At the same time, it decreased to 111 after installation.

Note: 111 above includes customers who have charged credit before the analysis period and use the remainder of the credit.

Table 9-4 Comparison of water tariff before and after PPWM installation

Item	Billed amount (before installation)	Amount collected (before installation)	Amount of credit charged (after installation)

Total (NIS)	55,004	22,102	50,389
Customer Average (NIS/Customer)	91.2	36.7	83.6
Maximum	1075	430	650
Number of 0 values	1	195	111

A comparison of the pre-installation PPWM billing and collection amounts and the post-installation credit billing amounts for the same customer groups with the water consumption as mentioned above is shown in the next figure. In all groups, the amount of credit billed after installation increased over the amount of credit collected before installation. It means that many customers who had not paid their bills before installation are now charging credit by PPWM. In the group with the highest water tariff (1-60), the collection rate is about 40% of the billed amount. This group's post-installation credit billed amount (11,722 NIS) is about 62% of the pre-installation billed amount. It also means that this group has greatly reduced their water consumption. The previously non-paying customers in this group may have reduced their water consumption and paid less for water because they have to pay 100% of their water bills in advance after installation. In addition, large water-using customers who pay water bills every month may also consider credit billing purchases and water consumption because of the prepayment. We believe that after installation, customers with high water consumption became more aware of water conservation.

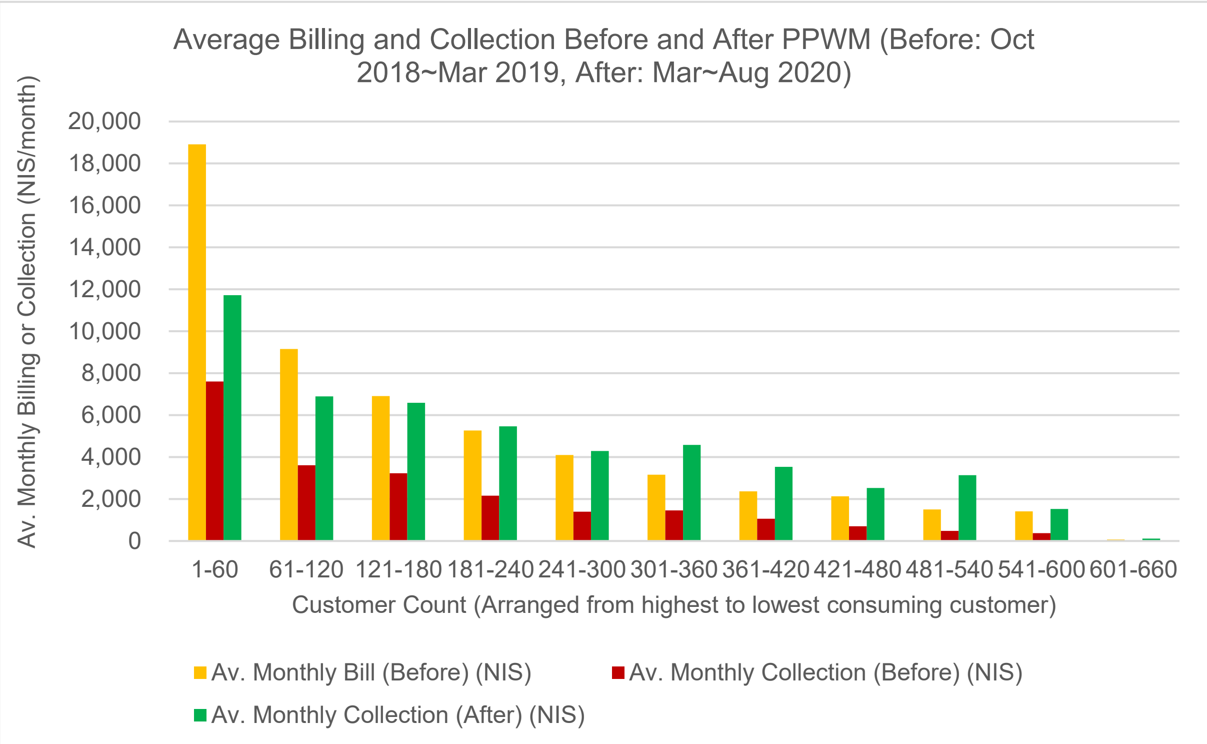


Figure 9-7 Water tariff (billed, collected, and credit charged) before and after installation of PPWM for each customer group

9.6. Tariff collection under COVID-19 pandemic

The following figure shows the collection rates by prepaid and post-paid meters before and after the

COVID-19 outbreak. It is mainly because post-paid meter customers' payments were affected by the COVID-19 outbreak. On the other hand, the payment of PPWM customers was not affected; the tariff revenue from PPWM at the beginning of the COVID-19 outbreak contributed significantly to the maintenance of water supply services. In addition, from March to May 2020, the payment of salaries to government public agency employees was suspended. Since Jenin City has many employees working for government public institutions, the suspension of salary payments makes them pay less for their water bills. It is one of the reasons for the decrease in tariff revenues.

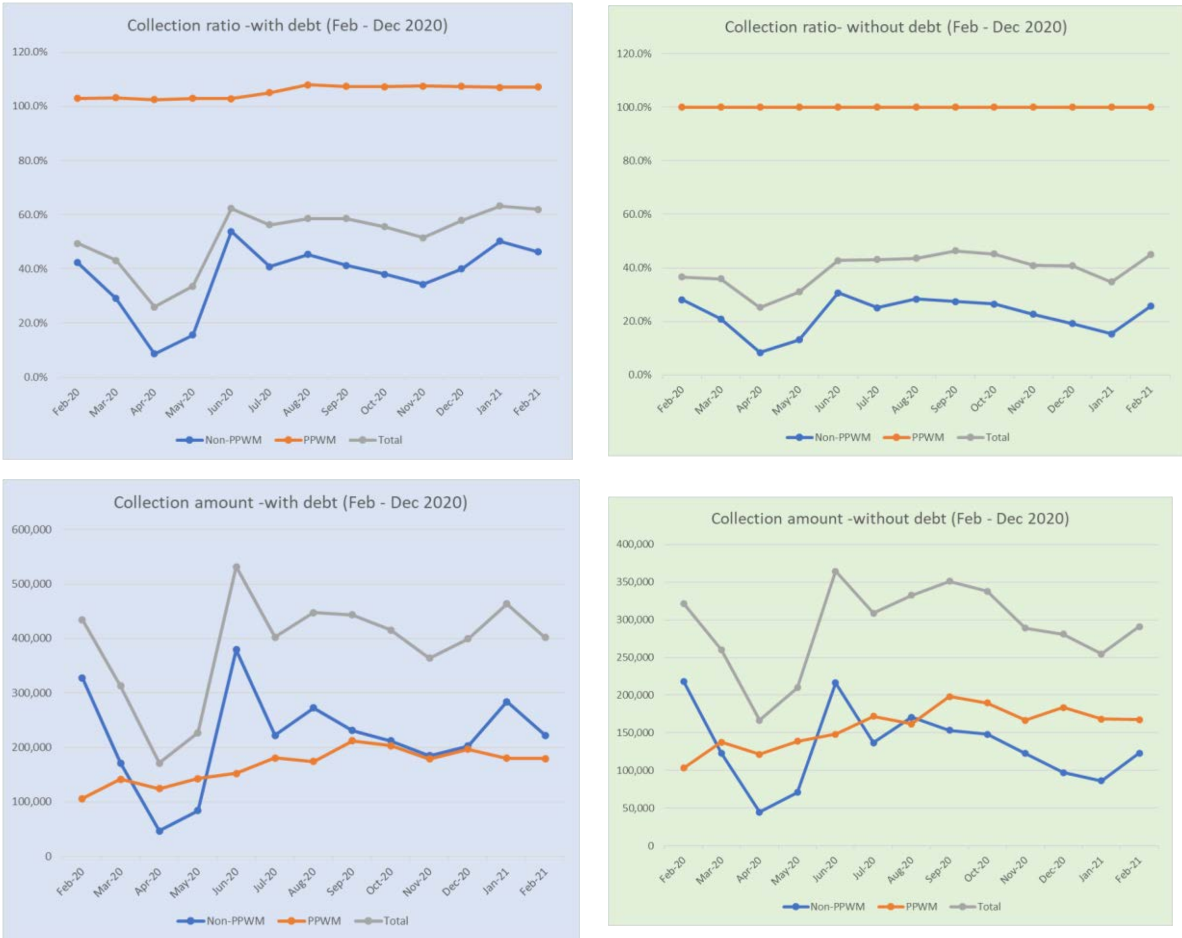


Figure 9-8 PPWM and post-paid meter collection tariff and collection rates before and after the COVID-19 outbreak, including and excluding uncollected revenue (debt)

9.7. PPWM customer satisfaction

9.7.1. Customer satisfaction survey

Customer visit surveys were conducted to obtain opinions on the overall experience of using PPWM and measuring customer satisfaction with PPWM. The number of door-to-door visits is shown in the following table.

Table 9-5 Number of door-to-door visits for customer surveys

District	PPWM all customers	Number of visits
PA1	753	70
PA2	526	62
PA3	524	60
Total	1,803	192

The PR team of JM conducted this survey by visiting the customers and getting their responses to the questionnaire. The PR team visited PPWM clients in the pilot areas to measure their satisfaction and understand the problems customers faced in using PPWM. The survey was conducted in PA1 in September 2019 and PA2 and PA3 in June 2020. The questions are as follows. The questions are in principle Yes or No type, and the reason for the choice is asked.

- Type of water meter installed
- Level of satisfaction when installing PPWM
- Problems when using PPWM
- Location of vending stations and problems in charging credit
- Satisfaction with the way of public awareness in implementation of PPWM
- Satisfaction with the use of PPWM
- Satisfaction with the use of billing cards
- Satisfaction with no meter reader visits
- Satisfaction with not having bills delivered
- Satisfaction with access to water

The following figure shows the level of customer satisfaction for each item. A summary of the survey results is shown below.

① Respondents in the three pilot districts understood the reasons why JM chose the ultrasonic PPWM and responded favorably to the selection and installation of the ultrasonic PPWM.

② Satisfied with the date and time of installation, the team, the informative PPWM booklet distributed, and the manual on how to use the PPWM and the PPWM operational procedures.

③ Generally satisfied with PPWM as there is no need for meter reading and delivery of bills.

④ 98% of the customers are satisfied with the installed PPWM and have not experienced any major problems with billing their cards or PPWM devices.

⑤ The overall satisfaction level is 98%. The remaining 2% were not due to problems with the use of the PPWM system but mainly due to inadequate water supply. More attention needs to be paid to improving the water supply situation.

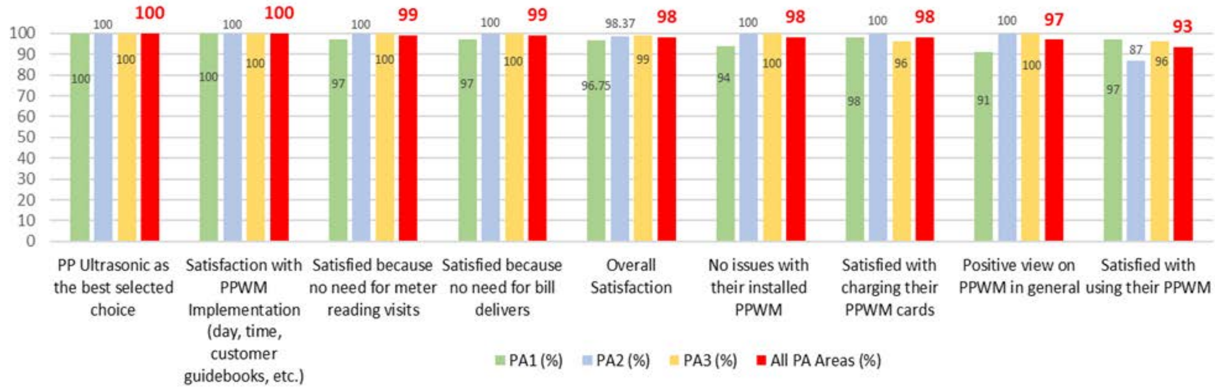


Figure 9-9 PPWM customer satisfaction

JM makes much effort to resolve customer complaints after receiving them. A 24/7 phone number is available for complaints. This kind of response is also believed to contribute to customer satisfaction.

9.7.2. Customer satisfaction interviews

a) Interviews in Dec 2019. The interviews were recorded as a short movie and shared on JM's FB for the public awareness purposes. Below is a translation of the customer's comments expressed in the interviews:

1) "It's more committed and easier to use."

   Note: We are now responsible for paying the water bills and reducing the unpaid bills. In the pre-paid system, the bills may not be paid regularly due to non-arrival of the bills collector or other reasons, and the unpaid bills may increase.

2) "The meter is very good and more comfortable."

3) "The way meter works is easy and helps the customer to control the consumption."

4) "Everything new is good. People like to try. There is no NRW in the PPWM. I encourage people to install it. There is no debt. When my credit finished, I can charge my meter from ALjaleel supermarket, I have PPWM in my house now for two months and I'm happy."

5) "The idea is good. The customer knows what he consumes and has satisfaction. There is no debt accumulation. We hope that the water will be available all the time. I advise people to agree to install this service."

6) "First benefit is that PPWM helped people not to have debts. In post-paid water meter system, customer forgets to pay. The second, is that we can follow-up our usage and check our remaining credit balance. When we use PPWM, there will be a rationalization of water consumption. If you know that there is not enough credit, then you do not have to use water a lot. I advise all people in Jenin to install PPWM."

7) "I'm happy, sometimes meter reader comes and I 'm not available. It's easier now. I can charge my PPWM credit by 100NIS, 200NIS, or 500 NIS. I advise everyone to install PPWM to avoid accumulating bills."

8) "With PPWM, we avoid the problems of payment for the municipality and meter readers/collectors. It's old way and no need to readers to read meter. We are with technology."

b) Interviews in October 2020. The interviews were recorded as the part of a longer Project movie. The project movie was shown at the Project's second knowledge transfer seminar and also was shared on JM's FB for the public awareness purposes. Below is a translation of the customer's comments expressed in the project movie.

1) "My PPWM is better than my previous mechanical water meter and I highly recommend use of PPWM to all people."
2) "My PPWM is more accurate than my previous mechanical water meter. The previous one counted air and the water supply to my place is better than before."
3) "In the beginning, I was reluctant and not convinced to install a PPWM because I didn't have a background experience with it. However, after installation of PPWM in my house and experiencing the result, I realized that PPWM is convenient and easy to charge the fee. I, also, understand that using PPWM could reduce NRW and I highly recommend people to install it."
4) "I'm satisfied in which PPWM enables me to manage and monitor my consumption and what I'm exactly charged for."
5) "I'm satisfied especially that it deducts debt gradually and also currently we are getting good water supply."
6) "Customers rationalize water consumption and show some commitments toward payments."
7) "The PPWM is very good and solves many problems."
8) "It's more convenient for the customers and enable the control of water consumption."
9) "New experience and idea. It helps to reduce NRW. I recommend people to install PPWM."

9.7.3. PPWM rejection cases and taken approaches

In case of JM, the Project faced a 3.8% of rejection in the pilot areas during the pre-installation DtD visit, as shown in table below.

Table 9-6: Rejections during Pre-installation DtD visits

Pre-DtD (year)	Total Customers	Visited	Number of refusals to install
PA1 (2019)	753	753	29 (3.8%)
PA2 (2020)	625	524	15 (2.8%)
PA3 (2020)	526	526	25 (4.7%)
Total	1,803	1,803	69 (3.8%)

The number of rejections increased by the time of the installation day. As a result, the number of rejected by year 2021 reached to 6%. The reasons for the increase in percentage of rejection were:

1) Since the installation delayed sometimes, some customers who agreed to install at the pre-installation DtD visits refused to install at the installation day perhaps were influenced by other customers who rejected PPWM. Note: It is important not to delay the installation after consensus of the customers.
2) The number of rejections increased after the DtD visits because some new buildings and some people moved in the area from the other areas (even from the camp area) after the DtD visits and JM went for installation without pre-DtD and thus JM faced some additional rejections in pilot areas. Note: It is important to conduct the pre-installation DtD visits continuously and not to neglect the pre-installation DtD for the new or re-located customers.

As a soft approach solution and to tackle with the rejecting cases, the Project team and the PR staff conducted a re-visiting activity accompanied by higher level of JM management team i. e. council members to re-visit and to convince these customers to install PPWM. Although the activity is ongoing, however, it has shown a positive impact and some customers have installed PPWMs after the revisits. As of April 2021, the rejection percentage has reduced to 4% in PA1 area.

Table 9-7: Rejection after the Re-visits

Pre-DtD (year)	Total Customers (Installed)	Rejected (On Installation Day)	Rejected after Revisits	Remarks
PA1 (2021)	860 (732)	66 (8%)	38 (4%)	Remaining rejected customers were referred to JM's legal unit.
PA3 (2021)	667 (534)	40 (6%)	23 (3%)	Revisiting is on-going.
PA2 (2021)	568 (526)	24 (4%)	24 (4%)	Revisits not started yet.
Total	2,095 (1,792)	130 (6%)	47 (4%)	% of Rejecting customers are expected to be lower after completion of re-visits.

As a stricter approach, the persistent cases of customers who refuse to install PPWM are referred to the JM's legal unit for legal actions.

The main reasons for rejections in the pilot areas:
1) Existing high debt
2) Not satisfied with JM's overall services
3) There is no reason to change to PPWM (compulsory payment) when the water bill is paid on time and there is no unpaid bill.
4) Has private well
5) Potential illegal use
6) Not happy with the water supply pressure and amount

9.8. Change in attitude and culture after introduction of PPWM

9.8.1. Solved issues of regular meters system after introduction of PPWM

Table 9-8: Solved issues of regular meters system after Introduction of PPWM

Existing Issues before Introduction of PPWM		Result of Introduction of PPWM
Meter reading	WWD needed to visit customers every month for meter reading which incurred more time, money and human resources. The activity was paper-based and thus there were cases of human errors in reading the meters or handling the data. Some meters were out of the reach for readers, or difficult to read, or needed revisits due to the absence of the customers on the reading days.	· No reading activities on site for all PPWM customers. · No reading error and no input error. · All meter readings issues have been solved.
Billing and collection	Before PPWM, the WWD's collection and billing team needed to enter the meter reading data from paper into the billing system, print, and deliver the bills on a monthly basis. There were also costs related to the bill printing and issues with printers and customer database system had to be stopped during the billing printing period every month. Since it was a time-consuming activity, the bills were delivered with a month delay. The collectors were also in charge of the bill collection if customers decided to pay at the door and the collection rate was very low. Sometimes there was a danger of unhappy or aggressive customers where the readers and collectors felt a need for protection.	· No billing and collection activity on site. · Collection rate is almost 100% for customers who installed PPWM. · Collection rate is almost more than 90% in the project pilot areas because some customers still rejected PPWM. · No input data manually and bill printing is not required from now on for all PPWM customers. · Meter readings and billing data is accurate in PPWM system. · All billing and collection issues have been solved by PPWM.
Illegal connection	Monitoring for illegal connections is among the challenging issues for the WWD within its limited manpower. Illegal connections, in addition to cases of broken meters and removed meters caused inaccuracy in the water consumption data. Detections of illegal connections is not efficient within its shortage of manpower and inaccurate estimated consumption data without reading.	· Reduced the tamper cases and illegal connections after installing PPWM. · Detect the illegal connection becomes more efficient by accurate database of PPWM. PPWM system helps WWD in monitoring the consumption and detecting potential illegal connections.
Debt increase and repayment issues	Since there is no supportive national regulation for disconnection for water services in Palestine including JM, and due to the approach of JM to enforce penalty for late payment and/or long procedures if customers referred to court for debts, WWD therefore faced a very low collection rate of not only the current month's bills but also low collection rate of the due debts.	· Reduced customer's debts by deducting 10% per each charge. · For commercial customers with high unpaid bills, PPWM sets up a high debt recovery rate. · The collection of current bills of the PPWM customers increased to 100%.
Meter ownership and monitoring	The mechanical meters are owned by customers. WWD needed a system to monitor the consumption and the meters and to find damaged water meters efficiently and through data analysis thus to take more informative decisions and actions, especially if meters are owned by JM.	· JM is the PPWM owner. · JM can make continuous monitoring of PPWM including consumption and give prosecution any customer try tamper or break the PPWM. · No water supply if PPWM damaged. · Suspension of meter use is detected easily through data analysis. · Customers pay water charge according to their water consumption.

Human resources (staff)	WWD faced shortage of manpower for reading and collecting staff and the data entry of a monthly basis.	· Reduced manpower and time (No need for readers and collectors and no need to input data manually and printing bills) · With PPWM system, the manpower can be relocated to other sections and tasks which lead to more efficient use of human resources.
Collection from refugee camp	WWD faces a challenging low collection ratio from the residents of the Jenin's Camp as well.	· If PPWM is installed the collection ratio of at least current bill could be 100%. However, the installation is paused due to political reason.
Water supply condition	· Inequitable water distribution, with some customers receiving sufficient water supply while others receive no water at all · Many illegal connections are made, and these customers are not conscious of water conservation. (Water consumption may decrease with a PPWM system as customers become more aware of use of water since they must pay for their consumption, and it discourages customers from illegal consumption due to the more efficient monitoring system. As result, more water can be supplied to more customers by reduced water consumption and there will be a fairness. On the other hand, WWD needed a function to limit consumption in summer for reasonable supply of water.)	· Water consumption of some customers especially high consumption customers decreased because the customers now aware of use of water since they pay their consumption. · Water supply became more equitable that reduced water consumption is used for other customers who used to be insufficient water consumption. · WWD contracted with new water sources (Private Wells) when PPWM was introduced.

9.8.2. Changes in WWD/CSS staff functions after PPWM in JM

Table 9-9: Changes in WWD/CSS staff functions after PPWM in JM

Indicator	Before PPWM	After PPWM
Workload	Not organized which led to heavy duty works that the staff cannot finish their missions on time	Well organized which led to minimize the workload and decreased the efforts and time.
Bill collection	Need more staff and more time and the billing zone needs to be equally distributed.	Easier by vending stations and cards charges.
Staff organization	Irregular with no fixed schedule.	Improved by more follow up and reporting works
Staff experience	Not trained well and the experience was low corresponding to the difficulties which the staff faced.	Gained a lot of experience after training and dealing with PPWM and related tools and activities.
Response to customer complaints	The complaints used to take more than 10 days to respond at which caused a lot of whimpering from the customers	The response time decreased to more than 70%. The complaints can manage remotely is some case and with data remotely collected.

9.8.3. Changes in customer behavior after PPWM system

Table 9-10: Changes in customer behavior after PPWM system

Indicator	Before PPWM	After PPWM
Customer mentality	The rationality of customers was more	The customers became more aware and

	difficult, and they could not relate that paying their accumulated bills contribute to improve water services in the city.	realized that paying their debts will improve water services in the city.
PPWM acceptance	Low acceptance before DtD and awareness campaigns related to the consumptions and the benefits of PPWM.	Increased after the installation and start using the PPWM.
Water consumption	Not aware of consumption.	Aware of consumption and can control of consumption in rational way.
Ultrasonic PPWM accuracy	Post-pay meters are inaccurate due to air count.	The confidence increased with ultrasonic PPWM accuracy.
Accessibility and usage	Customers were thinking that the conventional system is easier, and they thought that the ultrasonic PPWM is advanced technology and difficult to deal with.	Easy to deal with and the accessibility is the same as the conventional system.
Bills payments	Bill payment was more difficult and need to pay in JM or by the collectors.	Easier by charging the card directly in the vending station.
Debts payments	Need to pay 1 time or by settlement in JM.	Pay 10% of each charge.

10. Survey on consideration for the socially vulnerable (social cases)

10.1. Laws and definitions on socially vulnerable persons consideration cases

Plan to collect information in PWA, Ministry of Social Affairs (MoSA) and Ministry of Local Government (MoLG) (On-going).

10.2. Case of Jenin

With the increase in the number of PPWM installations, especially during the period of financial problems on the Israeli side between April and December 2020[iv], and during the COVID-19 pandemic in Palestine, WWD received many complaints from customers about their inability to pay their water charge in advance. This necessitated the consideration of mechanisms and solutions that would enable certain socially vulnerable groups to secure water in order to guarantee their right to equitable access to water as a human right and in accordance with Palestinian law.

After installing PPWM in JM, PPWM customers are now paying their water bills in advance. While visiting households for PR, the WWD dealt with socially vulnerable consideration cases (low-income households) who had difficulty paying for water after installing PPWM. JM reported the following 24 socially vulnerable consideration cases and solutions by municipal decision. The socially vulnerable consideration cases are categorized as the following 7 types with the number of cases. Some of them are registered in MoSA but mostly these cases were evaluated by PR and CSS staff of JM.

Table 10-1: Socially vulnerable consideration cases adopted to PPWM customers

Category	Number of cases	Solution
1. Elderly woman (No breadwinner and no pensioner)	9	WWD installed the PPWM as postpaid meter (Opened valve)
2. Low income	8	WWD installed the PPWM as postpaid meter (Opened valve)
3. Disabled	2	WWD installed the PPWM as postpaid meter (Opened valve)
4. Martyr’s mother	2	WWD installed the PPWM as postpaid meter (Opened valve)
5. Martyr’s family	1	JM council decided to exemption from their debts (Martyr's family requested to remove their debts)
6. Jenin Camp	1	WWD installed the PPWM as postpaid meter (Opened valve)
7. Prisoner's Family (No breadwinner)	1	WWD installed the PPWM as postpaid meter (Opened valve)

Remarks:

1) Period between 28/08/2019 to 07/11/2020.

2) Until a solution to the socially vulnerable consideration case is found, it will be recorded as debt.

To summarize the above results, the causes of socially vulnerable consideration cases can be categorized into social, economic, political, and medical reasons, in descending order of frequency, as shown in the figure below. Then, it is considered that economic reasons are the final cause for all reasons.

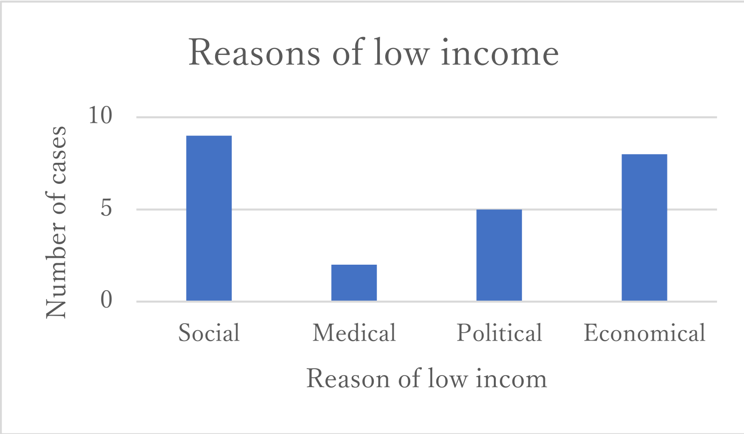


Figure 10-1 Causes of social vulnerability consideration cases (Jenin Municipality)

Social reasons mainly mean old people living alone with no breadwinner; economic reasons mean salary is not enough to cover family expenses; political reasons mainly mean refugee families in poor financial condition, and medical reasons mean people with disabilities. JM (WWD) deals with each case separately. The following three major measures are being taken.

1) Set the PPWM valve to constantly open, change to a post-paid system, and treat the water consumption as debt (to be continued until a solution is found).
2) Temporarily suspended collection of unpaid bills
3) For customers who were temporarily unable to pay their water in advance, the PPWM valve was opened only for a certain period, changed to a post-paid system. The amount of water consumed during this period was treated as debt.

10.3. Case of other water service providers

Generally, there is no clear approved policy by PWA or WSRC or existing laws to treat these cases in Palestine. Each water utility treats socially vulnerable consideration case individually.

JET and JM tried to find and set some countermeasures for socially vulnerable consideration case after conducting case study for low-income households and the ways of treatment in Palestine. In this case study, 8 water providers were visited by JICA Expert Team and JM.

The solution dealing with socially vulnerable consideration cases are categorized as following 3 cases.

Table 10-2: Main solutions for socially vulnerable consideration cases

Solution	Contents
1. By fundraising	Municipalities or water providers create a donation fund for low-income households, and they request people who have good financial situations to donate for these customers.
2. Charge by debts	Municipality charge the card for socially vulnerable consideration cases or low-income customers on PPWM software then record this charge on customer

	debts. They add it on the cumulative debt of customers until they find a way to cover this debt.
3. Technically by opening the valve temporarily	In this case, the municipality makes the meter as a postpaid meter by using technical features on PPWM software. This way is used for socially vulnerable consideration cases and sometimes for some customers who cannot charge temporarily. This approach is used in JM.

The other providers gave us the following ideas to deal with socially vulnerable consideration cases.

1. Technically by opening the valve and changing to postpaid meter temporarily
2. Fundraising by several ways
3. Make a list of the socially vulnerable consideration case and establish a fundraising for them
4. Charge by debts
5. Special tariff for the socially vulnerable consideration cases
6. Reduce water consumption (using PPWM's function of water consumption limit)
7. Cooperation with MoSA
8. MoSA should pay the water for the registered cases (as subsidy)
9. Any solution for the socially vulnerable consideration cases shall be approved by MoLG & MoSA
10. Establish rules without contradiction with the municipality policies

Table 10-3: Socially vulnerable consideration cases in other water providers

Water Provider	Average income (NIS)	If there are socially vulnerable consideration cases?				Have a study for SC?	Can you define the SC?	Characteristic of SC	How to deal with SC?	If there is policy for SC?	Cooperation with MoSA	Further ideas?
		Yes/No	Cases/ Month	Income for SC (NIS)	Reasons of cases							
1. Jenin JSC	2000	No	0	N/A	N/A	No	Registered in the MoSA	Null	null	No	No	Cooperation with MoSA
2. Maythalon JSC	2000	Yes	3	700	low income	Yes*	Registered in the MoSA	Null	Technically by opening the valve temporarily	No	No	1) Technically by opening the valve temporarily, 2) Fundraising, 3) cooperation with MoSA
3. Yabad Municipality	3000	Yes	5	700	low income	No	Registered in the MoSA	low income	By fundraising	No	Yes	1) Technically by opening the valve temporarily, 2) Fundraising, 3) Establish rules without contradiction with the municipality policies
4. Arrabeh Municipality	2200	Yes	6	700	low income	Yes*	Registered in the MoSA	low income	By fundraising	No	Yes	*4.3: Make a list of the SC & establish a fundraising for them *Other ideas: MoSA should pay the water for the registered cases
5. Nablus Municipality	2500	Yes	15	700	Physically handicapped or sick	No	Registered in the MoSA	Null	By fundraising	Yes: council decisions for special cases	No	
6. Aqraba JSC	3000	No	0			No	Registered in the MoSA	Null	null	No	No	Any solution for the SC shall be approved by MoLG & MoSA
7. Tubas JSC	2000	Yes	50	N/A	low income	No	Registered in the MoSA	Null	Charge by debts	No	No	1) Charge by debts, 2) Fundraising, 3) limit the consumption, 4) Special tariff for the SC
8. Zababdah Municipality	2500	Yes	19	700	low income/ Physically handicapped or sick	No	Registered in the MoSA	Null	By fundraising	No	No	Establish rules without contradiction with the municipality policies

10.4. Consultations with government agencies

10.4.1. Water Sector Regulatory Council: WSRC (Water Sector Regulatory Council)

The WSRC is the public body that determines water tariffs. It is a public body that can draft solutions on how to treat vulnerable cases or low-income customers. The JICA expert team and JM conducted a video conference with the head of WSRC. The following are the minutes of the meeting.

1. Addressing low-income cases is addressed in the Palestinian Water Tariff Law.
2. Policies to address special social situations and people with limited income need to be approved by a central government agency, and water utilities do not have the authority to approve special policies to handle these solutions separately.
3. Differences in tariffs need to be considered when formulating policies to deal with these special cases. This will require research and calculations for each region.
4. Free or discounted water supply is discouraged as it is seen as a waste of water.
5. Regarding the mechanism for defining vulnerability cases, WSRC advises adopting the MoSA (Ministry of Social Affairs) policy in this context.
6. Some solutions may include setting special fees outside the fee structure to cater to the poor.

Finally, the WSRC thanked JICA for its support in reviewing the draft policy on vulnerable populations cases to be approved and formalized by the government.

10.4.2. Human Rights Organizations

JLAC (Jerusalem Legal and Human Rights Center)[v] is an NGO that deals with human rights. The JICA expert team discussed with JLAC their views on the legality of PPWM and suggestions for addressing vulnerable populations cases.

(1) Legality of PPWM and reasons for rejecting the PPWM system
   a. JLAC believes that the PPWM system is not legal according to Palestinian law because it is based on wealth (In PPWM, the wealthy can use the water and the less wealthy cannot. This distinguishes between people and is against Palestinian law.).
   b. In some areas of Palestine, some water companies are using the police to force the installation of PPWM.
   c. There are water shortages in some areas.
   d. We believe that the installation of PPWM needs to be an option for all people.
(2) JLAC believes that the problem of low collection rates from customers should be solved by using other methods such as debt collection by legal authorities.
(3) JLAC said that if water utilities insist on installing PPWM, the installation procedure should be step-by-step and follow a soft approach, excluding socially vulnerable consideration cases.
(4) JLAC proposed to define socially vulnerable cases as follows.
   - People with a minimum monthly salary (1450 NIS)
   - Seriously sick person

- A family of six or more people
- Prisoners and Martyrs' Families

(5) In addition to revitalizing the role of PWA on these issues, JLAC recommends that PWA develop a national policy that takes human rights into account, provide basic services fairly to all people, and address vulnerable populations cases.

Finally, JLAC appreciated the work done in the Jenin project and the steps taken, including the soft approach, DtD visits, public meetings, selection of appropriate PPWM type (technical), and improvement of water supply prior to PPWM installation.

10.5. Recommendation to Jenin Municipality on how to deal with socially vulnerable consideration cases (Provisional)

Recommendations to JM on dealing with socially vulnerable consideration cases (Provisional) are as follows.

1) Open PPWM valves temporarily
2) Deferral of payment
3) Fundraising
    a. Referral to other agencies for financial support
    b. Develop a voluntarily donation program collected through credits by other customers or other PPWM customers
    c. Transfer of other existing donations funds to support the assistance
    d. Seek assistance from NGOs and CBOs
    e. Seek support from international donors
4) Cooperation of the city's private business owners for assistance in return of discounts in their water debt if any.
5) Provide subsidies by Municipality
6) Charging credit to the customer's PPWM and moving it to debt
7) Special tariff for the social cases
8) Limit water consumption with PPWM function

11. Issues/challenges and lessons learned

11.1. Remaining issues

(1) There are persisting rejecting customers to install PPWM although they are not many.

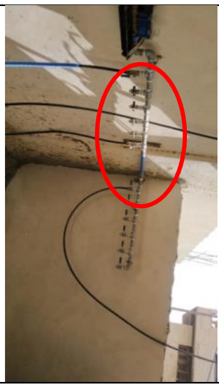
(2) Consideration on how to respond to socially vulnerable consideration cases (low-income family).

(3) Preparation for maintenance of prepaid meter after warranty period.

(4) Many illegal connections of PPWM were found (Table 11-1).

(5) There is difficulty in enforcing legal procedure for the penalty function in timely manner.

Table 11-1: Illegal connections

1	2	3	4
Illegal Connection in new House was found // they get water direct from pipe	Illegal Connection was found at residential building // he get water direct from Municipality pipe	Illegal Connection was found at residential building directly from pipe	Illegal Connection was found
Disconnected	Disconnected	Disconnected	Disconnected
			

11.2. Lessons Learned

The lesson learned from PPWM introduction in Jenin city are summarized as follow:

(1) Choose the right type of water meter and brand:
In Palestine, problems on water meters are air count, particles in water, and very low flow rate unable to be measured by water meter. Ultrasonic flow meter has solved these technical problems. Before choosing this meter type, meters experiments were done to confirm the suitability of ultrasonic meter.

(2) Support of higher management and political will:
Involvement and commitment of the Mayor and city council members were very effective in acceptance of PPWM. The WWD/JM staff work as a team and joined regular meetings on weekly basis and discussed installation issues and solutions.

(3) Value of customer awareness:
Willingness to accept introduction of PPWM and the importance of public relations role were very effective. Public awareness raising plays an important role to succeed the PPWM introduction in

Jenin city, where the activities have been organized to raise customers' awareness to convince them to install PPWM and to obtain the trust of people in the city.

(4) Focus on achieving success factors:

a) Free meter replacement for customer
b) 24/7 Good and responsive customer service
c) 24-hour water supply
d) Affordable and good quality water
e) Earn trust from customer by good communication

(5) Use of the LoRa Gateway data:

After introducing the gateway system WWD staff became able to monitor and follow up PPWMs instantaneously in addition to start studying remotely the control features. Also, by working on gateway system, WWD staff became able to solve some challenges such as PPWM without communication and obstructions of PPWM signal.

(6) Follow up with rejections:

Analysis of reasons of rejected customers and how to deal with this type of customers in addition to reduce the rejection cases.

(7) Solving of customer complaints in timely manner:

How to solve customers' complaints and take some preventive measures to reduce repeated complaints.

(8) Properly plan for installation process:

JM has gained a good experience in the installation process and how to deal with PPWMs and arrange required materials and formations which will facilitate and speed up the process for the next installation phase to provide perfect results. WWD staff also have learned to use the handheld machine and take PPWM reading and other information on site when needed.

(9) Improvement of the service:

According to the social survey, the customers are not satisfied with water supply service of JM. After obtaining the trust of customers, the acceptance of PPWM becomes easier. To obtain the trust, JM has improved their service of water supply at the time of introduction of PPWM, especially in the pilot areas at first by improving the water distribution management and contracting with private wells.

(10) Prepare for initial issues:

Initial failure of PPWM during the installation or initial use of PPWM due to malfunction or dead battery or by water entering PPWM screen in some cases.

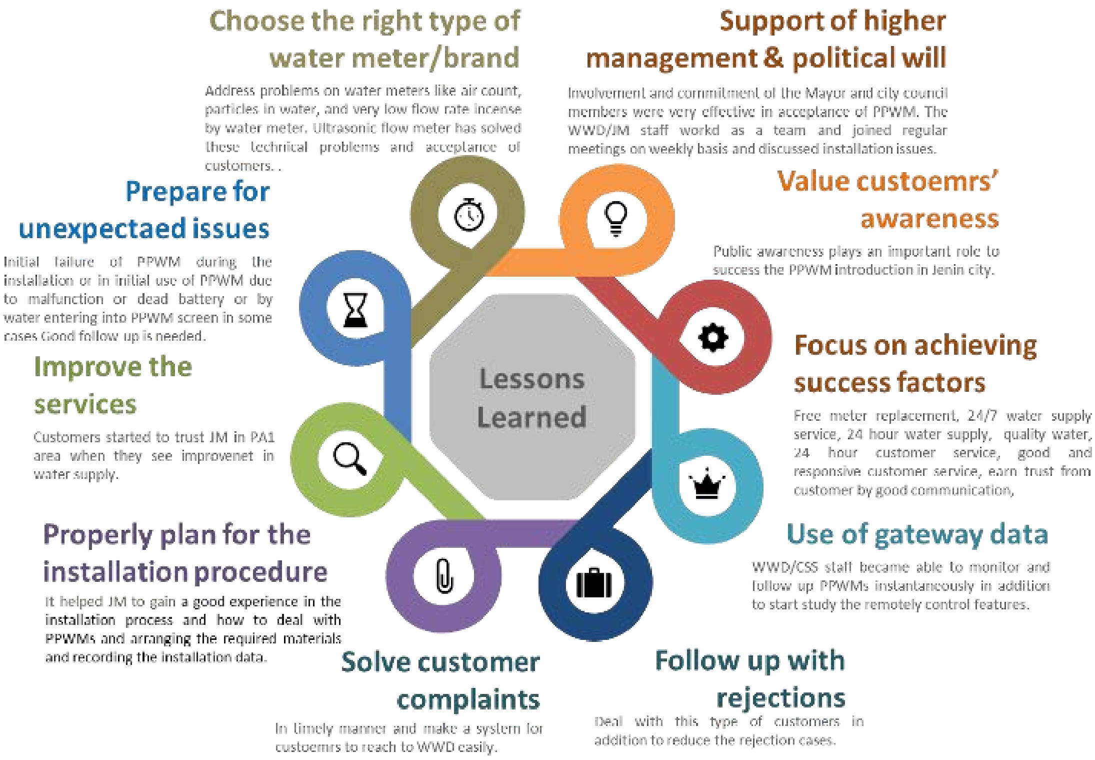


Figure 11-1: Lessons Learned from PPWM Installation in Pilot Areas

PPWM also plays a role in promoting the equitable use of water. Data analysis of individual customers before and after PPWM installation indicates that, with the introduction of PPWM, the water consumption by each customer is leveled.

It should be noted that PPWM helped in sustaining JM's water supply service in an initial hit of COVID-19 pandemic. Collection rate of postpaid meter customers was significantly affected by COVID-19 pandemic, while PPWM's customers were less affected, which contributed to sustaining water supply service.

[i] Performance Monitoring Report for the year 2016, WSRC, Palestine
[ii] Performance Monitoring Report for the year 2016, WSRC, Palestine
[iii] Strategies for Sustainable Financing of the Water Sector, Dec 2014, PWA, Palestine
[iv] Palestinian tax revenue was not paid by the Israeli side.
[v] Jerusalem Legal Aid and Human Rights Center（NGO/NPO）

Annex 2.2

Prepaid Water Meter Installation Plan for Entire City of Jenin – English Version

THE WEST BANK, PALESTINE

PALESTINIAN WATER AUTHORITY

JENIN MUNICIPALITY

Prepaid Water Meter Installation Plan

for Entire City of Jenin

SEPTEMBER 2022

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Abbreviation:

CSS: Customer service section
CU: Collection Unit
CDS: Customer Database Survey
GIS: Geographic Information System
JET: JICA Expert team
JM: Jenin Municipality
JSC-JWV: Joint Service Council Jenin Western Villages
MoLG: Ministry of Local Government
MoSA: Ministry of Social Affair
PA: Pilot Area
PA1: Pilot Area 1
PA2: Pilot Area 2
PA3: Pilot Area 3
PR: Public Relation Department
CSC: Citizen Service Center
PPWM: Prepaid water meter
PSI: Palestine Standards Institution
WS: Water Section
WSRC: Water Sector Regulatory Council
WWD: Water and Wastewater Department

CHAPTER 1 PPWM in Pilot Project Areas and Lessons Learned

1.1 Introduction

1.1.1 Description of Water supply and Customers Meters Situations in Jenin City

Jenin Municipality located in the northern part of the West Bank, Jenin Municipality provides an average of 10,000 m3/day of water to the population of 60,000, or about 9,500 households. The water and wastewater department consist of about 60 employees of the Jenin Municipality, who are responsible for the water supply service.

Jenin Municipality produces the water from its own wells (Al Saadeh, Al Mechanic, and Balama wells), some water is purchased from private wells within the Municipal boundary (Farathy, Alwaneh, and Muamar Jarrar, Alsa'di, Abu Sameer, and Abu Hatab wells), and some water is imported from outside (from Mekrot company via Al Jalameh connection and Al Swetat connection) and from West Bank Water Department (WBWD) via Abo Arraba connection. Main water supply facilities include wells, pumping stations, transmission mains, reservoirs, tanks, distribution mains, and booster pumping stations. These are shown in following figure.

The supply system is intermittent and cyclical. The cyclical does not cover the whole week. So supply days are not always the same day of the week but are variable. Consequently, most areas receive water once or twice a week for periods ranging from one to two days in the summer. In the winter season, the supply time becomes longer as the demand for water decreases. In addition, some people use rain water for drinking purposes. The water supply is controlled by manually closing and opening the valves by Water and Wastewater Department (WWD).

1.1.2 Reason to Replace Water Meters in Jenin

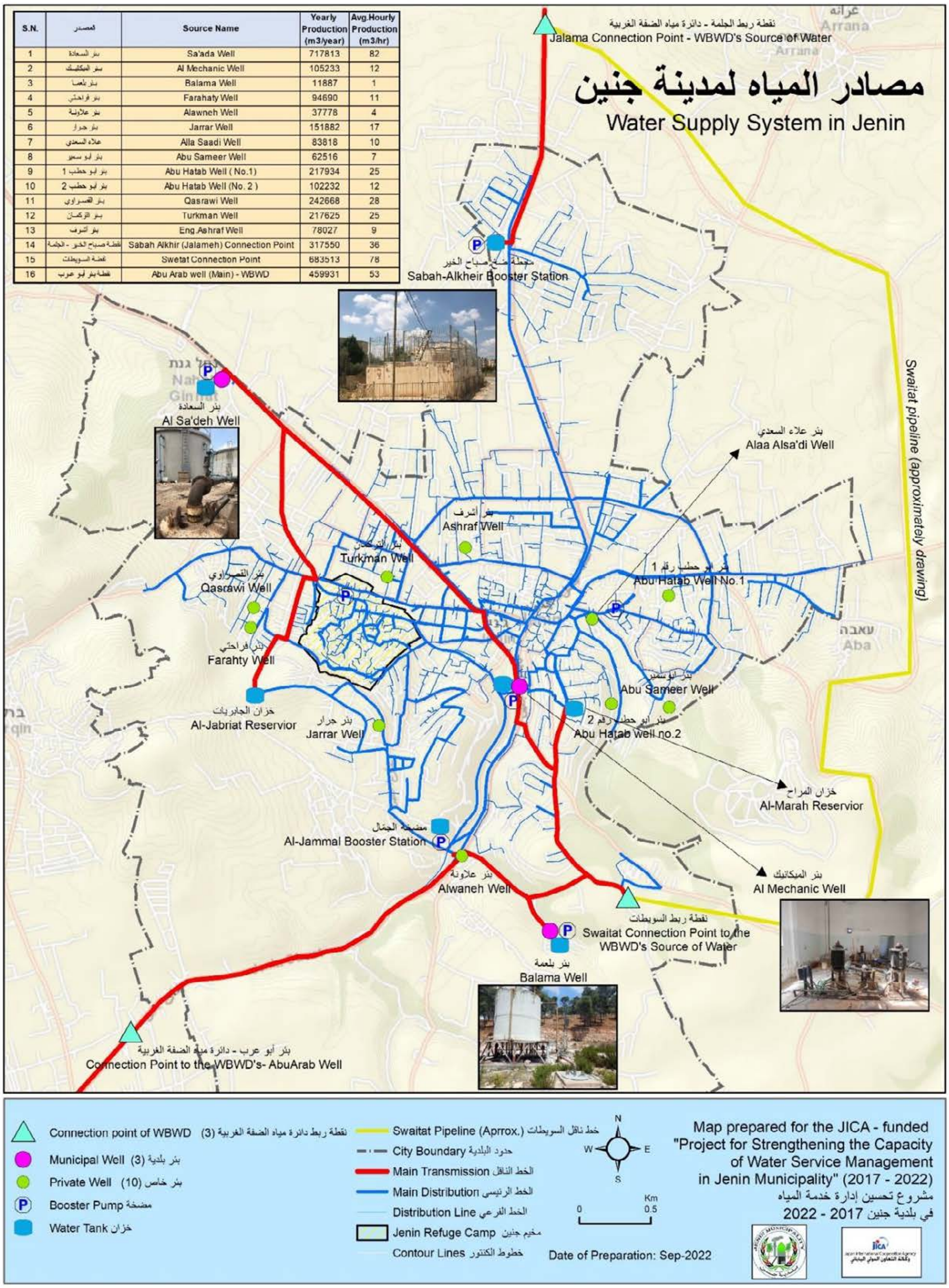
Jenin Municipality faces a high ratio of NRW. One of the reasons for high NRW in Jenin Municipality is aging of meters, where the percentage of meters older than 10 years is more than 50%, in addition to other reasons such as the leakage, the difficult to conduct an accurate meter reading in some areas and illegal connections. Based on that, replacement of current meters plays an important role to reduce NRW.

1.1.3 Reason to Replace Water Meters in Jenin with PPWM

In addition to the high NRW, other challenge of Jenin Municipality is a low collection ratio. There are many reasons for the low collection ratio as follow:

a) No policy for disconnection of service
b) Long legal procedures for JM to process unpaid debts/debtors at court
c) No-payment culture
d) Issues with meter ownership
e) Issues with meter reading/collection

   i. Time consuming reading and collecting
   ii. Expelling readers/collectors
   iii. Difficult access
   iv. Absent customers
   v. Many estimated readings



S.N.	المصدر	Source Name	Yearly Production (m3/year)	Avg.Hourly Production (m3/hr)
1	بئر السعادة	Sa'ada Well	717813	82
2	بئر الميكانيك	Al Mechanic Well	105233	12
3	بئر بلعمة	Balama Well	11887	1
4	بئر فراحتي	Farahaty Well	94690	11
5	بئر علاونة	Alawneh Well	37778	4
6	بئر جرار	Jarrar Well	151882	17
7	علاء السعدي	Alla Saadi Well	83818	10
8	بئر ابو سمير	Abu Sameer Well	62516	7
9	بئر ابو حطب 1	Abu Hatab Well (No.1)	217934	25
10	بئر ابو حطب 2	Abu Hatab Well (No. 2)	102232	12
11	بئر القصراوي	Qasrawi Well	242668	28
12	بئر التركمان	Turkman Well	217625	25
13	بئر اشرف	Eng.Ashraf Well	78027	9
14	نقطة صباح الخير - الجلمة	Sabah Alkhir (Jalameh) Connection Point	317550	36
15	نقطة السويطات	Swetat Connection Point	683513	78
16	نقطة بئر ابو عرب	Abu Arab well (Main) - WBWD	459931	53

Figure 1-1: Water Supply Map of Jenin
Source: JICA Expert Team

1.1.4 Purpose of Prepaid Water Meter Introduction

The main purposes of introduction of PPWM are as follows:

1. To achieve fair water supply by rationalizing water consumption
2. To improve water supply service by changing billing and payment system
3. To achieve people's equity for water supply service by achieving all customers to pay for water supply service they received.
4. To increase revenue of water supply service to improve water supply service and maintain good service for the customers by increasing bill collection and recovering debt.

1.2 Jenin Municipality's Experience with PPWM in Pilot Areas

The project initially targeted three pilot areas (PA-1, PA-2 and PA3) starting from February of 2019 with installation of 1,850 PPWMs funded by JICA. Jenin Municipality also funded some additional PPWM installations. The number of installations increased to a total of over 3,000 PPWMs by April 2021 including installation in some extended areas outside of PA funded by Jenin Municipality.

After successful implementation and installation of PPWM in the three pilot areas and in outside of the pilot areas, the Jenin Municipality has decided to extend the installation to continue with the PPWM installation for the entire city based on the experience gained from the PA areas and lessons learned.

1.2.1 General Procedure of PPWM Introduction in Pilot Areas

PPWM was introduced in the pilot areas through the followings:

1. Baseline survey for existing metering, billing, and collection system
2. Case study for PPWM introduction in other utilities in Palestine
3. Social survey of PPWM (pre-survey)
4. Sustainability and strategy report on PPWM (Feasibility study (F/S))
5. Preparation of implementation plan of PPWM introduction
    a) Strategy of introduction of PPWM (Selection of Pilot Areas)
    b) Improvement of water supply conditions
    c) Set up PPWM system
    d) Operation and maintenance plan
    e) Customer service plan
    f) Public awareness plan
    g) Training plan
    h) Implementation plan
6. Preparation of a check list for required decision to introduce PPWM
7. Procurement of PPWM
8. Installation of PPWM
9. Setting and implementation of operation and maintenance and customer service of PPWM
10. Setting of responsibilities and workflow of PPWM Installation and Operation
11. Post survey (Satisfaction survey)

1.2.2 Extensive Public Awareness Activities

Public awareness and informed customers play important role in acceptance of PPWM by customers. As for the pilot project period, there were extensive public awareness activities such as use of social media, distribution of flyers, installation of large project billboards, neighborhood meetings, give away items, etc. However, the major activity was to conduct door to door visits of every customers in the Project's pilot areas ahead of the installation time (between 2 weeks to 1 week before installation). At the pre-installation door to door visits (DtD), the team explained all details about the Project, and the reasons the customers should be installing PPWM and how they would benefit. The team also provided detailed instructions on how to use a PPWM and how/where to charge their PPWM cards. A 12 pages booklet was also prepared and delivered at the time of the visits. Though the rejection rate was low in pilot areas, majority were agreed to let the installation team to install PPWM when the team arrived on the installation day.

Method of DtD visit: The involved staff included two staff from the Public Relations Department for the DtD visits and filling out the forms. GIS bases maps were also prepared for marking of the location of the selected customers. The survey also included data entry of the responses on excel files. Additional customer data such as house ID, name and phone numbers were also collected. The data was utilized for installation tasks and also to measure customer satisfaction.

To measure the customer's satisfaction after using their PPWM, the JM's PR staff revisited a random 10% of the customers with PPWM after 1 to 2 months of usage and conducted a questionnaire to make sure the customers are satisfied and face no issues.

1.2.3 Acceptance and Rejections of PPWM

1) Acceptance of PPWM
The acceptance of PPWM in the pilot area was high and majority of customers agreed to install. The main reasons of the acceptance can be summarized as bellow:

1) Type of the selected PPWM: it doesn't count air and is accurate.
2) With PPWM, customer can monitor their consumptions.
3) The PPWM system helps customer to avoid accumulation of water debt, and/or pay their debt gradually, if any.
4) Easy payments can be done at a supermarket in the neighborhood or at other locations throughout the city.
5) No readers and collector monthly visits
6) Improvement in receiving and processing customer complaints
7) Well informed and educated customers. In cooperation of PR and CSS staff, extensive public awareness activities played an effective role in acceptance of the customers such as:
    a) Production and distribution of public awareness materials
    b) Use of social media
    c) Neighborhood meetings
    d) Production and distribution of movies on social media to share PPWM customers and their experience with the others
    e) Door to Door visits (DtD) before installation: at the time of DtD visits, the team ensured that every customer understands the followings:
        i. benefits of PPWM for customers and for the city and the municipality
        ii. reason of selection of the PP Ultrasonic PPWM by JM and the benefits such as not elimination of counting air which was an issue with existing meters.
        iii. PPWM installation plan in terms of the days and time of installation in their neighborhood
        iv. how their PPWM works, how to use the PPWM, where to charge their PPWM cards and how to pay, complaint system, etc. The same information was also provided in format of a 12-page booklet with Q/As, maps, vending station location, manual of how to use the PPWM with step-b step photos, etc.

2) Rejection of PPWM

Since rejection is a major issue in PPWM acceptance in general, in case of Jenin City's pilot project there have been number of rejections as well that needed to be addressed. The percentage of rejected customers was 3.8% at the time of pre-installation DtD visits and increased slightly by the time of installation day. The overall reasons for rejection were:

1) Customer has private wells and thus no need to install PPWM,
2) Customer has general unhappiness and no trust with overall services of JM such as water pressure and supply,

3) Hidden reasons to refuse PPWM installation such as high debt or illegal usage.

The following steps were taken for the refusing customers:

1) First re-visit by the PR staff to convince the customer and hear him out.
2) Second re-visit in company of higher management member of JM such as council members.
3) If the rejection persisted, they were referred to the legal unit of JM.

1.3 Lessons Learned from PPWM Installations in Pilot Areas

The lesson learned from PPWM introduction in Jenin city are summarized as follow:

(1) Choose the right type of water meter and brand: In Palestine, problems on water meters are air count, particles in water, and very low flow rate incense by water meter. Ultrasonic flow meter has solved these technical problems. But before choosing this meter type, meters experiments were done as we mentioned before in this study.

(2) Support of higher management and political will: Involvement and commitment of the Mayor and city council members were very effective in acceptance of PPWM. The WWD/JM staff work as a team and joined regular meetings on weekly basis and discussed installation issues and solutions.

(3) Value of customer awareness: Willingness to accept introduction of PPWM and the importance of public relations role were very effective. Public awareness raising plays an important role to success the PPWM introduction in Jenin city, where the activities have been organized to raise customers' awareness to convince them to install PPWM and to obtain the trust of people in the city.

(4) Focus on achieving success factors:
   a) Free meter replacement cost for customer
   b) 24/7 water supply service
   c) 24 hour water supply
   d) Affordable quality water
   e) 24 hour customer service
   f) Good and responsive customer service
   g) Earn trust from customer by good communication

(5) Use of the LoRA Gateway data: After introduce the gateway system WWD staff became able to monitor and follow up PPWMs instantaneously in addition to start study the remotely control features. Also, by working on gateway system, WWD staff became able to solve some challenges such as uncovered PPWMs and obstructions of PPWM signal.

(6) Follow up with rejections: Analysis of reasons of rejected customers and how to deal with this type of customers in addition to reduce the rejection cases.

Figure 1-2: Lessons Learned from PPWM Installation in Pilot Areas

(7) Solving of customer complains in timely manner: How to solve customers' complaints and take some preventive measures to reduce the repeated complaints.
(8) Properly plan for installation process: JM has gained a good experience in the installation process and how to deal with PPWMs and arranging the required materials and formations which will facilitate and speed up the process for the next installation phase to provide perfect results. WWD staff also have learned to use the handheld machine and take PPWM reading and other information on site when needed.
(9) Improvement of the service: According to the social survey, the customers do not satisfy with water supply service of Jenin Municipality. After obtains the trust of customers, the acceptance of PPWM becomes easier. To obtain the trust, Jenin municipality have improved their service of water supply at the time of introduction of PPWM, especially in the pilot areas at first by improving the water distribution management and contracting with private wells.
(10) Prepare for initial issues: Initial failure of PPWM during the installation or in initial use of PPWM due to malfunction or dead battery or by water entering PPWM screen in some cases.

1.4 Risks to Consider in Social, Technical, and Political Sustainability

(1) Social sustainability

It may be at risk due to the followings and must be well considered to avoid the risk or to lower the risk as much as possible.

- Rejecting customers: the PA area's experience showed that there are different reasons for customer to reject as follow:
  i. High debt (customer may try to hide this reason but JM should examine their debt and discuss the matter and provide some solutions for customer's re-payment plan)
  ii. Illegal connection (JM should investigate such suspicious cases)
  iii. Not satisfied with JM's overall services,
  iv. No reason to use pre-paid system when they pay on time and have no debt,
  v. Use their own private wells,
  vi. Not happy with the water supply pressure and amount
- Low-income families would affect by prepaid system. There should be plans prepared how to deal with these customers. (This case is still under study in order to formulate a strategy for dealing with such cases).
- Emergency situation like COVID- 19 lockdown: Jenin Municipality must be prepared how to react with the most proper actions with dealing with emergency situations.

As a soft approach solution and to tackle with the rejecting cases, the Project team and the PR staff conduct re-visiting activity with higher level of JM staff i.e. council members to accompany the PR staff, and to talk to convince the rejecting customers to install. The JM team should convince the rejecting customers how they would benefit from PPWM. With PPWM, the customers would expect improvement in the JM's water services and would be disappointed if no tangible improvements follow with their advance payment system and this could socially disturb the success of JM in its PPWM system.

Recommendations for social consideration

a) Customer's satisfaction on water supply (water availability and service) should be improved together with introduction of PPWM, which eases acceptance of PPWM.
b) Conduct public awareness and involvement activities before and after PPWM system for better understanding of the public.
c) Priority of installation is required, such as avoiding the area with low water availability and refugee camp.
d) The affordability of the advance payment for low-income families must be considered.

(2) Technical sustainability

The followings should be considered to avoid risks of any issues with technical sustainability:

- Proper storage of the stocked PPWMs and avoid installing any PPWM with factory issues and/or unsealed boxes.
- Proper plan for the operational setup: ensure quick response to customer complaints after installation,

monitor for any mis-functioned installed PPWMs, manage the PPWM database and the LoRa Gateway database systems, manage the vending stations and programs.

- Maintenance and monitor of the PPWMs, batteries, spare parts: assign well trained and experienced staff on the installation team and ensure the new staff members are well trained by the experienced senior team members.

(3) Political will and support

It is very significant that the installation activities are supported by the higher level of management like the City Mayor and the City Council Members are engaged with the installation project and provide advice and back up the team in difficult situations i.e. rejecting customers, any political unrest that may affect the installation, creating trust between customers and Jenin Municipality.

CHAPTER 2 PPWM for Entire City

2.1 Existing PPWMs

The PPWM system was tendered in 2018 according to PWA specifications and two companies were submitted for the tender (BAYLAN and Electro-med). After the evaluation, the tender was awarded to BYLAN brand for their agent in Palestine Fury Trade Company. The procurements of PPWM started in Feb 2019. The following set of PPWM system has been procured by JICA and JM.

Table 2-1: Number and Specifications of the existing PPWM System in Jenin

No.	Items and Specifications	Quantity procured by JICA	Quantity procured by JM
1	Prepaid water meter (DN20), PN16bar, Ultrasonic type	1,850	1500
2	Check valves DN (20mm), PN 16bar	1,850	1500
3	Ball valves DN (20 mm), PN 16bar	3,700	3000
4	Rigid plastic case for installing PPWM, valves, fittings	1,850	1500
5	Complete vending station with hardware equipment and software	4	8 (Only card reader and license)
7	Server management software and hardware	1	0
8	Installation including commissioning for Server management	1	0
9	Handheld Unit (field verifier)	3	0
10	Gateway	3	0

2.2 Procurement of Additional PPWM for Entire City

Jenin Municipality decided to install PPWM for the entire city. JICA procures additional 4,350 PPWMs to support the Municipality's installation projects. It is planned that the procured 4,350 PPWMs will arrive to Jenin in July 2021.

Since the PPWM system, like the server and the software and integration is already in place, the Jenin Municipality would need to increase the number of the system's vending stations and gateway devices as the number of the installed PPWMs increases.

Table 2-2: Number and Specifications of New PPWM System in Jenin

No.	Items and Specifications	Quantity procured by JICA	Quantity procured by JM
1	Prepaid water meter (DN20), PN16bar, Ultrasonic type	4,350	2500
2	Light Industrial and Commercial DN (50), PN 16 bar, Ultrasonic type	0	5
3	Check valves DN (20mm), PN 16bar	4,350	2500
4	Ball valves DN (20 mm), PN 16bar	8700	5000
5	Check valves DN (50mm), PN 16bar	0	5
6	Ball valves DN (50 mm), PN 16bar	0	10
7	Rigid plastic case for installing PPWM, valves, fittings	4,350	1000
8	Complete vending station with hardware equipment and software	0	8 (Only card reader and license)
9	Server management software and hardware	0	0
1	Installation including commissioning for Server management	0	0
1	Handheld Unit (field verifier)	0	0
1	Gateway	0	5

2.3 Features of the PPWM System

The product features remain the same as the features of the PPWM in the Pilot Areas.

2.3.1 Features of PPWM Device

The following table shows specifications of the PPWM that Jenin Municipality has already installed in for over 3,000 customers and will continue to install the same for the entire city (as of April 2021).

Table 2-3: Specifications of Installed PPWM

Brand	BYLAN	Product life/actual Life	7 yrs /not Specified
Type	Ultrasonic	Battery life/actual	10 yrs /not Specified
Diameter	3/4 inch (ND20mm	Vending method	Smart card
Q1(minimum flow)	≤ 0.016 m3/h.	Guarantee period	3 yrs
Q3 (permanent flow)	2.5 ~ 4.0 m3/h	LoRA Gateway	Yes
Integration status	With AlShamel (WWD)	Integration status	With AlShamel (FD)
PPWM functions	✓ Realtime clock ✓ Remaining credit ✓ Reserve for emergency ✓ Low credit alarm ✓ Tariff setting ✓ Debt recovery ✓ Consumption limit		
After sales service	✓ Software support 24/7- 5 yrs ✓ Technical support 24/7 – 5yrs ✓ Onsite support on request – 5yrs		

The PPWM device includes the user interface for the loading of credit and other data. The PPWM device must be securely mounted to prevent tamper.

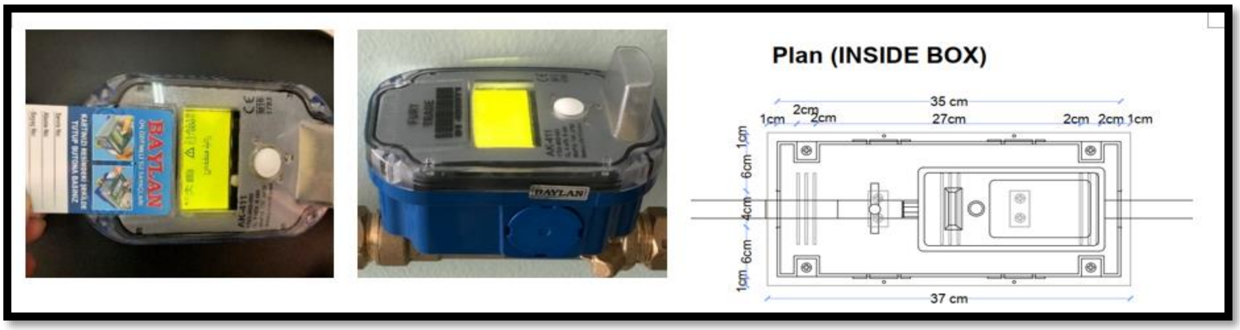


Figure 2-1: PPWM with Charging Card

2.3.2 PPWM Box

PPWM plastic box: For protection purpose the PPWM shall install inside the box. PPWMs are installed in a plastic box as shown in the photo, plastic box is more flexible than the metal box, in addition to that, metal box may affect on signal between PPWM and gateway system. The plastic boxes should be sealed to prevent customers to tamper the meter.

Figure 2-2: Sample of PPWM Box

2.3.3 PPWM Smart Card and Vending Station

Each PPWM customer is provided by a registered PPWM smart card from WWD in which they should use to charge the credits at a vending station to be able to use their PPWMs.

Vending stations shall be established at accessible points for customers' convenience for extended hours. A vending station per 1,000 customers is suggested by the supplier. The equipment necessary for vending station are PC system including software, the device for charging credit, etc., and one staff shall be deployed at these stations at the Jenin Municipality. No staff is needed if the vending stations are located at supermarkets. Convenient and hassle-free payment methods; properly located charge centers (vending stations) with extended service hours. The software will be used on a standard computer with an attached card reader.

There are currently 12 vending stations (as of April 2021) in which two (2) are installed at the Jenin Municipality's collection centers and one (1) at the WWD. The remaining nine (9) authorized VSs are distributed through the city to serve the current PPWM customers, mainly at chosen neighborhood supermarkets. As the number of PPWM customers increases, the number of VSs should also increase.

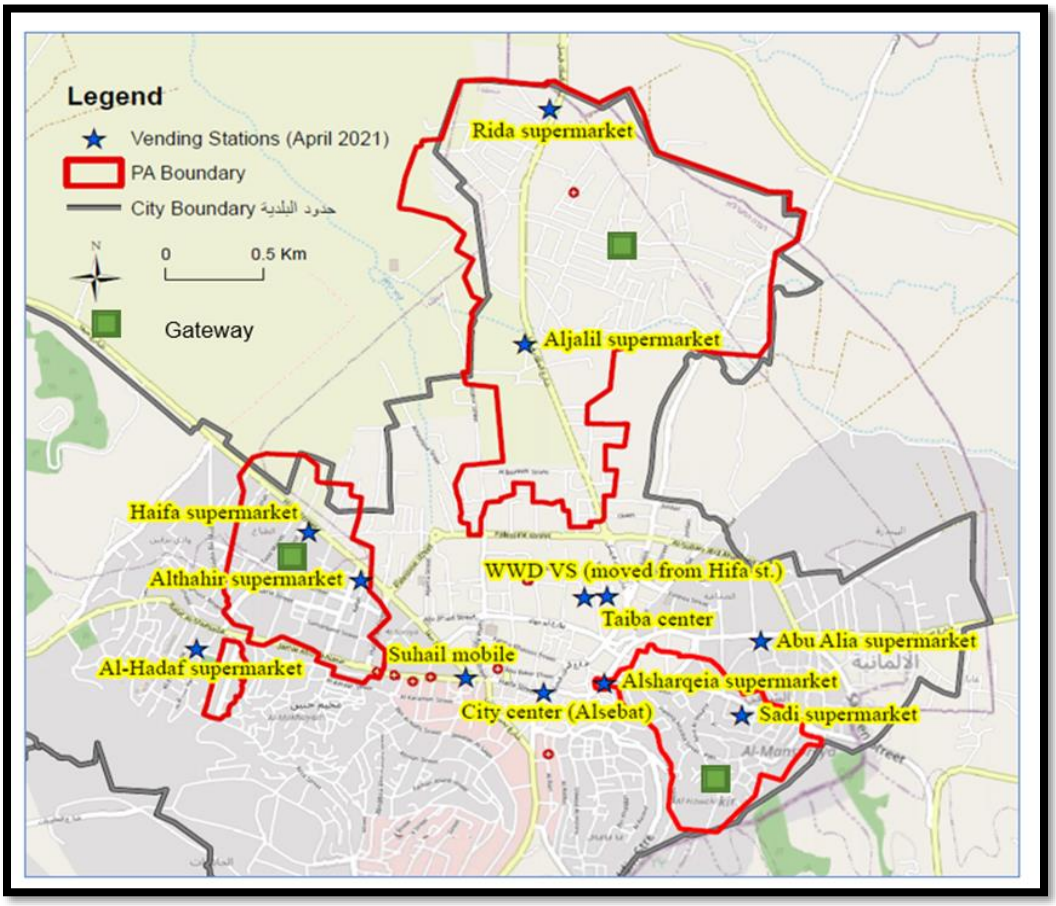


Figure 2-3: PPWM vending stations and gateways in Jenin City (as of April 2022)

The customers can purchase credits for their water use at the following places. The places will extend as the number of customers increase over time.

1) At authorized vendors

Currently, the Pal-Pay company is outsourced for card charging services and bill payments to facilitate the management of charging the PPWM cards by customers at the authorized supermarkets. The PPWM vendor is chosen by Jenin Municipality based on the pre-existing condition of the internet availability, a computer, personal smartphone, computer and communication skills, popularity and safety of the place, convenient location, and long opening hours. PalPay is responsible to transfer the collected amount to the JM by bank transfer.

2) At the Jenin Municipality's two collection centers: in city center and at the Haifa street collection center

These centers are conveniently located for customers to visit to charge their cards as they are in the area for shopping or for business. A permanent staff of the JM is available at the collection center with access to the PPWM software and printer with limited authorization. The staff is also authorized to view up to past 12 months of customer's transaction history and print as requested by the customer at the center. These centers have been rehabilitated for the purpose of providing a more welcoming atmosphere for customers. New wall and floor tiling, painting, and refurnishing, and improved internet and phone connections are some of the major rehabilitations at the centers.



Figure 2-4: Sample of Vending station

Currently there are additional 37 points of sale for mechanical meter customers to pay their bills. As the PPWM installation increases, the appropriate points of sale can also be equipped with PPWM card readers and thus provide services to PPWM customers and VS location.

Table 2-4: Current PPWM VS Locations

No.	VS	Location
1	Aljalil supermarket	PA1
2	AlThahir supermaket	PA2
3	Al-Madina supermarket	PA3
4	Haifa st. center's VS (Transferred to WWD)	WWD building.
5	City center's VS	City center
6	Taiba center (New)	Naser Street
7	Alsadi supermarket (New)	PA3
8	Suhail Mobile (New)	City center
9	Rida supermarket (New)	PA1
10	Abu Alia supermarket	PA3
11	Alhadaf supermarket (New)	Alhadaf
12	Haifa supermarket (New)	PA2

Table 2-5: Current Point of Sales for Mechanical Meter Customers

Location	Store	Location	Store	Location	Store
Enab	Supermarket	Alsereesi	Supermarket	Almashreq	Mobile
Abu Zahiw	Supermarket	Wifi	Mobile	Altayeh	Supermarket
Alnaseem	Supermarket	Eathar	Supermarket	Abu Aleel	Mobile
Abo Zahiw	Supermarket	Osama	Supermarket	Alhilal	Mobil
Mays Alreem	Supermarket	Abo Obeid	Supermarket	Alfayed	Supermarket
Almadeena	Supermarket	Aljammal	Supermarket	Alsnabel	Supermarket
Paltik	Mobile	Alsayeh	Supermarket	Royal	Supermarket
Almazar	Supermarket	Alhadeel	Supermarket	Abo Ammar	Supermarket
Abo Sroor	Supermarket	Orbit	Mobile	Safe Side	Supermarket
Diana	Supermarket	Albhaa	Mobile	Haifa	Supermarket
Almajd	Supermarket	Balawi	Supermarket	Althaher	Supermarket
Daily	Supermarket	Alaela	Supermarket		
Althaher	Supermarket	Alaela	Supermarket		

2.3.4 Handheld Unit

Handheld unit: Handheld unit allows to access water meter via authority card directly to read data. Handheld unit allows read tokens, create special purpose cards including time, authorization, maintenance, open, close, control (Info)...etc.

Figure 2-5: Handheld Unit

2.3.5 PPWM Software

The PPWM software is used at the Customer Service Section (CSS) of the WWD. The CSS uses the software to register the new customer data in advance and ensures that the data is correct before the customer charges his first PPWM. Also, the CSS staff identifies the meter and its card under the specific names of customers. Hence the meter will be ready to charge directly after the installation. The software is utilized to change of the status of the customer on Al-Shamel software as PPWM user. The result of this modification is to cancel issuing the bills and removal of the PPWM customers from the meter reader list during their ordinary site work to read the postpaid meters. The software is also used for issuing any required reports from the PPWM software or Al-Shamel upon request. The other use is to help resolving customer complaints if there is any issue with customer information and data.

2.3.6 Integration with Al-Shamel

The PPWM is integrated with both of the Al-Shamel's customer management System at the WWD and the Al-Shamel's financial and accounting system at the Financial Department. Once the customer's status changes from a regular meter customer to a PPWM customer, the changes and all the related information is updated on the Al-Shamel's customer management database. As on the accounting software, the PPWM data such as credits is continuously transferred from the PPWM system. The following are purposes / benefits of integration:

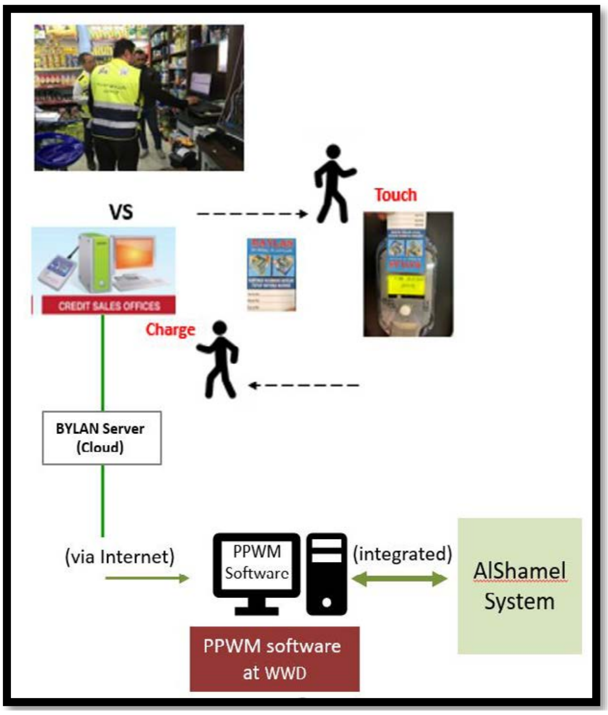


Figure 2-6: Vending Stations and Integration of PPWM Software with AlShamel

(1) Speed up accounting, save manual entry time, cost, human errors, miss typing, and additional employees or employees time. Without integration, daily all the charging records of PPWM transaction should be entered manually to accounting and financial software (Al-Shamel).

(2) Illegal transaction /Security (No frauds /misuse of money protect data from change or being copied or viewed by un-authorized persons). It prevents any illegal use of PPWM charging money.

(3) Guarantee financial transactions of all sources are entered to the financial system and get real treasury and bank balances.

(4) Get real time financial transactions.

2.3.7 LoRa Gateway System

To facilitate and strengthen the monitoring process of PPWM, the LoRA Gateway system is in use. The system allows to admin full monitoring of PPWM remotely, preparing reports and to give the technical orders as needed. LoRa gateways devices receive data from PPWMs (via low range radio frequency) and transfer them to the LoRa server. The monitoring software at WWD can view the data from the LoRa server via internet. The data is specially very helpful in monitoring consumption of the PPWM customers and control of closing or opening of the valves -when needed- and also monitor for any abnormal consumptions and pinpointing of any mis-functioning or mis-used PPWMs. The following figure shows the overall system layout of PPWM and gateway system.

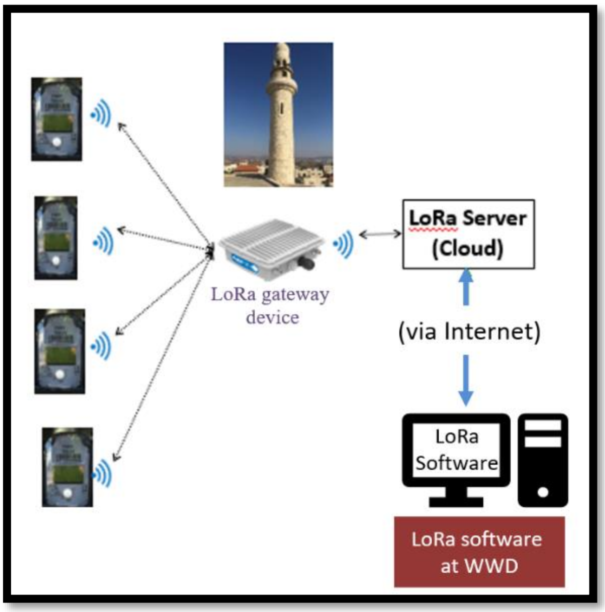


Figure 2-7: LoRa Gateway System

There are currently 3 gateway Lora system collectors for the existing installed PPWMs. There will be additional 6 additional gateway collectors that JICA will procure for the upcoming procured PPWM installations. Out of the 6, some will be installed as rewired and the remaining gateway collectors can be used as back up collectors (spare collectors) in case of failure of a collector.

2.4 Overall Specifications of PPWM System

(1) The PPWM device**:** The required specification of **ultrasonic PPWM** is shown below considering the availability of PPWM in Palestine.
  a) Diameter: 3/4 inch (ND20mm)
  b) Q3 (permanent flow) =2.5 ~ 4.0 m3/h and Q1 (minimum flow) ≤ 0.016 m3/h.

(2) Vending station: hardware equipment and software. It includes PC, and LCD Screen, printer, card (tag) reader, stand by card (tag) reader unit and UPS, On-line software, router, etc.

(3) Software and server: BAYLAN PPWM software, Server management software and hardware server is suitable for the application required. It also includes a suitable UPS, On-line software, router, etc.

(4) Technical specifications: HPE computer with 8 core processor32 GB memory1 TB hard disk including license for Windows &SQL 2016 standard license for 8core & Unlimited Cals.

(5) Handheld unit: Model: Symbol, Workabout pro4, Platform: PXA270 624 MHz Processor 1 GB Flash ROM, 256 MB RAM, Operating System: Microsoft Windows CE 5.

(6) Device boxes
  Gateway: Box shall be enough capacity for storing Gateway device with the antenna in this box.
  Box decided to be metal.
  PWM device: Box shall be strong enough for installing at outdoor site.

(7) Gateway system as seen below.

Table 2-6: Specification of the LoRA Gateway

Specifications and standards	
Communication	LoRa WAN 1.0 and 1.01 Compliant
Antenna Connectors	“N” type RJ-45 for female POE
Max Transmitter Power Output	27 dB
External LoRa Antenna	3.0 dB additional gain
External H5 or LTE Antenna	2.15 dB additional gain
PoE Splitter (Inside IP67 enclosure)	48 Volt PoE at 25 Watts

Operating temperature	-40 to +70 cent degrees
Storage temperature	-40 to +85 cent degrees
Accessories	Lightning arrestor, outdoor cable, antenna, etc. necessary for operation shall be included in.
Model	Ethernet m-Linux programable

CHAPTER 3 Implementation Plan for Entire City

Implementation of the PPWM installation is based on the experience of the installation in the pilot areas. The installation will be for all customers. The Jenin Municipality will decide whether to install PPWM in the refugee camp and for the governmental institutions. At the time of preparation of this document there is no plan to install PPWMs of these groups of customers.

3.1 Strategy in Introduction of PPWM for Entire City

A general strategy to introduce and install PPWM is prepared below based on the opinions of the Counterparts in JM.

Table 3-1: Strategy Adopted for PPWM Introduction and Installation

Items	Strategy
1. Main success factors	To increase customer satisfaction and increase acceptance of PPWM
2. Policy for introduction	To prepare introduction policy to reduce risk and succeed in PPWM
3. Awareness raising	To increase of awareness of water supply service of JM and PPWM
4. Technical	To strengthen technical capacity to back up introduction of PPWM
5. Water tariff and debt recovery	To give financial motivation to participate in PPWM
6. Customer service	To strengthen capacity to manage PPWM system and improve customer service

Following are the components of the strategy for success of PPWM introduction. There are 3 main strategies, in which several components of the strategies are composed. The success probability of PPWM introduction will be increased by implement this strategy.

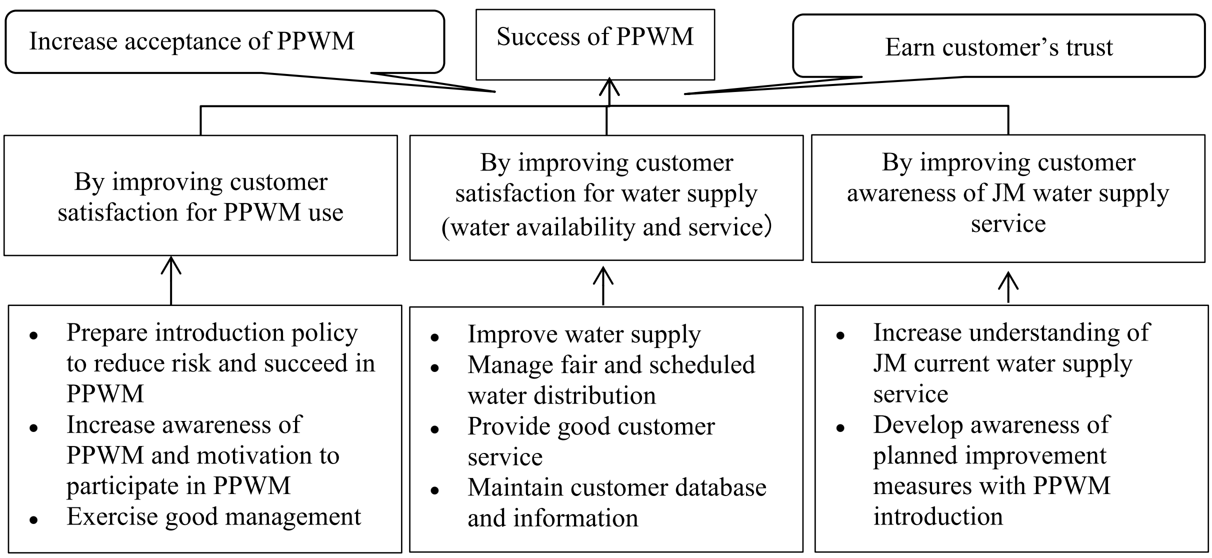


Figure 3-1: Strategy of Introduction of PPWM for Success

3.2 Role of the Involved Departments and Sections

Installation of PPWM for entire city is a teamwork and involves several departments and sections. Although some departments may play smaller roles, they have important impact of success of the project.

Table below shows the related department at Jenin Municipality in which play different roles by providing specific services. The Water and Wastewater Department (WWD) plays the most role in execution of the project by involvement of mainly its Customer Service Section with assistance of the Water Section, the GIS unit and the PR department of JM.

Table 3-2: Organizations Involved in PPWM Implementation

Organization	Major involvement
Water and Wastewater Department	Customer Service Section, Water Section, Studies and Planning Section Warehouse
Public Relation Department	Public awareness and door to door visits
IT Department	Technical issues with PPWM software and servers, VS
Financial Department	Customer payments database, financial reports
Public Citizen Center	Service applications on DMAS system
Legal Unit	Process for illegal users, enforce penalties
Human Resources Department	Hire of new staff if needed
City Council	Provide support for the team when needed
Mayor's office	Provide support for the team when needed

Figure below describe the workflow of the CSS and involvement of the other sections and departments.

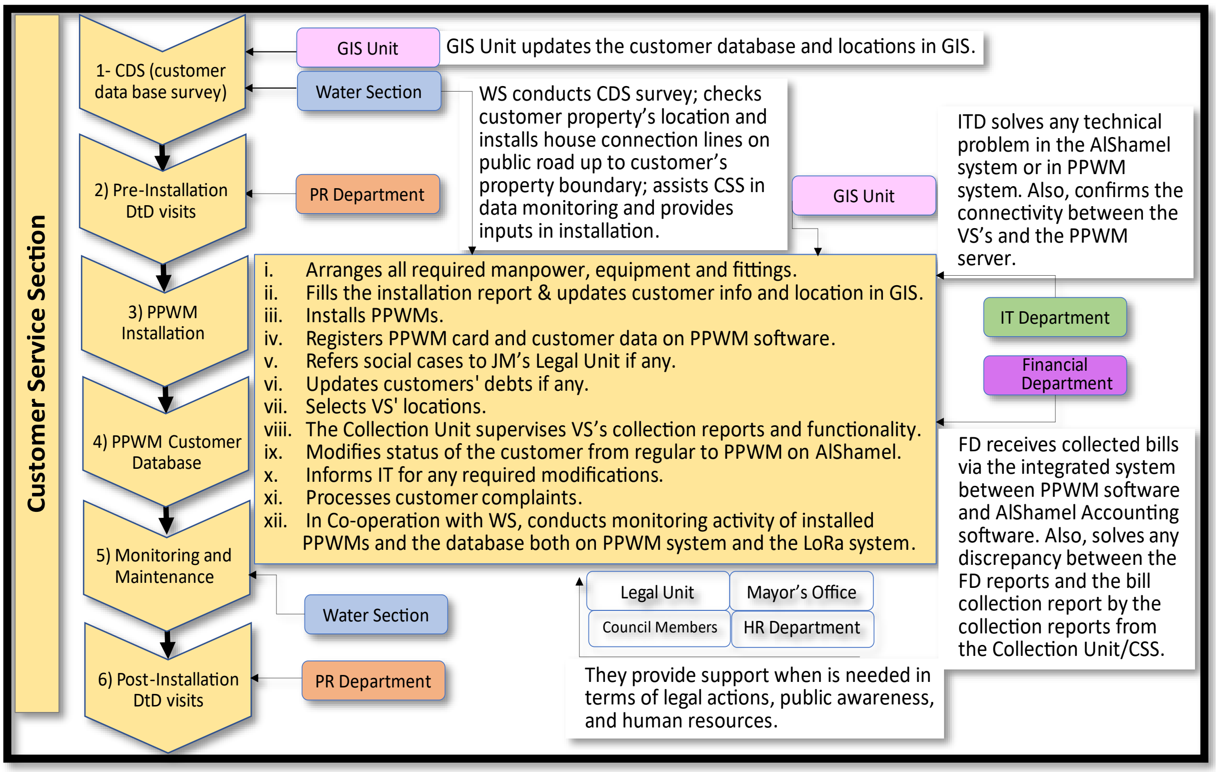


Figure 3-2: PPWM Implementation Plan and Tasks by Section and Department

Bellow shows tasks of each related section in the PPWM installation for entire city.

3.2.1 Customer Service Section (WWD)

The first step of the PPWM installation/replacement for the existing meters starts from this section as follows:

1) Decides the installation area and prepares the necessary information and conducts the DtD visits with PR Department for customer acceptance of PPWM installation 1 to 2 weeks before the installation period. Re-visits any rejecting customers when needed.

2) Prepares the GIS map of customer locations and other information such as water meter number, name, etc. collected by the Customer Database Survey (CDS) into GIS system.

3) Prepares the customer database on the PPWM software in advance and will make sure that the data is correct by crosschecking the PPWM database before the customer charges his PPWM. About 20-30 meters are supposed to be registered daily according to the installation teams and productivity experience during the pilot project period.

4) Identifies the PPWM and its charging card under the specific names of customers before the installation. This is because the PPWM should be ready to be charged immediately after installation.

5) Changes status of the customer on Al-Shamel software to PPWM user directly after the installation date of the PPWM noting that this modification on Al-Shamel is done newly. The result of this modification is to cancel issuing the bills and removal of the PPWM customers from the meter reader list during their ordinary site work to read the regular meters.

6) Updates customer financial status automatically by the integration between the Al Shamel Accounting software and the PPWM software.

7) Supervises the PPWM installation together with Water Section. Conducts the final water meter reading before replacing with PPWM. Confirms the customer satisfaction and documents the complain if necessary, by the PR staff of the team.

8) CSS in cooperation with the PR department, conducts and supervises customer awareness of the PPWM system especially the first time PPWM customers prior to the installation, and provides them with all necessary information and PPWM booklets -individually and using tools such as social media and JM website.

9) CSS (GIS assistant) receives the installation reports from the installation team and archives/updates the customer database in GIS.

10) Processes any complaints from the other sections and units such as the Collection Unit or the Water Section if there is any problem in the database which affect the vending functionality or issues with the installation itself. Also, CSS processes complaints from customers if there is any difficulty in using the PPWM or any issues with the PPWM malfunction/damage, and consumption, etc. CSS will do with its staff any required maintenance/replacement for the malfunctioned PPWM as possible as they can or they will coordinate to send the PPWM to the supplier for maintenance.

11) Issues any required reports from the PPWM software or Al-Shamel upon request.

12) CSS assigns monitoring staff for periodically monitoring of the PPWM customer database for any observed abnormality in credit charges or long period of zero/low consumption and solves the discovered issues in cooperation with the assigned monitoring staff of the Water Section. Updates the database, as necessary (LoRa System, PPWM software, Al-Shamel)

13) CSS-WS monitoring team coordinates and conducts random check and/or periodic check of the installed PPWM and takes the necessary actions to solve any issues.

14) Sends SMS reminder for debt payment.

The Collection Unit of CSS is the unit responsible for receiving the cash money from the water bill collector. As for the PPWM related activities, the Collection Unit is responsible for functions of the Vending Stations as follows:

1) Confirms that VS’ s functionality is in good situation and they are able to vend to customers.

2) Contacts daily with the Vending Station points (i.e. contracted supermarkets) and collects the water charging reports.

3) Reports to the CSS if any technical problem occurs in the vending stations.

3.2.2 Water Section (WWD)

The water section is responsible for installing the house connection after registration process being completed by the CSS.

1) Completes the Customer Database Survey (CDS) prior to the installation period to collect the following information:
    (1) Building owner’s name,
    (2) Building code number,
    (3) Number of households and family,
    (4) Registration status in customer database,
    (5) Water meter number, route of house connection, Utilized pipe material and diameter,
    (6) XY coordinates of the water meter location and branched points XY,
    (7) Usage of private network,
    (8) Number and volume of water tanks,
    (9) Building photo.
2) Assists the GIS Unit for digitizing of the customer location maps and the house connection line maps. Provides input if any modification required for the house connection line or meter location on the site and on the map.
3) Assists CSS in filling the installation report of the house connection file of the customer with all required details and deliver it to CSS for feedback.
4) Assigns monitoring staff to cooperate with the CSS’s monitoring staff on PPWM database observations for abnormality of credit charges, zero/low consumptions, battery issues, and solves any discovered issues by coordinating with CSS and prepares the report.
5) The same CSS-WS cooperation monitoring staff will also coordinate and conduct random check and/or periodic PPWM checks and follow up with the necessary actions from WS.

3.2.3 Warehouse Section (WWD)

This section under the WWD provides inventory of the PPWMs, boxes, and fittings.

3.2.4 Planning and Studies Section- GIS specialist (WWD)

1) Prepares the CDS and DtD maps for targeted area selected by WWD and CSS.
2) Prepares the GIS database and the installation maps for targeted areas selected by WWD and CSS.
3) Updates customer status and PPWM location on GIS database after the installation.
4) Updates customer information and status (Frozen, disconnected, illegal) in cooperation with CSS.
5) Issues any required reports from GIS database to head of CSS upon request.

3.2.5 Public Relation Department

In addition to carrying out PR activities to promote PPWM in entire city by use of social media and JM website and production of PR materials, interviews and short movie productions, the following major public awareness activities play a significant role in success of the PPWM acceptance by customers if conducted prior to the installation period of the installation area:

1) Pre-Installation Door-To-Door (DtD) visits These visits include visiting every customer 1 or 2 week prior to the installation with the purpose of receiving the customer's consent on installation of PPWM. The customer will be well explained and informed about 1) PPWM and its benefits, 2) type of the selected PPWM and the reasons, 3) how to use the PPWM, 4) where to charge the PPWM card, and 5) how the installation would work and what day they should expect the installation team. A PPWM booklet with all of the necessary information will be also handed to the customer and the PR staff make sure that the customers understood the PPWM and all their questions are answered before the installation day. Customers who refused to be installed, will be recorded for a re-visit with higher level of management of JM.

Figure 3-3: DtD Visits

The following steps can be used as a reference when conducting the pre-installation DtD visits.

i. Set up the area of visit.
ii. Extract customer information from the Al-Shamel database for the selected area.
iii. Set up team members, means of transportation, and visiting time: weekdays mornings are more suitable when it is expected that customers are present at home.
iv. Prepare accompanied documents: 1) hardcopy map of the visiting area using GIS map, 2) PR materials such as PPWM booklet and VS time/schedule, and 3) a hardcopy of list of the customers including their name, water meter number, and subscription number.

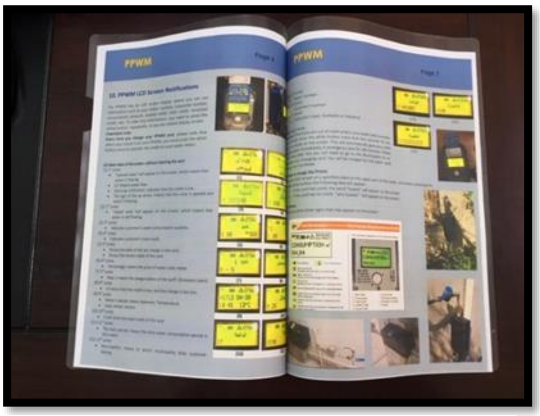


Figure 3-4: PPWM Booklet

In the booklet customers can read about:

- PPWM in Jenin
- PPWM Benefits
- Type of PPWM in PA Areas and How It Works
- Water Fee and Credit Charges
- Where to Purchase Credit for Your PPWM Smart Card (charging your card)
- Customers Responsibility on Their PPWM
- How to Maintain the PPWM from Damages or Misuse
- Where to Report If Notice Any Damages in the PPWM or Misfunction
- Installation Timetable
- PPWM Screen Notifications

Additional information:

- Location of Tested PPWMs in Pilot Areas
- Results of Accuracy Test of Three Types of Water Meters
- Other Activities by the Project

2) Accompany the installation team on the installation day

In addition, a PR staff should be included on the installation day to talk to customers and get permission to enter. Sometimes, customers change their minds by the installation day. Presence of a PR staff would help to get consensus again and avoid any conflicts for PPWM installation.

3) Re-visit of rejecting customers

The visit's purpose is to convince those customers who remain rejecting installation of PPWM for their property. According to experience form the pilot project areas, most of these customers finally accept the installation. It is important that higher level of management and key people such as the mayor, head of the WWD, key community people, or council members accompany the PR team for the second visits for a more successful result.

4) Neighborhood meetings and meetings with community leaders

These neighborhood meetings are also very significant in group discussions prior to the installation period. It is effective when it is well planned and key members of the community such as mosque imam, and community leaders are also attending. Attendance of higher level management of the JM is essential in these neighborhood meetings.

Figure 3-5: Meeting with Community Leaders

5) Public awareness during installation and operation

The activities focus on the proper use of the PPWM, procedures for the related service applications, new service procedures, complaints system, etc.

- Prepare and distribute instruction sheet on how-to use PPWM.
- Prepare and distribute information sheet about misusing the service.
- Facilitate installation's team working by open the doors for installation's team.
- Receive any complaint by customers and send it to Head of CSS.
- Periodic information about the progress of the installation project on JM's website and Facebook for the citizen's awareness
- Periodic FB posts on benefits of PPWMs
- Production of PPWM short movies i.e. interview with PPWM customers to share their experience with the citizen's. The movies can be shared on FB, YouTube, and JM website.
- Production of PR materials such as flyers, etc.

3.2.6 IT Department

The IT section in JM is mainly responsible for the technical issues related to the PPWM system.

1) Conducts installation for the VSs, Server, Internet, and solves any issues.
2) Confirms the connectivity between the VS's and the PPWM server.
3) Solves any technical (IT) problems in the PPWM system in coordinating with the PPWM supplier.
4) Solves any technical (IT) problem in the Al-Shamel system in coordinating with the Al-Shamel software supplier.
5) Ensures functionality of the Integration between Al-Shamel and PPWM software and provides training to the CSS employees in this regard.

3.2.7 Financial Department

1) Confirms the financial data on Al-Shamel software on a monthly basis and ensures that the money transfer movements are correct via integration between PPWM & Al-Shamel software. Cooperates with CSS and the Collection Unit.

3.2.8 Citizen Service Center

1) Receives new customers' applications for PPWM water subscription.
2) Receives subscription fees and transfers the application to CSS to install the PPWM.
3) Follows up with customers complaints on PPWM if any.

3.2.9 Legal Unit

1) Follows up with CSS service for any rejected cases to install the PPWM especially if the customer has cumulative debt.
2) Transfers rejected customers information to the Mayor office to take the necessary actions such as sending an installation notification or transfer customer file to the Court.
3) Follows up any illegal case after PPWM installation.

3.2.10 Human Resource Department

1) Follow up with WWD and CSS to assign new staff for PPWM installation if required.

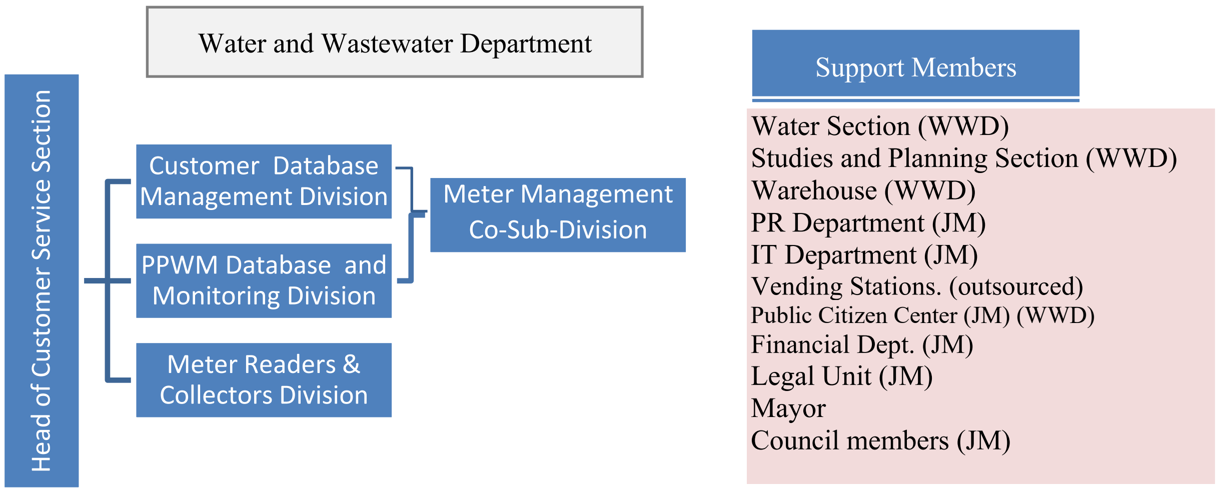
3.2.11 Mayor Office and Council Members Office

1) Supervises and instructs WWD and CSS for PPWM installation process, in general.
2) Provides all possible support to speed up and success of the PPWM installation whether financial or organizational.
3) Follows up the rejected cases with CSS and takes the required actions to install the PPWM for these cases.

3.3 Involved Members

CSS is responsible for the installation. However, support members from other sections and departments are also involved directly or indirectly.

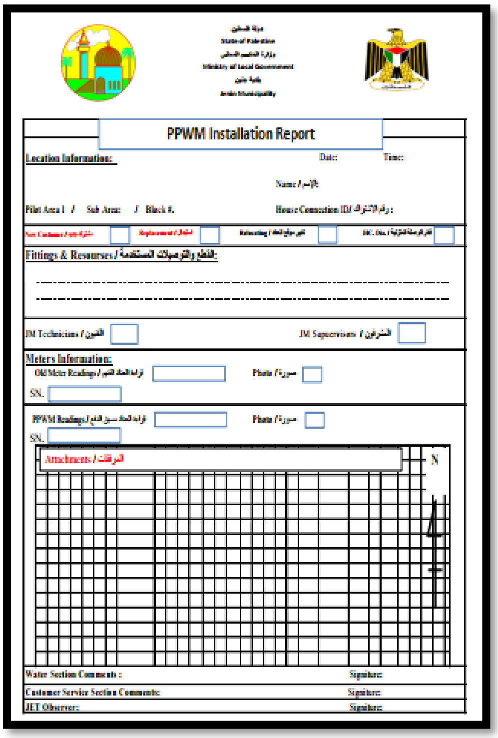
Figure 3-6: Involved Members of PPWM Installation Team



3.4 PPWM Replacement and Installation Procedures

It is important to make sure that the Municipality provides good services to the PPWM customers, during the replacement and after the replacement. The following are taken into consideration by the Municipality when providing PPWM services:

- Proficiently manages the services and reduces processing period.
- Makes the procedures as paperless as possible and holds digital documentations of the provided services.
- Reduces number of customer commutes to the Municipality for services as possible.
- Focuses on customer satisfaction, clear, and smooth procedures for the services.
- Takes constant measures to reduce or prevent errors when providing and/or handling the services.


State of Palestine
Ministry of Local Government
Jenin Municipality

PPWM Installation Report

Location Information: Date: Time:

Name / الإسم:

Pilot Area 1 / Sub Area: / Block #. House Connection ID / رقم الإشتراك:

Replacement / استبدال

Fittings & Resourses / القطع والتوصيلات المستخدمة:

JM Technicians / الفنيون   JM Supervisors / المشرفون

Meters Information:

Old Meter Readings / قراءة العداد القديم   Photo / صورة

SN.

PPWM Readings / قراءة العداد مسبق الدفع   Photo / صورة

SN.

Attachments / المرفقات   N

Water Section Comments : Signature:

Customer Service Section Comments: Signature:

JET Observer: Signature:

Figure 3-7: Installation Report

3.4.1 Existing Customers (Replacement)

Replacement for the existing customers includes following steps:

1) DtD pre-installation visit 1 to 2 weeks prior to the installation
2) Revisits of rejecting customers if needed.
3) CSS issues the PPWM's charging card to be ready to use by customers immediately after installation.
4) On installation day:

i. Last meter reading, just before replacement, is documented for customer's information and also to avoid any sorts of claims by the customer at later time. The replacement team needs to fill out the final reading form, sign, and take the following photos. The filled-out form and the photos are electronically filed for each customer by using the customer house ID, back in the office. A specific person (from PR department preferable) is assigned for the entire of this task including filling out the form, take the photos, and file electronically.
Photo 1: Existing water meter.
Photo 2: Existing water meter showing the surroundings.

ii. Technician installs the PPWM and includes the following photos to the lats meter reading form above:
Photo 3: Installed PPWM
Photo 4: Installed PPWM showing the surroundings

iii. After replacement: PPWM is a new system to the city and the residents are not familiar with. Thus, an assigned JM staff (PR staff) is available at the time of replacement/new installation and the new installed PPWM and makes sure that the customer understands how to use the system. A printed label with 24/7 phone number of contact for any possible issues is attached to the PPWM box for the time of need.

3.4.2 New Customers (Installation)

Installation of PPWM for new customers starts from the Public Citizen Center (PSC) as follow:

1) Pre- applications for PPWM (Site check)

This application is available to applicants who first need to inquiry if there is water network available in their area before they apply for a subscription.

i. The applicant needs to go to the PSC and fill out the "Site Check "application on DAMAS system. The application will go through the following electronic paths for processing:

- The application once entered on DAMAS is passed to the Head of Customer Service section (for view only) and the Head of Water Section to process. If there is no water network, the Head of Water Section comments on the request and sends back to the PSC. The PSC sends an SMS or calls customer to inform the unavailability of the water network. If there is water network, the Head of Water Section comments on the request and sends back to the PSC. The PSC sends an SMS or calls customer to inform the availability of the water network and that the customer needs to go back to the PSC and apply for the new connection. The customer will be also informed what documents to bring to the PSC.

2) Submission of application for PPWM: The applicant submits application for a new meter (PPWM) installation. The customer visits the PSC with the required documents and fills out the applicant for new connection on DAMAS and signs the contracts.

3) Installation of PPWM: The application, once completed on DAMAS, is electronically sent to the Head of Customer Service who checks the documents and the application and order for network connection. The Head of Water Section completes the connection up to the property. CSS completes the PPWM installation and enters the new customer information is entered into both the Al-Shamel system, PPWM system, and GIS database.

4) Awareness activity: On the installation day, the customer is well explained and informed about the installed PPWM and the usage, and a copy of the PPWM booklet is handed to the customer. A printed label with 24/7 phone number of contact for any possible issues is attached to the PPWM box for the time of need.

3.5 PPWM Inventory

The inventory system of Al-Shamel has not yet been used by the WWD and yet is being conducted on paper base. The staff should be assigned and trained to track the inventory of the PPWM fittings and devices and prepare reports as required.

3.6 Handling Customer Complaints

When CSS receiving complaints, they should handle professionally, and the staff ensures that the issue is resolved within a reasonable period of time to the customer satisfaction. Customers' complaint is usually received through JM website, JM social media pages and by phone call several ways.

1) Complaints received through the JM Website:

To avoid or reduce phone calls by the complainers, the new Municipality website is designed to electronically received complaints letters. The customer complaints -once sent via the website- goes through the following paths:

a) Once the complaint is filled out on the JM website, it is electronically sent to the account of the head of WWD (to process) and also the head of the PSCC head (to view only).
b) The head of WWD orders the related section to process the complaint.
c) After the issue is resolved the head of WWD electronically comments on the complaint with the actions taken to resolve the complaint issue.
d) The response is electronically sent to the PCSC account.

e) The PCSC forwards the response to the complainer by SMS or phone call if SMS is not available. The SMS includes a link to the website where customer can view the head of the WWD's response.
f) After viewing, a satisfaction survey window pops up so customer can express his/her satisfaction by rating.
g) The satisfaction rating is sent back to the head of the WWD to view and follow up in case it is not satisfactory.

2) Through social medial

When PR staff received customer complaints, they directly send it to the Head of CSS who will instruct the technicians to go to the site and fix the issue.

3) Through phone call

A 24h/7 service phone number must be available for customers to address their issues to CSS staff. When needed, CSS orders the technicians to go to the site. All complaints must record and report to head of CSS for analyzing and taking protective actions for future.

3.7 Monitoring of PPWMs

Monitoring the installed PPWM plays a significant role in time and cost management of the project and also in satisfaction level of customers and thus success of the project in terms of customer acceptance.

3.7.1 Use of LoRA and PPWM Database

The customer database of PPWM should be constantly checked for any abnormality in transactions and water consumptions database. This data inspection helps identify any problems or misuse of the service. In the database check, the staff looks for:

a) Customer who has not charged the PPWM card for a while.
b) Customer whom consumption or credit charge amount has suddenly dropped in last few months.
c) Customer whom usage of water or amount of credit charge has increased suddenly in past months which could be sign of some leakage in water meter in which customer has not noticed.

Effective measures and actions are taken when any of the above is discovered. Penalty is in place for misuse cases.

3.7.2 Regular Check

JM should launch PPWM inspections every regular x months to check and confirm the PPWMs for the following status:

1) Working status of the water meter and the box:

2) Illegal use and meter leakage:

   - Checks if the censor is tempered.
   - Checks the valves.
   - Checks leakages before and after the water meter
   - Checks the charges dates

3) Checks displacement or damage of the water meter

After the inspection, a sticker is placed on the PPWM box showing the date of the inspection and record the inspection data on CSS database. A GIS map of the location of the issues will be useful for analyzing the reasons of the issues and taking proper actions.

PPWMs' Check list — Date: xx/xx/xxxx

Checked items / HC-ID	PPWM box	Valves	Charged	Sealing	Region	Notes

Figure 3-8: Sample of PPWM checklist

3.7.3 Random Check

In addition to a regular check of the installed PPWM, CSS and WS together conduct a random check of meters for any issues in the device, boxes, illegal use, leakage, etc. And prepare a monthly report and maps of location of the issues by type.

3.8 Subscription Contract

The subscription contract was revised for PPWM customers. The following are main revised parts. Main revised parts in the subscription contract for PPWM customers in JM:

Table 3-3: Main Revised Parts in the Subscription Contract for PPWM Customers in JM

Term	Revised content
Connection fee	Increased from 682 to 1150 NIS
Term 2: Deserved fee when reconnecting water lines	The insurance fee (50JD) for the new connection has been canceled
Term 10: Water meter preservation	1. Penalties for PPWM were added: a. Any illegal case is 5,000 NIS and estimated consumption during the illegal use b. If customer damage the meter: 3,000 NIS for minor parts or illegal use fine amount (5000NIS+) for main part of meter c. Pipe connected before meter, playing with meter system: illegal use fine amount (5000 NIS + consumption) d. If the customer sells municipal water to others will pay 10,000 NIS as penalty. e. If the customer install pump directly to the network: 2,000 NIS and pump is removed and taken to Municipality.

	2. Transferred the ownership: Water meter installed in customer's property is owned by the Municipality
Term 17: Minimum tariff	1. The minimum tariff (17.36NIS) has been canceled for PPWM customers. 2. The Municipality is authorized to collect 6.2 NIS from the customer as the cost of the network maintenance and 1 NIS for water meter maintenance.
Term 19: Transfer subscription	The insurance fee for transfer subscription has been canceled

3.9 Penalty

Effective measures and actions/penalties are taken when any of the above is discovered.

All these penalties include in the new customer contract.

- Any illegal case is 5,000 NIS and estimated consumption during the illegal use
- If customer damage the meter: 3,000 NIS for minor parts or illegal use fine amount (5000 NIS+) for main part of meter
- Pipe connected before meter, playing with meter system: illegal use fine amount (5000 NIS + consumption)

3.10 PPWM and Customers of Low Income and Social Cases

With the increase in the number of the installed PPWMs in the Pilot Areas, there were complaints from families as for financial or physical inabilities to use PPWMs, especially in periods of political and social instability.

The social cases were categorized as following 7 types with the number of cases. Some of them were registered at the Ministry of Social Affair (MoSA) but mostly these cases were evaluated by PR and CSS staff of JM.

Table 3-4: Social Cases Adopted to PWM Customers

Category	The number of the cases	Solution
1. Old woman	9	WWD installed the PPWM as postpaid meter (Opened valve)
2. Low income	8	WWD installed the PPWM as postpaid meter (Opened valve)
3. Disabled	2	WWD installed the PPWM as postpaid meter (Opened valve)
4. Martyr's mother	2	WWD installed the PPWM as postpaid meter (Opened valve)
5. Martyr's family	1	JM council decided to exemption from their debts (Martyr's family requested to remove their debts)
6. Jenin Camp	1	WWD installed the PPWM as postpaid meter (Opened valve)
7. Prisoner's Family	1	WWD installed the PPWM as postpaid meter (Opened valve)

Remarks: Period between 28/08/2019 to 07/11/2020.

Jenin municipality (WWD) have taken different actions to treat some cases (individually) as follow:

- Open PPWM valve for some of these customers and record their bills on their cumulative debts.
- Stopped debts deduction temporarily.
- Some customers have a temporary situation in which they couldn't pay for water, so WWD opened the PPWM for these customers for this period only and record their consumption during this period on their debts.

JET and JM tried to find and set some countermeasures for low-income households after conducting case study for low-income households and the ways of treatment in Palestine. In this case study, 8 water providers were visited by JICA Expert Team and Jenin municipality. The result of case study of the other water service provides is shown in the following table. The solution dealing with social cases are categorized as following 3 cases.

Table 3-5: Main Solutions for Social Cases

Solution	Contents
1. By fundraising	Municipalities or water providers create a donation fund for low-income households, and they request people who have good financial situations to donate for these customers.
2. Charge by debts	Municipality charge the card for social cases or low-income customers on PPWM software then record this charge on customer debts. They add it on the cumulative debt of customers until they find a way to cover this debt.
3. Technically by opening the valve temporarily	In this case, the municipality makes the meter as a postpaid meter by using technical features on PPWM software. This way is used for social cases and sometimes for some customers who cannot charge temporarily. This way is used in JM.

The other providers presented the following ideas to deal with social cases:

1. Technically by opening the valve and changing to postpaid meter temporarily
2. Fundraising by several ways
3. Make a list of the social case and establish a fundraising for them
4. Reduced percentage for debt deduction
5. Special tariff for the social cases
6. Limit the consumption
7. Cooperation with MoSA
8. MoSA should pay the water for the registered cases
9. Any solution for the social cases shall be approved by MoLG & MoSA
10. Establish rules without contradiction with the municipality policies

3.10.1 Recommended Actions

Recommendations to Jenin Municipality on how to deal with social cases are as follows.

1) Open PPWM valves temporarily
2) Deferral of payment
3) Fundraising
    a. Referral to other agencies for financial support
    b. Develop a voluntarily donation program collected through credits by other customers or other PPWM customers
    c. Transfer of other existing donations funds to support the assistance
    d. Help of NGOs and CBOs for assistance
    e. Use of international donors
4) Cooperation of the city’s private business owners for assistance in return of discounts in their water debt if any.
5) Provide subsidies by Municipality
6) Reduced percentage for debt deduction
7) Special tariff for the social cases
8) Limit the consumption

At the time of preparation of this Report, JM has not defined social cases and also has not decided on a system and process to dealing with such families.

3.11 Installation Risks

The major risks may include the followings:

1) Delay in PPWM delivery especially due to the Israel' s custom
2) Political risks that may affect the operation delays
3) COVID lockdown

CHAPTER 4 Installation Plan

4.1 Current Status of Installed PPWMs in the City

Refer to Table 4 3: Detailed Activity for The Stages of The Installation Process

4.2 Projected Installation Plan for Entire City

The installation plan for the installation is as follows:
1- WWD tended to go with one multi-stage tender.
2- The installation stages will be according to the number of expected customers in the zones selected for the installation.
3- Priority of the installation areas will be first for new DMAs, then for other areas with good water supply and no readers.

4.2.1 Description of Implementation

The implementation will be on four stages, each stage will consist multi tasks for JM staff and contractor staff. JM role in these stages will be supervisory compared to the previous installation process; JM/ WWD staff will be supervisors of the contractor teams works. While the contractor will install and fill the forms that WWD will provide them with. While JM/ PR staff will start the installation process by conducting CDS works at the early stages, then followed by DtD at the end stages.

4.2.2 Points of Contact

Table 4-1: Contact List for the Installation of PPWM

Role	Name	Phone	Email
Project Owner	Jenin Municipality/ WWD	42502023	Jenin_munic@yahoo.com
Project Director JM Mayor	Nidal Abd Alfattah Obaidi	599740255	-
Project Manager (Acting)	Eng. Khairia Souqia	595069998	Khairia.souqia@gmail.com
Contractor	Not decided		
Supervisor/ Head of CSS	Khaled Abu Obaid	599290094	Khaled1981obeed@gmail.com
Field Supervisor	Eng. Maen Hendawi	597249393	Maenhendawi@gmail.com
	Eng. Fadi Nasharti	595196518	Fadi.nasharti@hotmail.com
CSS: Data Entry	Eng. Bara Abu Tabiekh	597319919	Barajamal78@gmail.com
CSS: PPWMs Management	Naseem Saaydeh	592172116	naseemsaaydh@gmail.com
	Shareef Zakarneh	592872987	water.20@yahoo.com
CSS: Customer Database Management	Omar Faza	598925588	Faza.omar@gmail.com
Software follow up / IT	Eng. Mahmoud Nassar	599270786	Mahmoud.nassar@outlook.com

JM/ PR	Basheer Matahen	599882233	Jenin_munic@yahoo.com
	Naser Ghazal	598928080	
	Mohammad Zo'bi	599970463	
Warehouse	Hisham Aqhash	599661607	-
	Abdullah Abu Alhaija	595020112	
Financial Dep.	Mohammad Ali	599436051	Muhammad_ali2020@hotmail.com
JM Council- Water Committee	Mohammed Saba'aneh	597808087	-
	Mahmoud Albaik	599525730	
	Mohammed Toqan	568345670	
	Shireen Omari	592900679	

4.2.3 Implementation Schedule

The following is the strategy that will be adopted and implemented during the installation process of the 4350 PPWMs. This strategy was applied in JM during the installation of PPWMs in the PAs. The main strategy for the PPWMs installation works is that the city will be divided into 4 areas.

The following table provide descriptions of the major implementation tasks.

Table 4-2: The Major Implementation Tasks for Installation Process of PPWM

Tasks	Responsible	Start	End	Days	comments	Attendance	Status
8/25/2021							
Set kick-off meeting	Eng. Khairia	25-Aug	25-Aug	1	Meeting with FT to set timeline for installation	Eng. Abd Al-Hadi, Eng. Khairia, Ameed Shafie (FT), Eng. Alaa	Complete
Agree on objectives	All Parties	26-Aug	26-Aug	1	Agree on the activities of FT teams, JM teams (PR and WWD)	Eng. Abd Al-Hadi, Eng. Khairia, Ameed Shafie (FT), Eng. Alaa	Complete
Initiation - 2022							
Installation areas	WWD	25-Apr-21	10-May-21	15	Determine the installation areas and targeted customers		Complete
Document Preparation	WWD	4-Sep	5-Sep	1	Forms		Complete
Delivery of 4,350 PPWM	FT	5-Sep-22	10-Sep-22	5			Complete
Customer Data Survey (CDS)	PR	4-Sep-22	20-Apr-23	228			In progress
Installation							
Training	WWD	25-Sep-22	1-Oct-22	6	Train the contractor's teams to fill the forms		Not started
Preparation of daily works	WWD and PR	25-Sep-22	25-Apr-23	212	will continue with the installation process		Not started
Site map preparation	CSS	25-Sep-22	25-Apr-23	212	will continue with the		Not Started

Tasks	Responsible	Start	End	Days	comments	Attendance	Status
					installation process		
DtD visits	PR	15-Sep-22	25-Apr-23	222	will continue with the installation process		Not started
1st Stage (installation of 1600 PPWM)	Contractor under the supervision of WWD	25-Sep-22	25-Nov-22	61			Not started
2nd Stage (installation of 850 PPWM)	Contractor under the supervision of WWD	27-Nov-22	30-Dec-22	33			Not started
3rd Stage (installation of 970 PPWM)	Contractor under the supervision of WWD	2-Jan-23	15-Feb-23	44			Not started
4th Stage (installation of 1170 PPWM)	Contractor under the supervision of WWD	19-Feb-23	12-Apr-23	52			Not started
Inspection of Installation and Sealing	WWD	26-Sep-22	25-Apr-23	211	Weekly		Not started
Operations							
PPWM Data Entry and Registration	CSS	25-Sep	25-Apr	212			Not started
Customer Data Management	CSS	25-Sep	13-Apr	212	Continue after the installation if need		Not started
Card Distribution	CSS	25-Sep	13-Apr	212	Continue after the installation if need		Not started
End Line							

The following table depicts the detailed activities for the installation zone:

Table 4-3: Detailed Activity for The Stages of The Installation Process

Stage			Current Status as of August 2022				
			Estimated Number of Customers	Installed PPWMs	Remaining Customers	CDS Status	DtD
1	Stage 1	Ibrahemeen+School St. (est.)	250	84	166	Completed	Not Started
2		Almaniya (est.)	200	102	98	Completed	Not Started
3		Al-Basateen	465	111	354	Completed	Not Started
4		Industrial Area (est.)	250	29	221	Ongoing	Not Started
5		Al-Hadaf+Wadi Burkin (est.)	350	129	221	Not Started	Not Started
6		other areas within stage1 of installation	285	0	285	Not Started	Not Started
7		Al-Jinan	57	44	13	Completed	Completed

					(Rejecting)		
Total Number of Customers Stage 1					1857		
Total Number of PPWMs to be Installed Stage 1					1358		
1	Stage 2	Wadi Izz Al-Dien	500	0	500	Not Started	Not Started
2		Al-Swaitat and Al-Marah	350	0	350	Not Started	Not Started
Total Number of Customers Stage 2					850		
1	Stage 3	Nablus St.	485	0	485	Not Started	Not Started
2		Khalet Al-Soha	340	0	340	Not Started	Not Started
3		Al-Jabriyat	145	0	145	Not Started	Not Started
Total Number of Customers Stage 3					970		
1	Stage 4	City Center (Commercial Square)	670	0	670	Not Started	Not Started
2		Old City	500	0	500	Not Started	Not Started
Total Number of Customers Stage 4					1170		
Total Customers for Installation					4348		

The following figure provides the timeline for the major implementation tasks.

	Tasks	Start Date	End Date	Duration (Days)
1	**Initiation**			
1	Delivery of PPWM, metal boxes and fittin	7-Sep-22	8-Sep-22	2
1	PPWM Installation bidding	10-Sep-22	22-Sep-22	12
1	Customer database survey (CDS)	10-Sep-22	20-Apr-23	222
1	Pre-installation visits (DtD)	10-Sep-22	20-Apr-23	222
2	**Installation**			
2	Train the contractor's teams to fill the installation forms	25-Sep-22	1-Oct-22	6
2	Site map preparation	25-Sep-22	25-Apr-23	212
2	Preparation of daily works	25-Sep-22	25-Apr-23	212
2	1st Stage (installation of 1358 PPWM)	25-Sep-22	25-Nov-22	61
3	2nd Stage (installation of 850 PPWM)	27-Nov-22	30-Dec-22	33
3	3rd Stage (installation of 970 PPWM)	2-Jan-23	15-Feb-23	44
3	4th Stage (installation of 1170 PPWM)	19-Feb-23	12-Apr-23	52
3	Inspection of Installation and Sealing	26-Sep-22	25-Apr-23	211
3	**Operations**			
3	PPWM Data Entry and Registration	25-Sep-22	25-Apr-22	212
3	Customer Data Management	25-Sep-22	25-Apr-22	212
3	Card Distribution	25-Sep-22	25-Apr-22	212
	End			

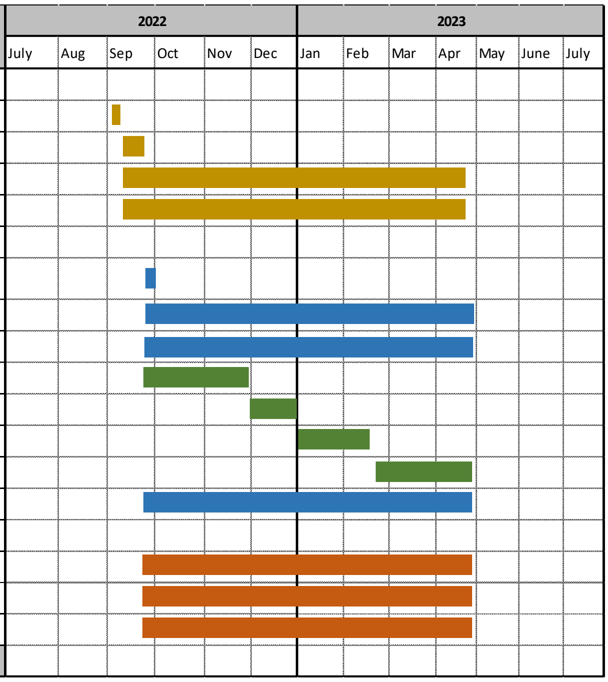
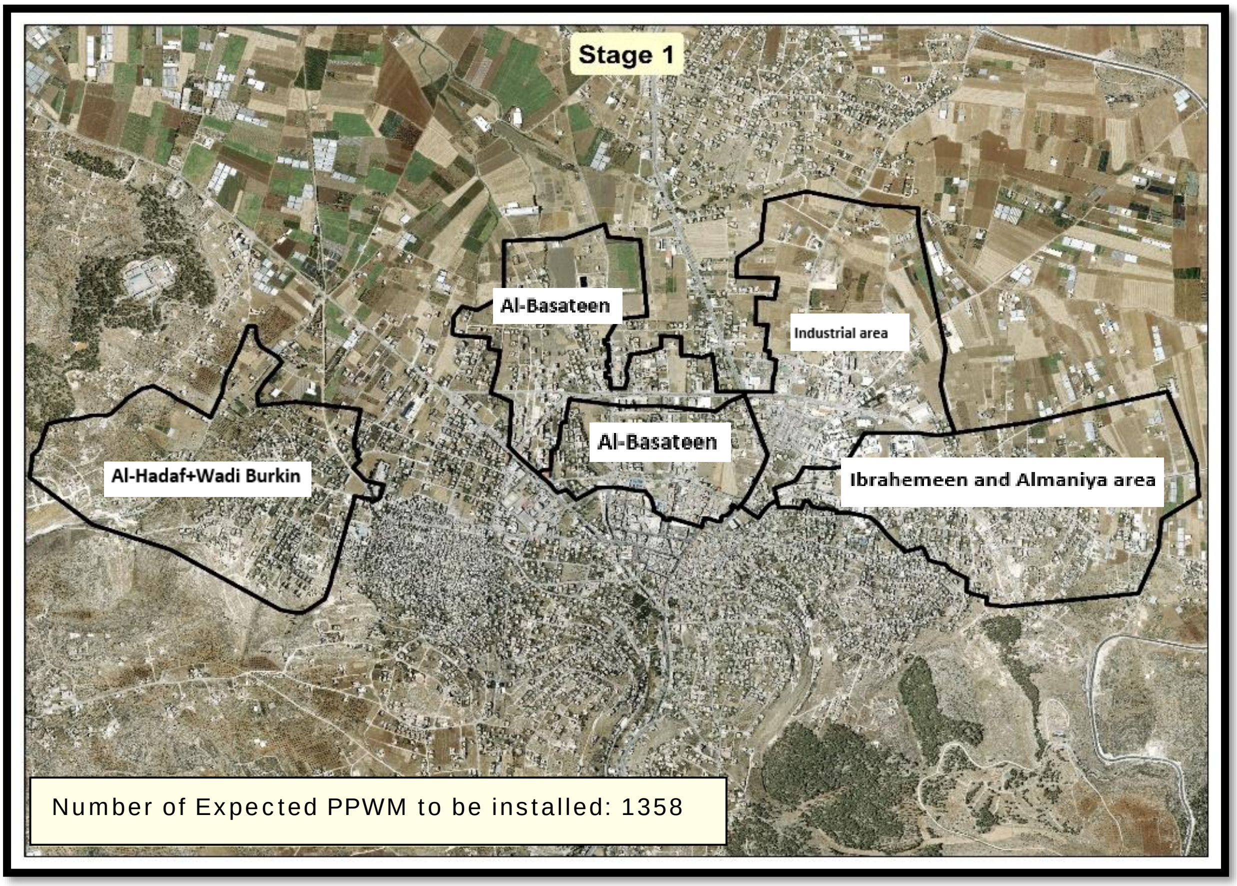
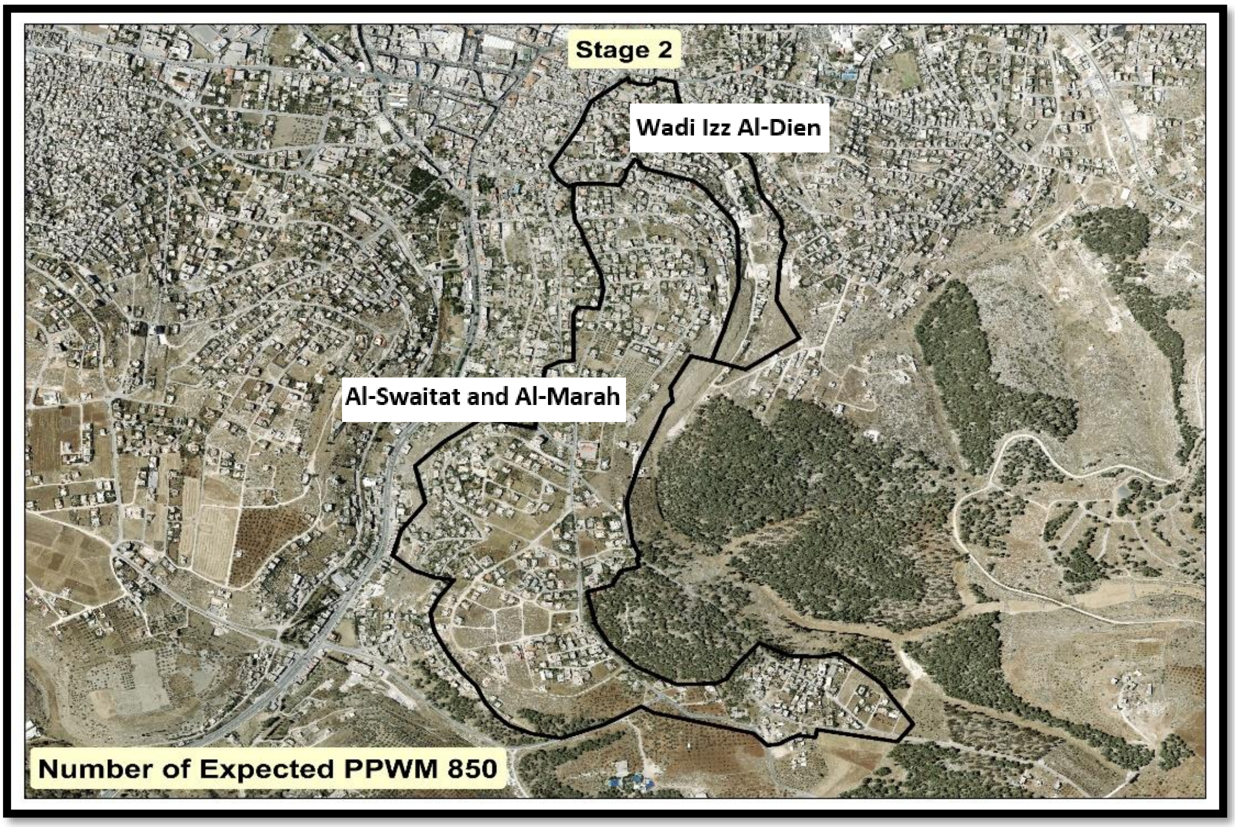
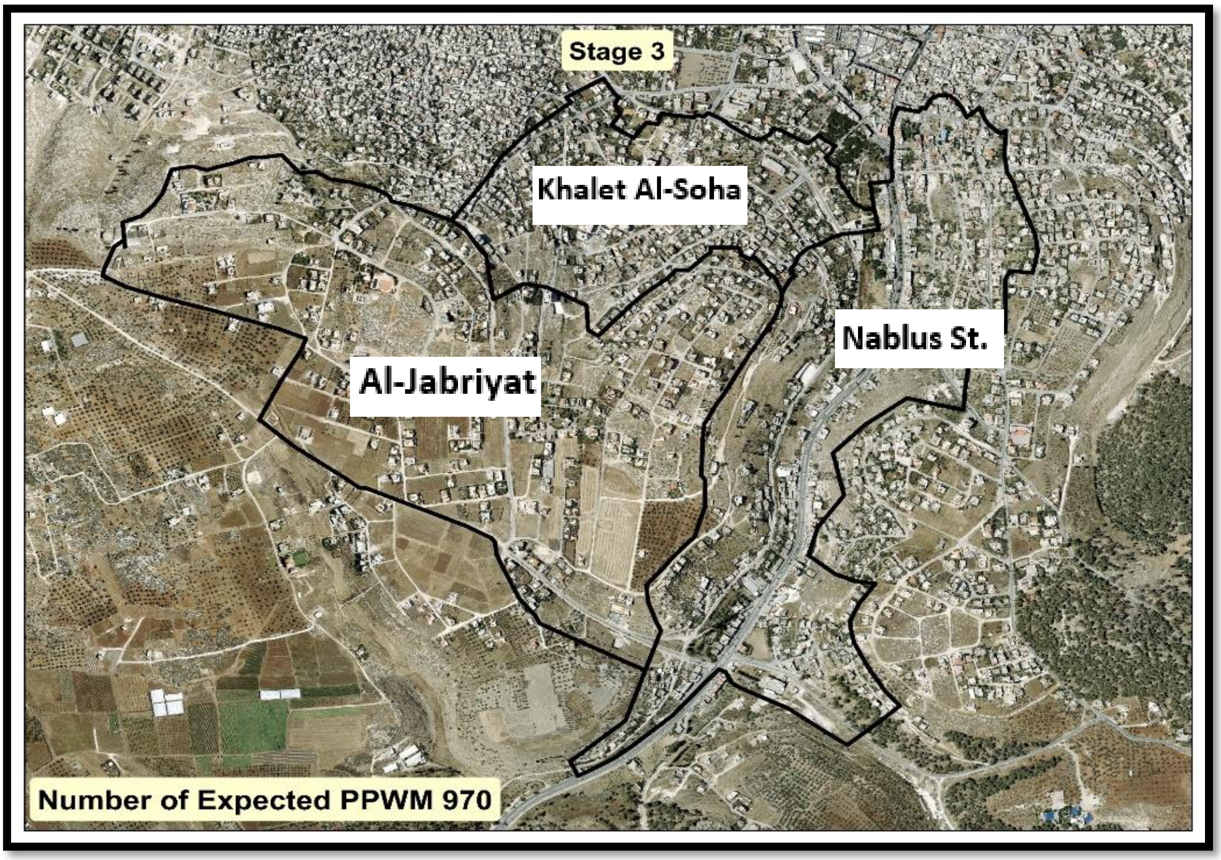


Figure 4-1: Timeline Diagram for The Installation Plan of PPWMs


Stage 1
Al-Basateen
Industrial area
Al-Basateen
Al-Hadaf+Wadi Burkin
Ibrahemeen and Almaniya area
Number of Expected PPWM to be installed: 1358


Stage 2
Wadi Izz Al-Dien
Al-Swaitat and Al-Marah
Number of Expected PPWM 850



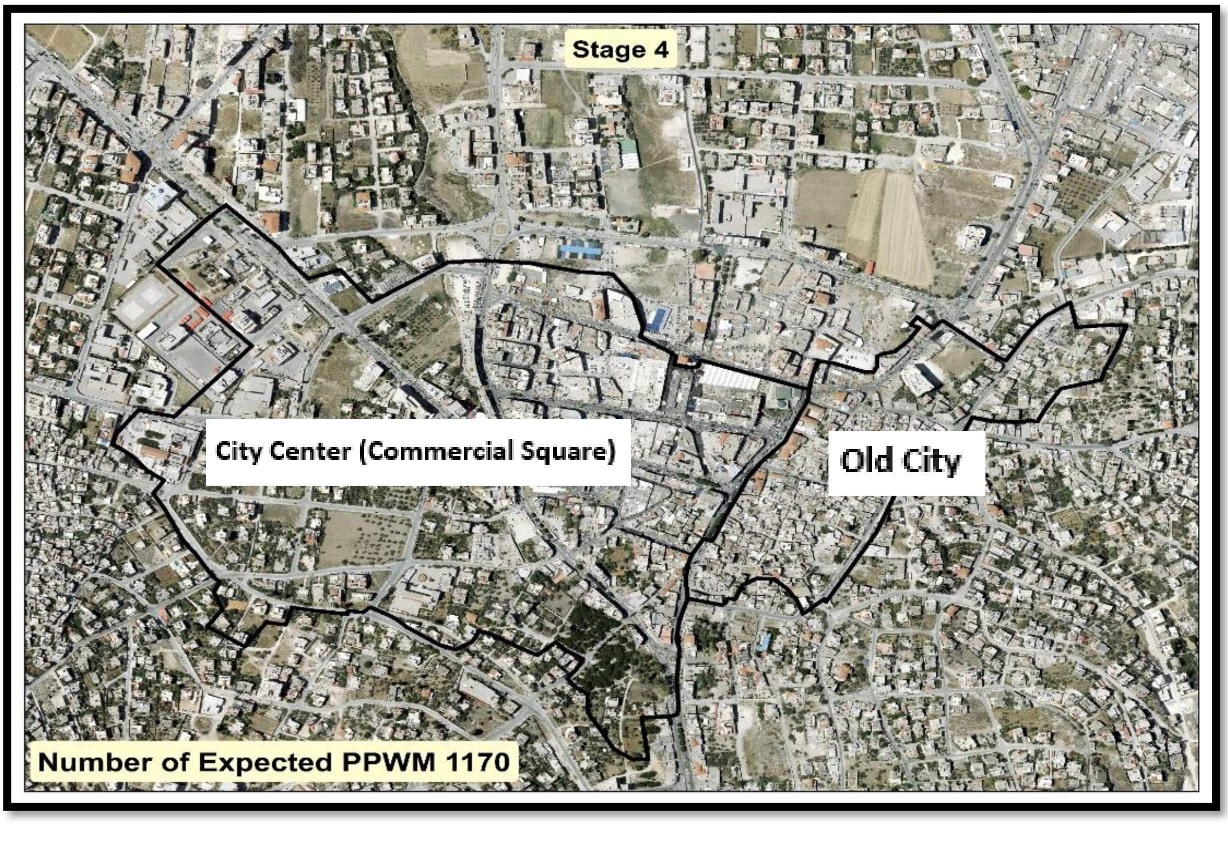


Figure 4-2: Installation of PPWMs with The Expected Number of PPWMs in each Stage

Table 4-4: Installation Teams Breakdown

Team/Names			Remark
Coordination with contractor			
Head Supervisor	Member	Supervisor Engineer	Contractor
Proposed Teams			
Team 1	Member	Foreman	
	Member	Water Technician	
	Member	Technician Assistant	
Team 2	Member	Foreman	
	Member	Water Technician	
	Member	Technician Assistant	
Team 3	Member	Foreman	*Stand-by Team/ Contractor*
	Member	Water Technician	
	Member	Technician Assistant	
CDS team			
Team 1	Member	Nasir Ghazal	PR/ JM
	Member	O	Assistant
Team 2	Member	Mohammad Zo'bi	PR/ JM
	Member	O	Assistant
DtD/PR team			
Team1	Member	Nasir Ghazal	PR/ JM
	Member	O	Assistant
Team 2	Member	Mohammad Zo'bi	PR/ JM
	Member	O	Assistant
GIS team			
WWD	Member	Eng. Bara Abu Tabiekh	CSS/WWD/JM
PPWM cards/registration, etc			
WWD	Member	Mr. Naseem Saaydeh	CSS/WWD/JM
	Member	Mr. Sharif Alafif	CSS/WWD/JM
PPWM monitoring team			
WWD	Member	Eng. Maen Hindawi	WS/WWD/JM
	Member	Eng. Fadi Nasharti	WS/WWD/JM
PPWM Fittings Monitoring			
WWD	Member	Mr.Abdullah Abu Al-Hija	Warehouse/WWD/JM
	Member	Mr.Hisham Aqhash	
Top Supervisor			
WWD	Member	Eng. Khiria Souqia	WWD/JM

Table 4-5: Productivity of Taskforce

Role	Avg Expected Installed Per Day	# Of Working Days Per Month	Avg/ Installed/ Month
Contractor			
Team 1	15	20	300
Team 2	15	20	300
Team 3	0	0	0
Total			600
PR (CDS+ DtD)			
Team 1	15	20	300
Team 2	15	20	300
Total			600
GIS			
Team 1	30	20	600
Card Registration			
Team 1	30	20	600
Fittings Monitoring			
Team 1	Al-Shamel Monitoring		

4.3 Installation by Municipality Staff: Small Scale (New Customers and Selected Customers)

4.3.1 CDS and PR Activity

PR section is working only for existing customers now and the required explanation of PPWM is done by CSS when customer come to receive their card PPWM as you see in the last step in the workflow.

4.3.2 Workflow

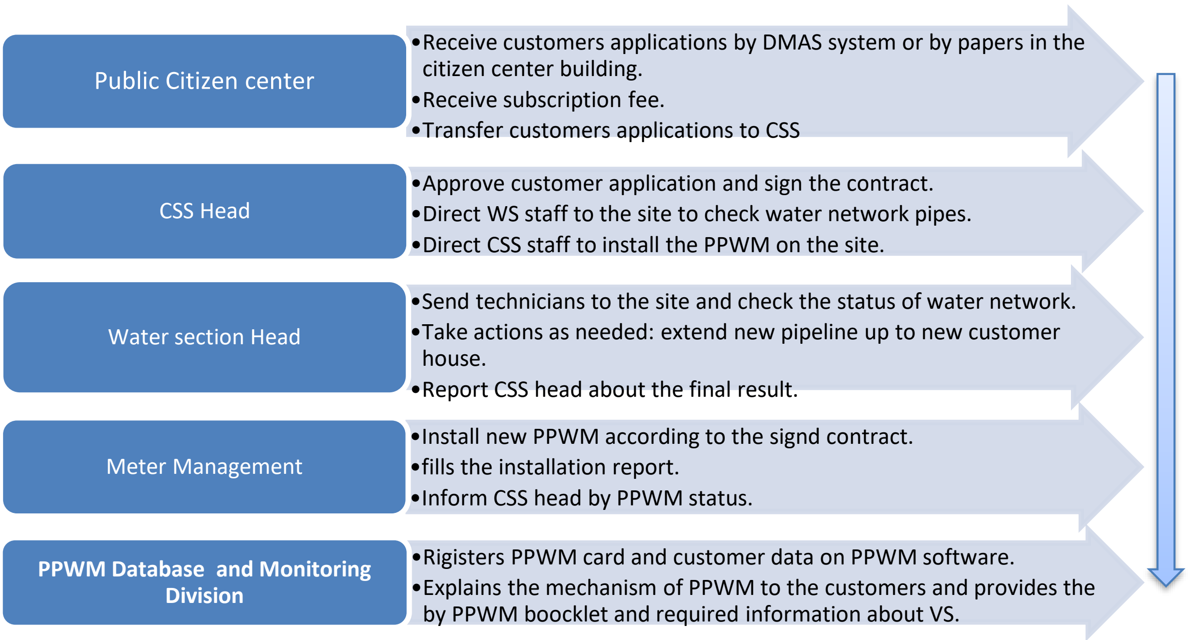


Figure 4-3: General Work Flow Diagram for The Installation Plan of PPWMs

4.3.2.1 Customer Database Survey (CDS)

PR staff in cooperation with WS, conduct a field survey to obtain all customers information before PPWM installation which includes:

a) Building owner's name,
b) Building code number,
c) Number of households and family,
d) Registration status in customer database,
e) Water meter number, route of house connection, Utilized pipe material and diameter,
f) XY coordinates of the water meter location and branched points XY,
g) Usage of private network,
h) Number and volume of water tanks,
i) Building photo.

4.3.2.2 Pre-installation DtD visit before installation: at the time of DtD visits, the team ensured that every customer understands the followings:

a) benefits of PPWM for customers and for the city and the municipality
b) Reason of selection of the PP Ultrasonic PPWM by JM and the benefits such as not elimination of counting air which was an issue with existing meters.
c) PPWM installation plan in terms of the days and time of installation in their neighborhood
d) How their PPWM works, how to use the PPWM, where to charge their PPWM cards and how to pay, complaint system, etc. The same information was also provided in format of a 12-page booklet with Q/As, maps, vending station location, manual of how to use the PPWM with step-b step photos, etc.

In addition, a PR staff should be included on the installation day to talk to customers and get permission to enter. Sometimes, customers change their minds by the installation day. Presence of a PR staff would help to get consensus again and avoid any conflicts for PPWM installation.

4.3.3 Workflow of PPWM installation by contractor

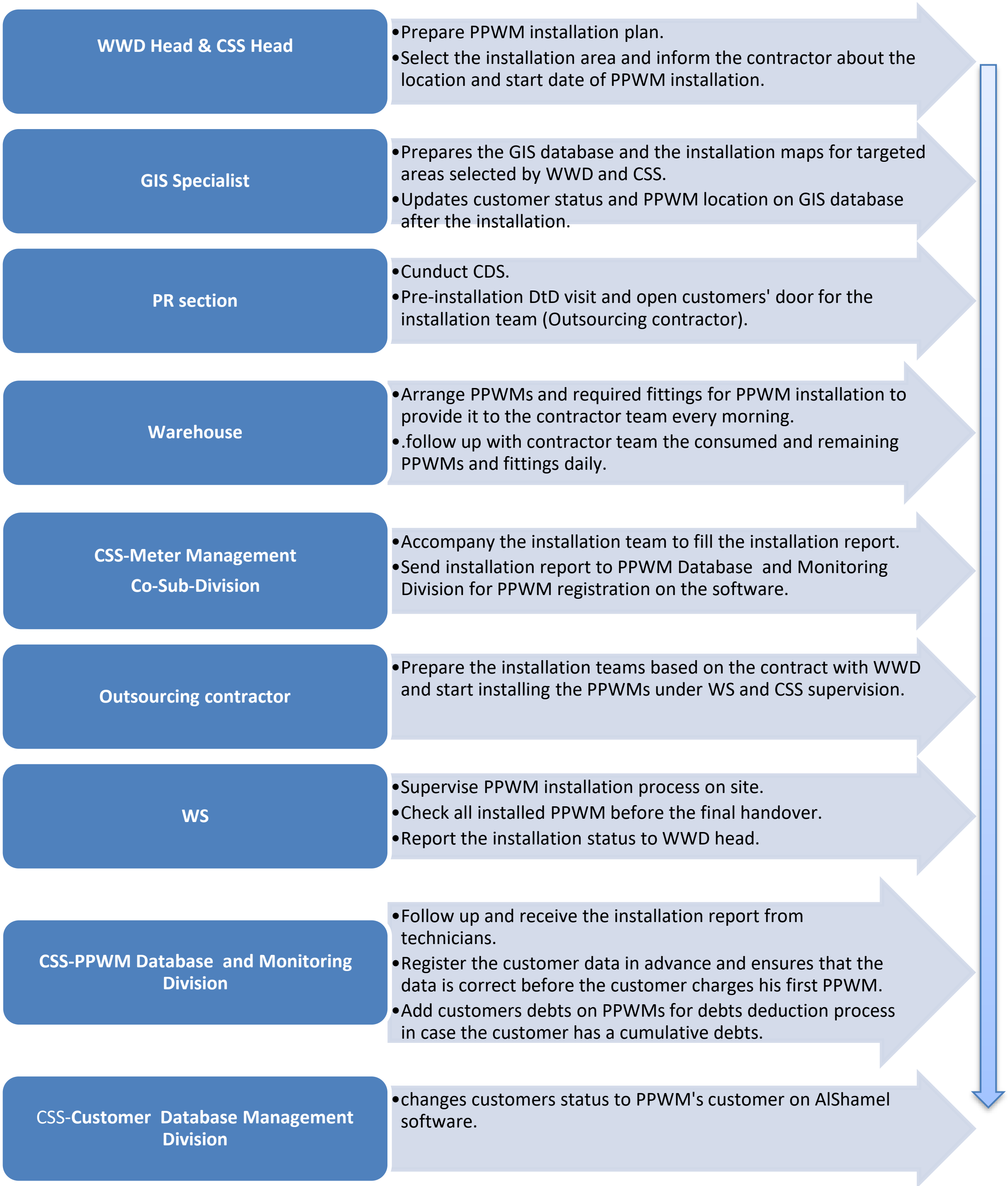


Figure 4-4: Work Flow Diagram PPWM installation by contractor

CHAPTER 5 Operation and Management

5.1 Workflows of Major Activities

5.1.1 Workflow of Random Check of Installed PPWMs

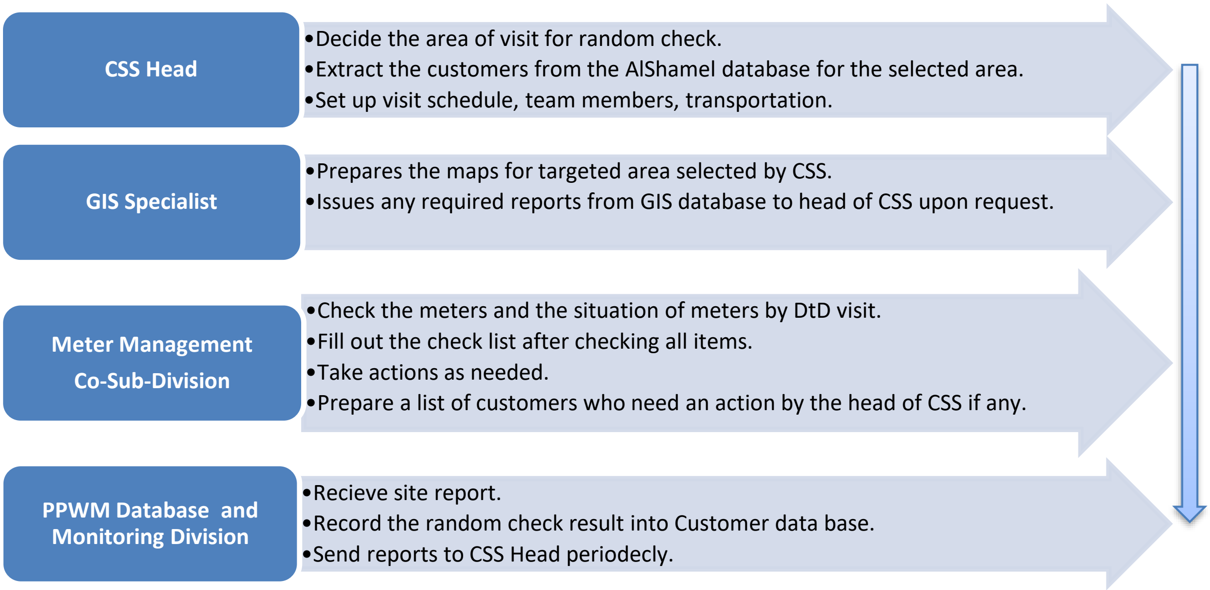


Figure 5-1: Work Flow of Random Check of Installed PPWMs

5.1.2 Workflow of Examination of PPWMs with Zero-consumption

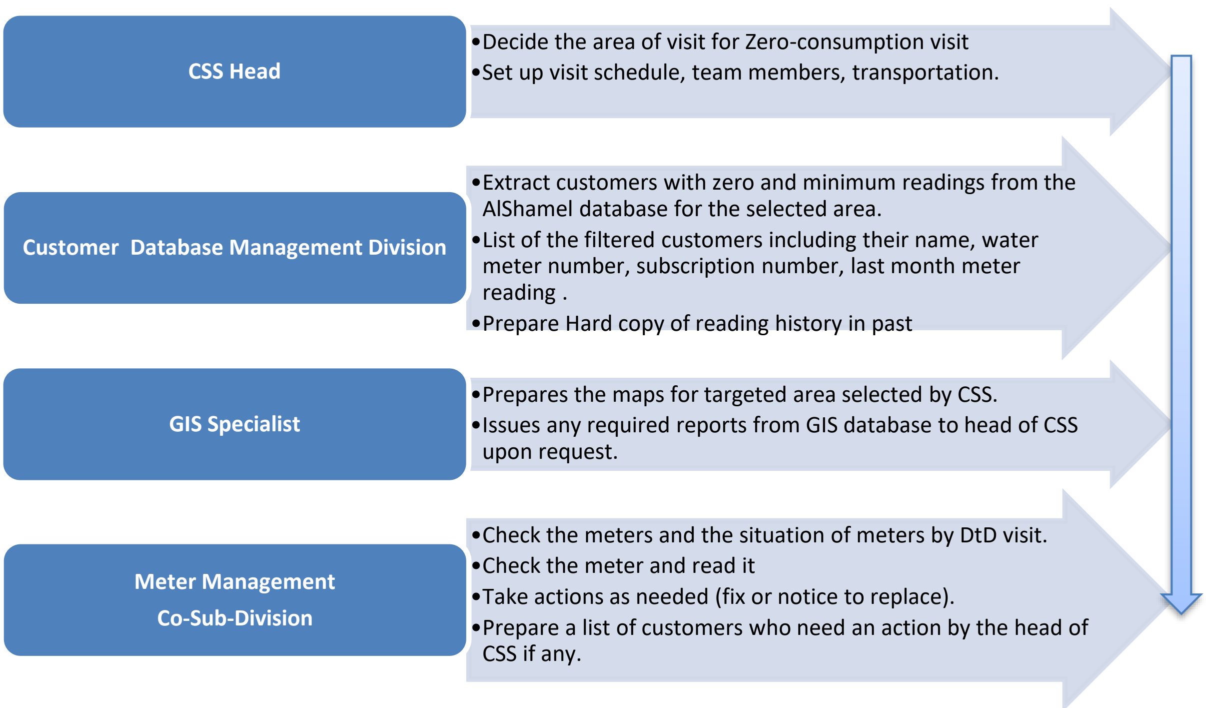


Figure 5-2: Work Flow of Examination of PPWMs with Zero-Consumption

5.1.3 Workflow of PPWM Customer Complaints

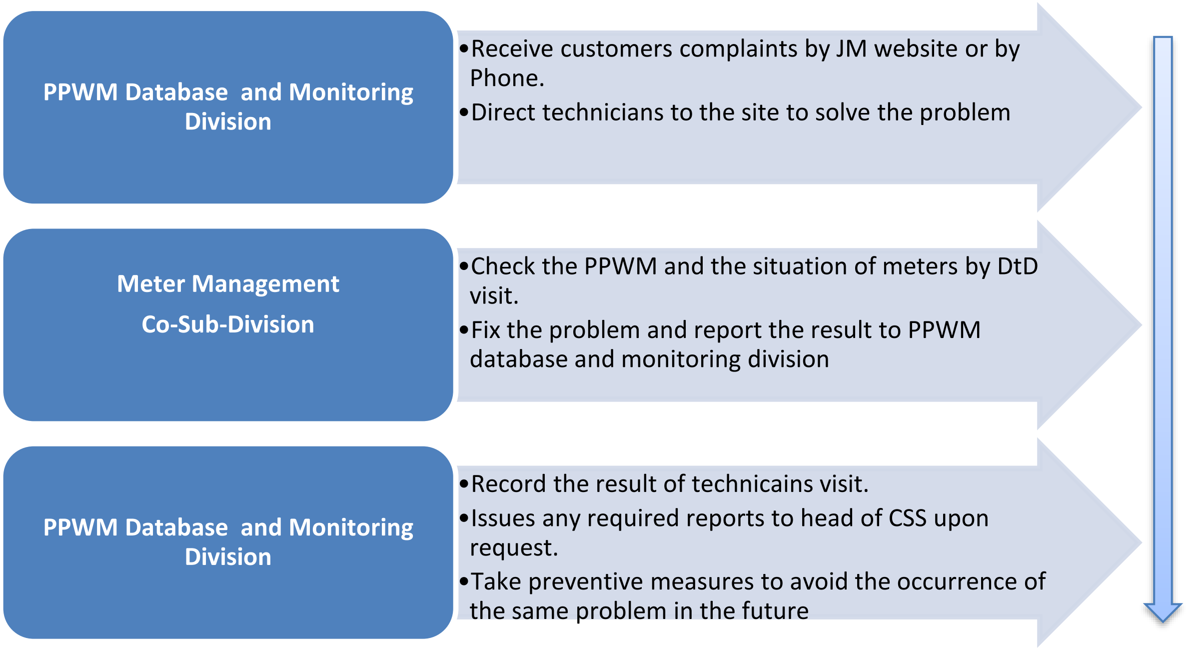


Figure 5-3: Work Flow of PPWM Customer Complaints

5.1.4 Workflow of Illegal Connections

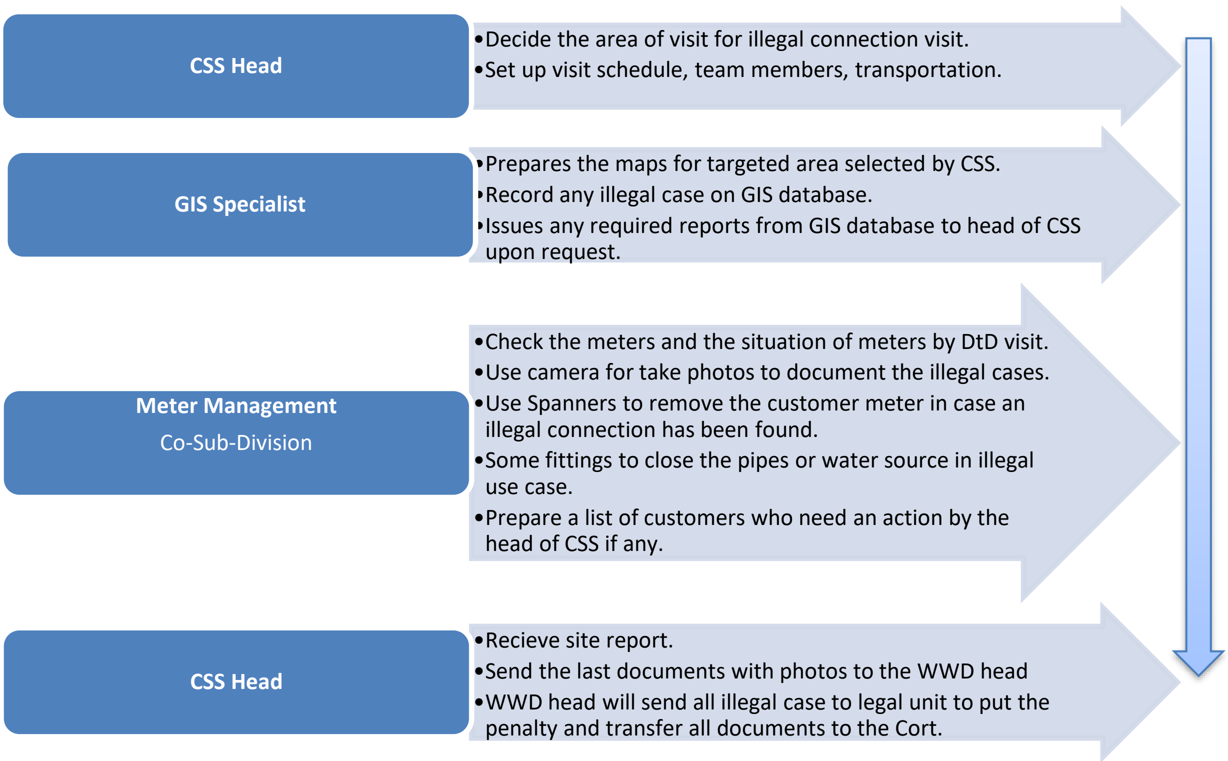


Figure 5-4: Work Flow of Illegal Connections

5.1.5 Workflow of PPWM Repair

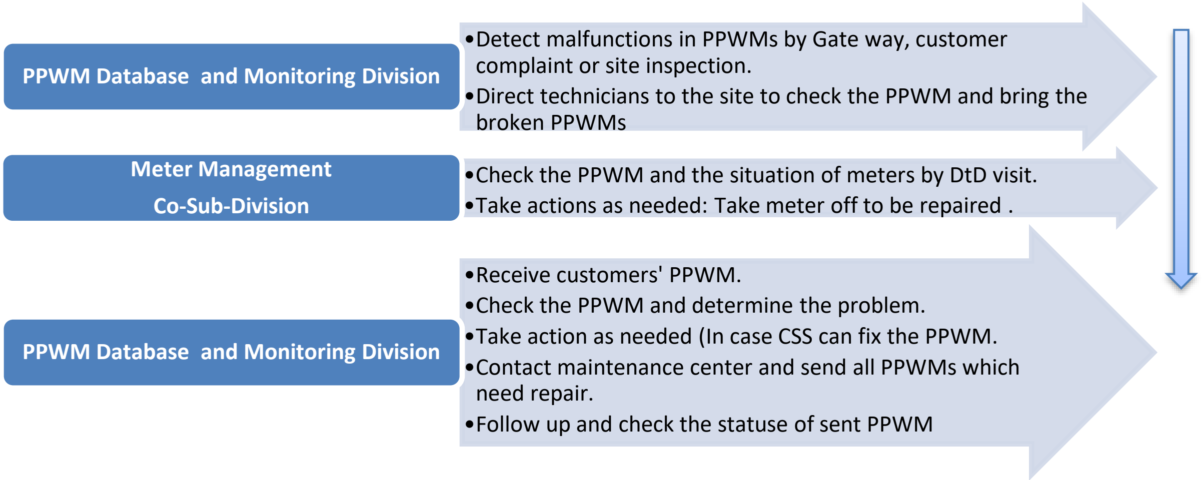


Figure 5-5: Work Flow of PPWM Repair

5.1.6 Workflow of Rejection Cases

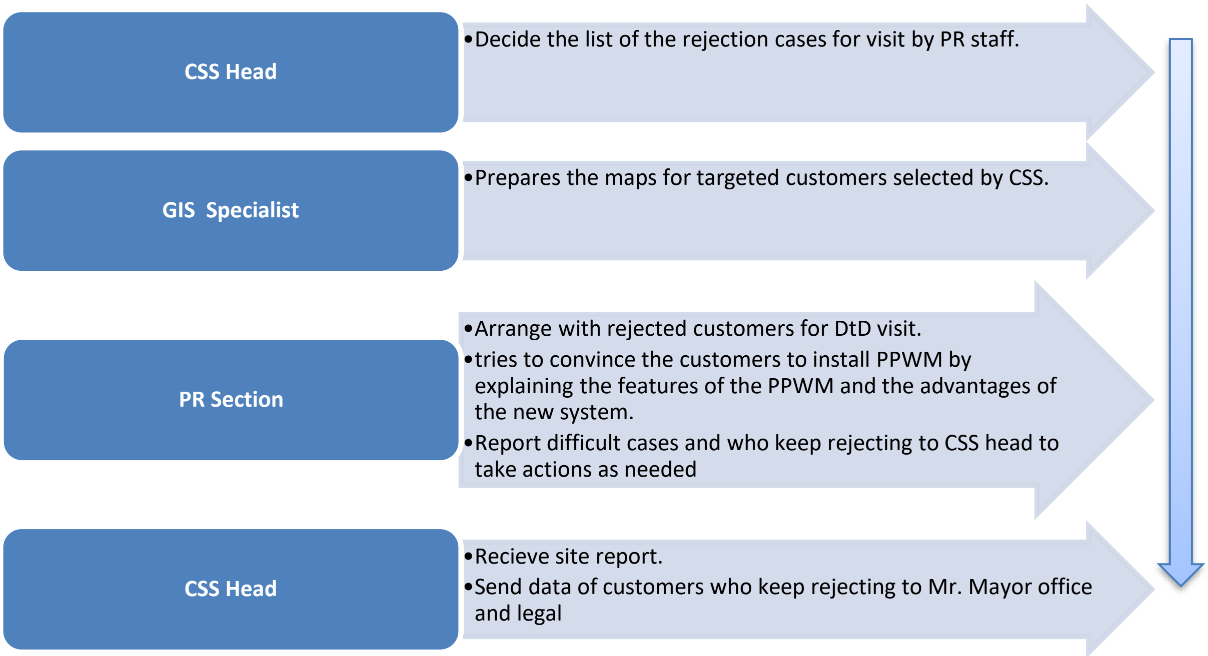


Figure 5-6: Work Flow of Rejection Cases

5.1.7 Workflow of Social Cases

There is no specific procedure to deal with these cases. It is currently don case basis.

5.1.8 Workflow of Monitoring Collection Ratio

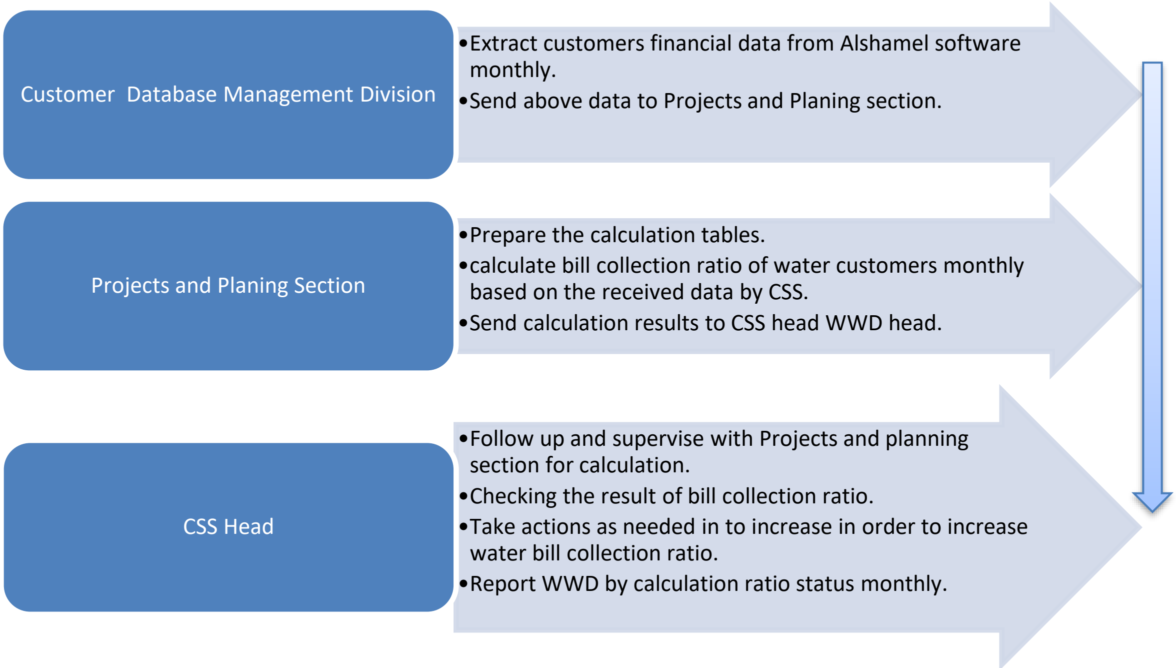


Figure 5-7: Work Flow of Monitoring Collection Ratio

5.1.9 Workflow of Customer Satisfaction

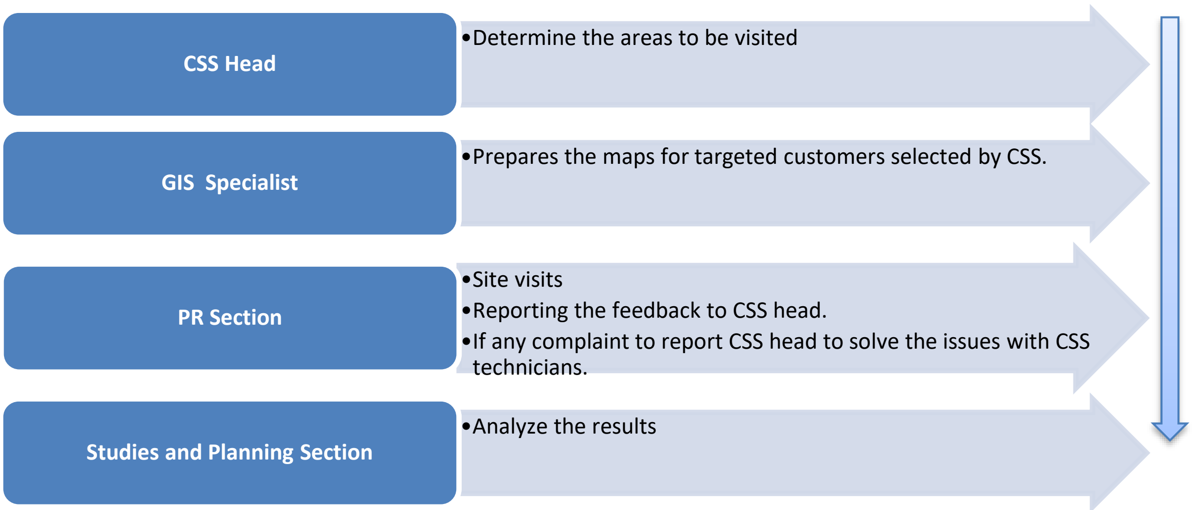


Figure 5-8: Work Flow of Customer Satisfaction

5.1.10 Workflow of PPWM Maintenance

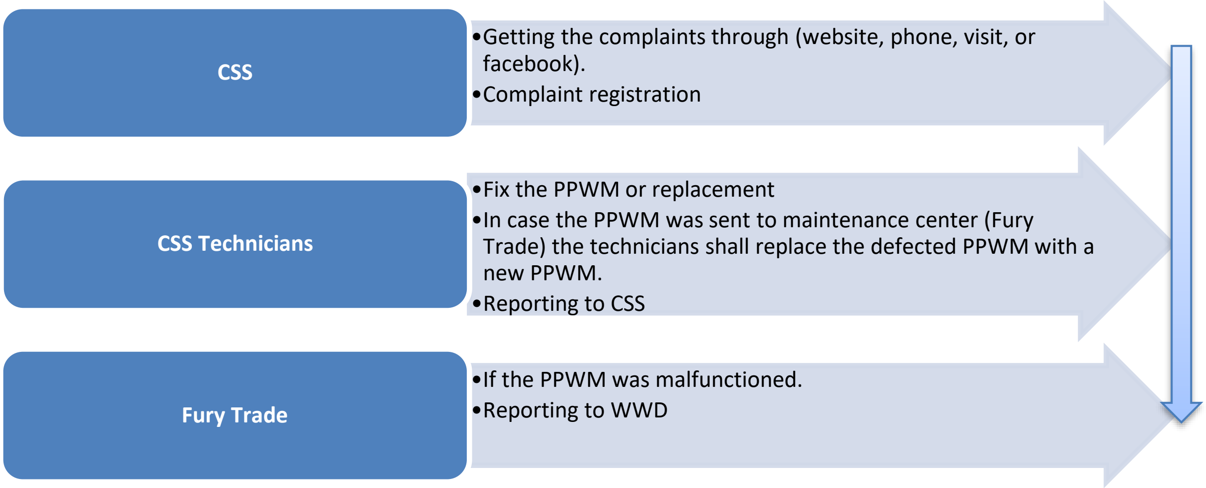


Figure 5-9: Work Flow of PPWM Maintenance

5.1.11 Workflow of Updating PPWM Inventory

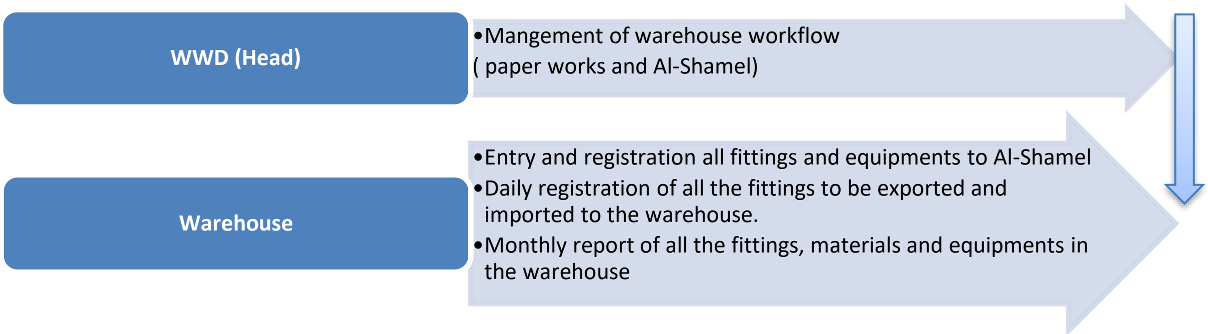


Figure 5-10: Work Flow of Updating PPWM Inventory

5.1.12 Workflow of Team Meetings (weekly)

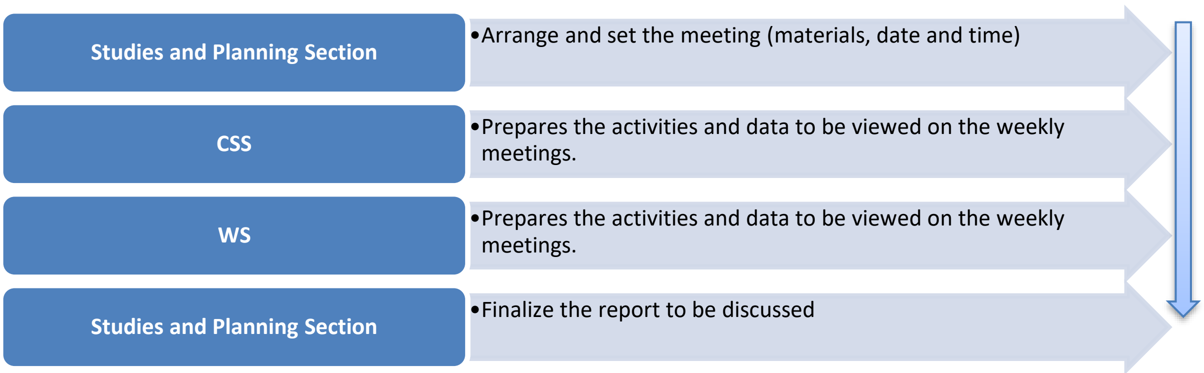


Figure 5-11: Work Flow of Team Meetings

CHAPTER 6 Challenges to Be Considered

6.1 Organizations

The issue of organizational structure and lack of staff is an obstacle for the installation of PPWM. This issue has been covered by recruiting new staff from Engineers Association in order to distribute the duties of the installation and the current staff will not face any problems with continuity of their responsibilities. Besides, the municipality requested that the installation is outsourced to cover the lack of staff issue.

6.2 Maintenance of PPWM

To describe the current situation of 3200 installed PPWM; CSS is the most related section to the maintenance and after interviewing the person in charge of maintenance, the following issues were highlighted:

- Availability of staff to interact with the maintenance complaint directly.
- Improving response time for the maintenance complaints.
- Improving maintenance quality from maintenance center (FT).
- Build the capacity of the current staff to overcome the maintenance issues. Furthermore, to adopt the idea of implementing a small maintenance center in WWD.

6.3 Implement Improvement Measure of Water Supply Condition

Firstly, the water supply conditions in Jenin city are described with two terms: shortage of water and low-pressure network in some areas. These issues could be handled by improving the current network (rehabilitation and maintenance of network), reducing NRW ratio, and increasing the customer share of water by contracting with new sources.

6.4 Reporting

The reporting and meetings in WWD has been improved due to capacity building in the project of "Strengthening the Capacity of Water Service Management in Jenin Municipality" compared with the base time. The staff of WWD is able to create reports to reflect all the activities conducted in the department. The monthly report is created and established by Planning and Studies Section in WWD, besides arranging weekly meetings to review the activities by each section of the department.

The documentation of all activities in WWD could be classified for a scale 1-5 as 4.5. Any employee could review any document or any activity by going to the data base of the department and find it easily.

6.5 Customer satisfaction measures: survey, post installation, social media

6.5.1 Survey

The challenge that has occurred was the availability of PR staff in WWD: It is preferable to recruit a new staff for PR activities in WWD (one person).

6.5.2 Post Installation

- Reducing the response time of CSS toward the complaints of customers.

6.5.3 Social Media

- Design of published posts
- Training courses for the PR staff on design software (Adobe Photoshop)
- Lack of equipment (high quality camera and PCs)

CHAPTER 7 Forecast of Revenues

7.1 Estimated Revenues for PPWMs

The revenues (including debt collection) of the installed PPWMs are calculated based on the trends of the revenues of Dec 2019 to July 2021. Since there was no installation due to the delays in the PPWMs by the Israel customs during July 2021 to September 2022, these dates were excluded for the above trend to avoid a break in the trend The estimated revenue from October 2022 is based on the trend. The rate of installation time schedule from contractor were into consideration for the forecast till the end of the 4,350 PPWMs by April 2023. After April 2023, the installations would be only for the new customers – which is counted as average 40 new PPWMs customer per month. The following tables present the forecasting of the revenues after 3 years of installation.

Table 7-1 Revenues from PPWMs from Dec 2019 to July 2021 (including debt collation**)**

Month	Total Installed	No. of Installed	Charge per month	Total paid
Dec-19	793		447	56,127.00
Jan-20	1301	508	663	73,086.00
Feb-20	1743	442	992	106,195.00
Mar-20	1824	81	1159	141,808.00
Apr-20	1863	39	1072	124,572.00
May-20	1902	39	1149	143,030.00
Jun-20	2011	109	1234	152,315.00
Jul-20	2171	160	1377	180,766.00
Aug-20	2371	200	1386	174,593.00
Sep-20	2613	242	1660	212,527.00
Oct-20	2728	115	1633	203,205.20
Nov-20	2822	94	1581	179,061.00
Dec-20	2911	89	1643	196,930.50
Jan-21	3075	164	1631	180,056.50
Feb-21	3139	64	1660	179,660.00
Mar-21	3160	21	1795	210,551.00
Apr-21	3189	29	1919	220,585.62
May-21	3189	0	1916	254,961.00
Jun-21	3189	0	1906	254,927.00
Jul-21	3201	12	1892	261,974.80
Total				3,506,931.62

Table 7-2: Forecasted Revenue of PPWMs for Years 2022-2025

Month	Installed PPWM	Avg. Install/ Month	Total Customers Without Camp	Remaining	Charges Per Month[1]	Total paid
22-Oct	3813	640[2]	8100	4287	1892	272,808.22
22-Nov	4453	640	8140	3687	2576	318,901.30
22-Dec	5093	640	8180	3087	2943	364,994.37
Total						956,703.89
23-Jan	5733	640	8220	2487	3309	411,087.44
23-Feb	6373	640	8260	1887	3675	457,180.52
23-Mar	7013	640	8300	1287	4041	503,273.59
23-Apr	7653	640	8340	687	4408	549,366.66
23-May	8293	40[3]	8380	87	4774	595,459.74
23-Jun	8333	40	8420	87	4797	598,340.55
23-Jul	8373	40	8460	87	4820	601,221.37
23-Aug	8413	40	8500	87	4843	604,102.19
23-Sep	8453	40	8540	87	4865	606,983.00
23-Oct	8493	40	8580	87	4888	609,863.82
23-Nov	8533	40	8620	87	4911	612,744.64
23-Dec	8573	40	8660	87	4934	615,625.45
Total						6,765,248.97
24-Jan	8613	40	8700	87	4957	618,506.27
24-Feb	8653	40	8740	87	4980	621,387.09
24-Mar	8693	40	8780	87	5003	624,267.91
24-Apr	8733	40	8820	87	5026	627,148.72
24-May	8773	40	8860	87	5049	630,029.54
24-Jun	8813	40	8900	87	5071	632,910.36
24-Jul	8853	40	8940	87	5094	635,791.17
24-Aug	8893	40	8980	87	5117	638,671.99
24-Sep	8933	40	9020	87	5140	641,552.81
24-Oct	8973	40	9060	87	5163	644,433.63
24-Nov	9013	40	9100	87	5186	647,314.44
24-Dec	9053	40	9140	87	5209	650,195.26
Total						7,612,209.19
25-Jan	9093	40	9180	87	5232	653,076.08
25-Feb	9133	40	9220	87	5255	655,956.89
25-Mar	9173	40	9260	87	5277	658,837.71
25-Apr	9213	40	9300	87	5300	661,718.53
25-May	9253	40	9340	87	5323	664,599.34
25-Jun	9293	40	9380	87	5346	667,480.16
25-Jul	9333	40	9420	87	5369	670,360.98
25-Aug	9373	40	9460	87	5392	673,241.80
25-Sep	9413	40	9500	87	5415	676,122.61
25-Oct	9453	40	9540	87	5438	679,003.43
25-Nov	9493	40	9580	87	5461	681,884.25
25-Dec	9533	40	9620	87	5483	684,765.06
Total						8,027,046.84

[1] Charges Per Month: Number of charged cards monthly.
[2] 640 PPWM: 600 installed by contractor and 40 PPWM installed by CSS technicians as new customers.
[3] Expected average new customers per month to be installed by CSS technicians.

7.2 Estimated Revenues for Mechanical Water Meters

The collection ratio from the mechanical water meters as shown in the following table. Debt collection may increase as the debt collection campaign is strengthen and will have impact on the forecasted revenue from July 2022 as shown in the table.

Table 7-3: Forecasted Revenues Summary Table for Mechanical Meters

Month	Regular	Installed PPWM	Total Customers including camp	Bill Regular	Paid with debt	Paid w/o debts	Debt only
Feb-20	6228	1743	9471	775,535	322,352	212,571	109,781
Mar-20	6045	1824	9369	588,740	164,724	116,190	48,534
Apr-20	5946	1863	9309	540,289	39,205	37,184	2,021
May-20	5953	1902	9355	538,032	77,219	63,908	13,311
Jun-20	5679	2011	9190	695,426	369,940	206,628	163,312
Jul-20	5568	2171	9239	537,219	215,738	130,421	85,317
Aug-20	5542	2371	9413	594,689	265,708	163,420	102,288
Sep-20	5378	2613	9491	549,605	221,351	143,622	77,729
Oct-20	5217	2728	9445	549,091	203,421	139,112	64,309
Nov-20	5152	2822	9474	533,125	177,692	115,025	62,667
Dec-20	5068	2911	9479	499,355	195,659	90,427	105,232
Jan-21	4976	3075	9551	560,843	279,479	82,323	197,156
Feb-21	4939	3139	9578	476,526	218,245	119,364	98,881
Mar-21	4863	3160	9523	451,079	159,154	106,982	52,171
Apr-21	4836	3189	9525	460,989	165,295	118,560	46,735
May-21	4843	3189	9532	606,496	182,252	112,031	70,221
Jun-21	4843	3189	9532	975,690	282,423	199,127	83,296
Jul-21	4831	3201	9532	595,256	207,102	151,678	55,425
Aug-21	4840	3201	9541	554,098	227,841	151,759	76,082
Sep-21	4842	3201	9543	547,251	278,434	184,230	94,204
Oct-21	4837	3201	9538	541,956	273,192	197,340	75,852
Nov-21	4843	3201	9544	471,981	227,122	156,354	70,767
Dec-21	4851	3201	9552	462,985	222,176	130,440	91,736
Jan-22	4899	3201	9600	509,049	255,678	108,761	146,917
Feb-22	5018	3173	9691	488,769	215,857	141,653	74,205
Mar-22	5022	3173	9695	477,013	230,234	162,259	67,975
Apr-22	4952	3173	9625	508,706	154,808	108,109	46,699
May-22	4970	3173	9643	601,179	271,830	190,056	81,774
Jun-22	5017	3173	9690	546,948	205,925	126,148	79,777
Jul-22	5007	3173	9680	536,891	180,428	148,601	31,827
Aug-22	5007	3173	9680	557,289	212,648	133,369	79,278
Sep-22	5007	3173	9680	506,039	197,584	122,502	75,082
Oct-22	4287	3813	9740	416,329	171,216	103,479	67,737
Nov-22	3687	4453	9780	341,570	149,243	87,626	61,617
Dec-22	3087	5093	9820	266,812	127,270	71,774	55,496
Jan-23	2487	5733	9860	192,053	105,297	55,921	49,376
Feb-23	1887	6373	9900	117,295	83,323	40,068	43,255
Mar-23	1287	7013	9940	42,536	61,350	24,216	37,134
Apr-23	687	7653	9980	32,222	39,377	8,363	31,014
May-23	87	8293	10020				-

After installation of the 4,350 PPWMs, the remaining customers that still have a mechanical water meter are 2,187 customers (including camp).

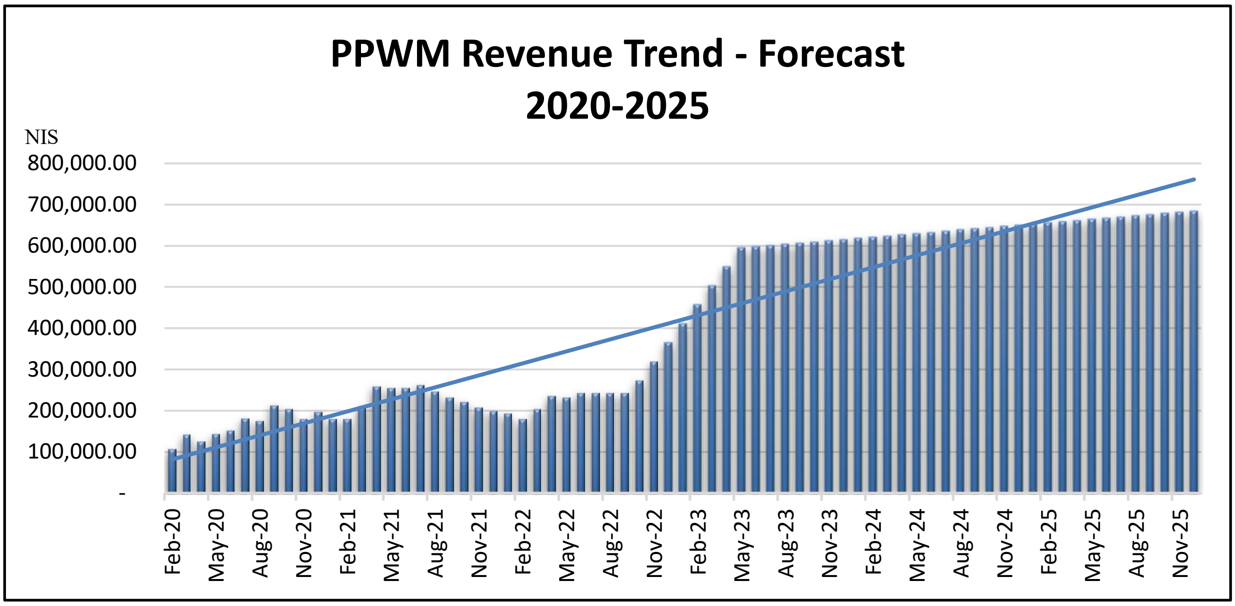


Figure 7-1: Revenue Increasing Trend with Debts by Month for PPWM

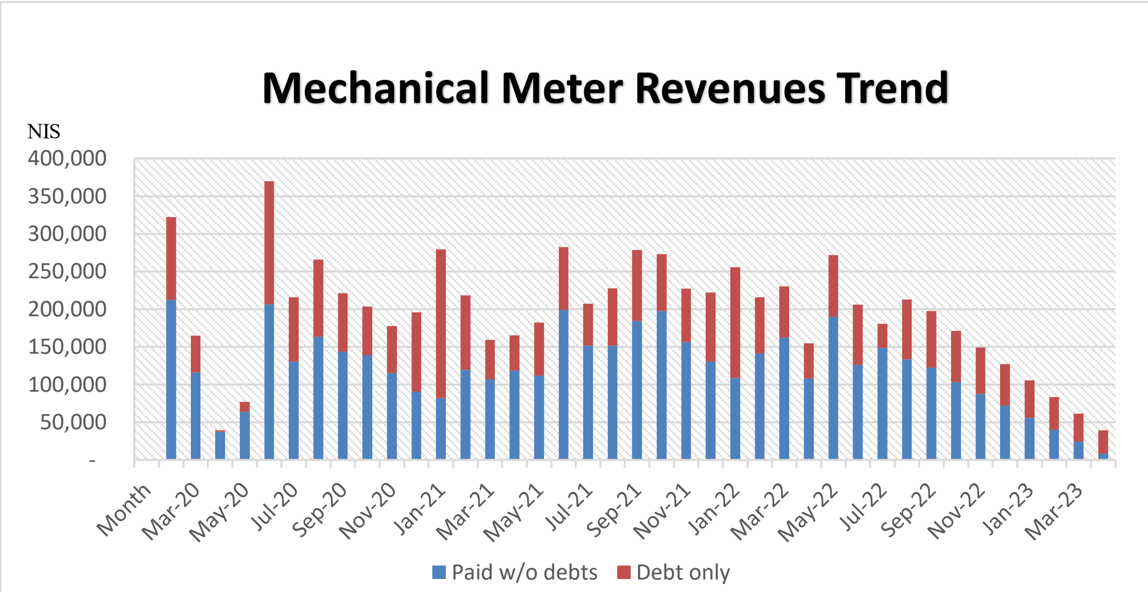


Figure 7-2: Revenue Decreasing Trend with Debts by Month for Mechanical Meters

Annex 2.3

Case Study of Prepaid Water Meter

Case Study of Prepaid Water Meter

(Final Report)

Part 1. Case Study of Prepaid Water Meter (PPWM) in Sub-Sahara Africa

Part 2. Key Findings and Recommendations on Introduction of PPWM

June 2022

Japan International Cooperation Agency (JICA)

TEC International Co., Ltd.

PADECO CO., Ltd.

Final Report

Part 1:
Case Study of Prepaid Water Meter (PPWM) in Sub-Sahara Africa

Table of Contents

Abbreviations

CI	Commercial Institutions
CIU	Customer Interface Units
DMA	District Metered Area
K	Zambian Kwacha
MMU	Meter Management Unit
NWASCO	National Water Supply and Sanitation Council
NRW	Non-Revenue Water
O&M	Operation and Maintenance
PI	Public Institutions
POS	Point of Sales
PPWM	Prepaid Water Meter
PSP	Public Standpost/Standpipe
PTS	Public Tap Stand
R	Residential
STS	Standard Transfer Specification
USD	United States Dollar
UShs	Ugandan Shillings
WASREB	Water Services Regulatory Board

Part 2. Case Study of Prepaid Water Meter (PPWM) in Sub-Sahara Africa

1. Introduction

In 2014, the World Bank Group's Water and Sanitation Program (WSP) conducted a comprehensive survey of water meter prepaid systems (hereinafter referred to as "prepaid water meters (PPWM)") in eight African cities: Lusaka in Zambia, Nakuru and Nairobi in Kenya, Mogale in South Africa, Maseru in Lesotho, Kampala in Uganda, Maputo in Mozambique and Windhoek in Namibia. Based on internet-based literature surveys it was found that PPWM was applied more commonly in the Sub-Saharan Africa region than in the other parts of the world. Therefore, the PPWM survey was decided to focus on Sub-Saharan Africa.

The eight WSP cities mentioned above were contacted through the JICA field offices and requested to participate in the PPWM survey. Only six cities responded with cooperation to participate in the survey except South Africa's Mogale and Lesotho's Maseru. In Zambia, four additional cities (Nkana, Kafubu, Mulonga, and Lukanga) were also willing to cooperate in the survey. Finally, it was decided to conduct a survey of 10 cities (see Fig. 1).

In this survey, an email-based questionnaire survey method to collect information was adopted. In addition, in order to facilitate the answer, the questionnaire was mainly composed of multiple choice questions.

A questionnaire was distributed to water utilities in 10 cities to conduct a survey during the months of January to March 2021. Of these, responses from 9 cities (except Windhoek, where PPWM was not fully implemented) were analyzed between March and April 2021 and is presented in this report.

Figure 1 Location of Participant Cities of the Prepaid Water Meter Survey

In addition, with the help of field assistants in Uganda and Zambia, a face-to-face survey of users of public PPWM/water kiosks and individual PPWM users and focus groups was also conducted in Kampala and Lusaka. The results of the face-to-face survey follow the summary of the PPWM experience of the utilities.

2. Summary of PPWM experience of Utilities

2.1. Prior issues and objectives of PPWM installation

All the surveyed water utilities faced numerous water supply problems prior to PPWM introduction. Some of those issues faced by the water utilities are listed below. PPWM has are mainly of 2 types: individual and public standpost (PSP)

Table 1 Issues of Water Utilities before PPWM Introduction

Major Issues	Individual PPWM						Public Standpipes (PSP)		
	Lusaka	Nkana	Kafubu	Mulonga	Lukanga	Maputo	Nairobi	Nakuru	Kampala
High NRW	√	√	√	√	√	√	√	√	√
Low revenue collection	√	√	√	√	√	√		√	√
Errors in Billing	√	√	√	√		√			
Low supply Pressure		√	√					√	
Intermittent Supply	√					√		√	

Remarks:
1: In Kampala, there are individual type PPWM, but these types of PPWM are installed only in public institutions and not in households. Since water utilities in Kampala did not answer the questionnaire for individual PPWM, this table does not show individual PPWM.
2: In Lusaka, PSP type PPWM also exist, however since the water utility of Lusaka did not answer the questionnaire of PSP type, PSP type PPWM is not shown in this table.

Some utilities faced other specific issues as listed below:

- Huge water loss due to customers puncturing water mains (Nakuru)
- Supply duration was dependent on caretaker availability (Kampala PSP)
- Public institutions had accrued a huge debt in water bills (Kampala)
- Caretakers of PPWM and landlords were not paying bills although they collected it from the residents (Kampala PSP, Nakuru)

To overcome the issues mentioned above, the surveyed utilities introduced PPWM with the objective as listed below:

Table 2 Purpose of Introduction of PPWM

Objectives to Install PPWM	Individual PPWM							Public Standpipes		
	Lusaka	Nkana	Kafubu	Mulonga	Lukanga	Maputo	Kampala	Nairobi	Nakuru	Kampala
Increase revenue collection	√	√	√	√	√			√	√	√
Reduce staff workload	√		√	√	√			√	√	√
Supply water to low-income areas	√							√	√	√
Enable pro-poor tariff									√	√
Curb intermediaries									√	√
Efficiently distribute water	√								√	

In addition, PPWM was also introduced to reduce complaints in billing errors (in Maputo), to improve hygiene in low-income areas (in Nakuru), and to curb arrears of government offices (in Kampala).

2.2. Decision making process and funding arrangement

Decision of PPWM introduction were self-induced for some utilities while others conducted market study, field visits (local and abroad), and supply-sales analysis. Lukanga conducted a benchmarking visit to Lusaka to learn about PPWM and avoid the problems and challenges faced in introducing PPWM. In Kampala, the utility introduced PPWM following government's pro-poor service strategy. Mulonga and Kafubu's water utility's management and board meetings decided on PPWM introduction.

PPWM decisions require careful fund management plans as the initial cost of PPWM system is 3-4 times costlier than postpaid system. In the surveyed cities, Kampala and Lukanga initiated PPWM with their own funds, whereas Nkana, Kafubu, Nakuru, and Mulonga relied on donor and/or subsidies from government. Figure 2 below presents the sources of funds and the estimated investment recovery period of PPWM for the surveyed utilities. Overall, the estimated payback period of investment cost of PPWM for the surveyed utilities was in the range of 3 - 12 years.

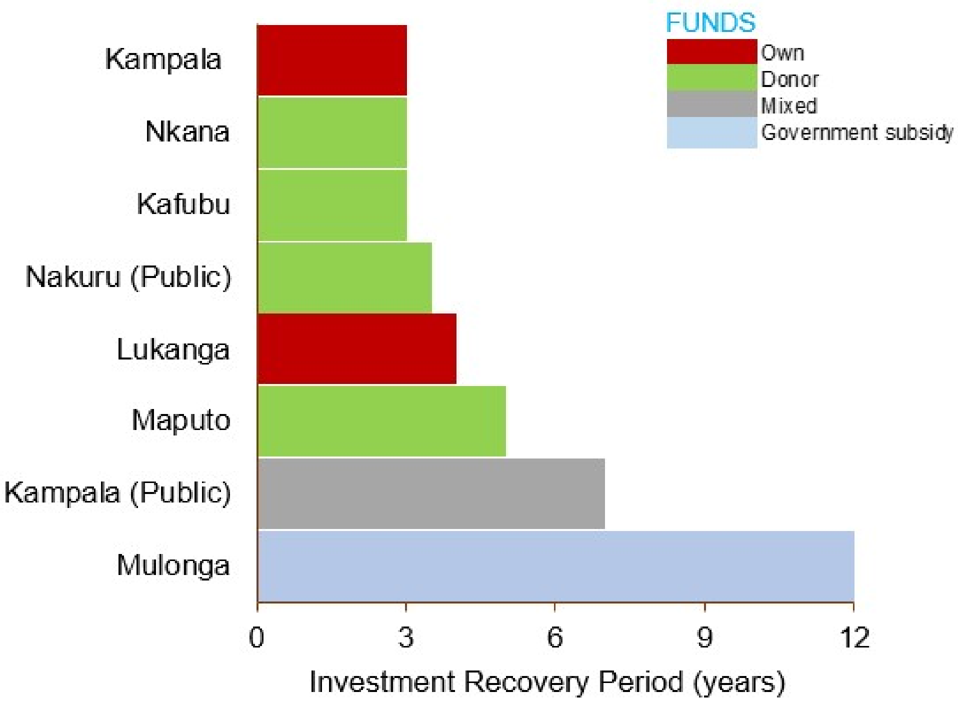


Figure 2 Source of Funds and Estimated Recovery Period of PPWM Investment

2.3. Implementation

Among the target cities, Kampala was the first to introduce PPWM in 2006, while other cities introduced PPWM later, some as recent as 2019 (Kafubu). Table 1 outlines the target area, type of installations, initial roll out units, total current installations, household served and average annual installations.

Table 3 Outline of PPWM Implementation in the Surveyed Utilities

Start Year	City	Target Area	Initial roll out (units)	Total current installations	Households served	Average annual installations
2006	Kampala	Urban Poor		1500 PSP	150,000*	N/A
2012	Nakuru	NA	15	155 PSP	3,875	Not continuous
	Nkana	Stable water supply, Areas with DMAs, High debt areas	250 (2012) 1,400 (2015) 13,816 (2018)	21,742 R 156 C 100 PI	21,998	1400 (2015) 13816 (2018)
2013	Lusaka	Govt. offices, Unmetered satellite towns, High debt areas, Stable water supply		12,113 R 789 C 72 PI	13,110	4500
2015	Mulonga	Transit town, Low-income area	300	300 R	300	10-20 (replaced)
2016	Lukanga	High debt areas		1,133 R 136 C 16 PI	1,300	10
2017	Nairobi	Unplanned settlements Low-income area		165 PSP	25,000	60
	Kampala	Public Institutions	200(in Uganda)	200 PI		
	Maputo	High debt areas Stable water supply	2500	2,400 R 100 C	2,500	
2019	Kafubu	Low & Middle-income areas		10,000 R	10,000	

R: Residential C: Commercial PI: Public Institutions PSP: Public Standpost/Standpipes *: Population served

2.4. Credit vending in PPWM

Credit vending is done in different forms according to the installation type and the brand of the PPWM. Tokens or coins were used for credit vending for both individual and public PPWM in Lusaka, Kafubu, and Maputo. Smart cards were mostly used in individual PPWM in Mulonga, Nkana, Lukanga and Kampala. Nkana and Lukanga have also introduced STS[1] (standard transfer specifications) systems of payment of water bills. Nkana, Kafubu, Maputo, Kampala, Nakuru have introduced electronic payments such as mobile money. An example of credit recharge via mobile money is shown in Figure 3.

[1] Standard transfer specification (STS) is a secure message protocol that allows information to be carried between point of sale (POS) equipment and payment meters.

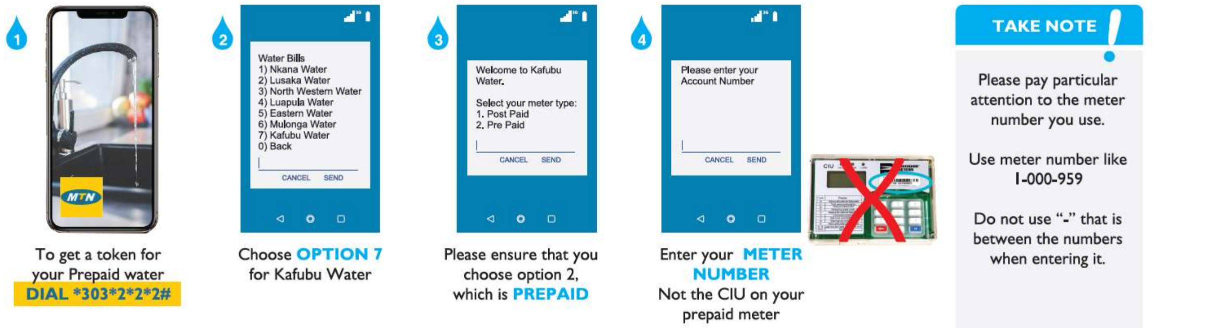


Figure 3 Example of Kafubu Water PPWM payment via MTN Mobile money

Table 4 Details of various vending methods in the surveyed utilities

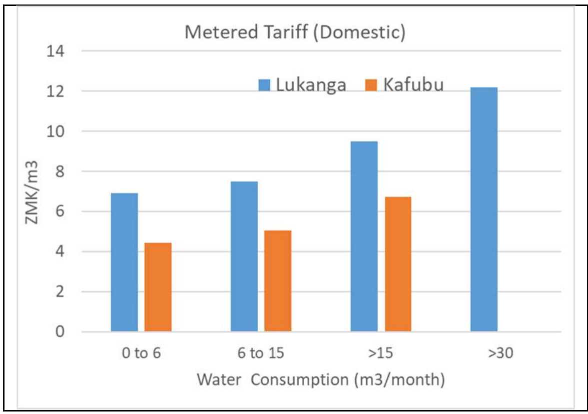
City	Vending Method	Number of Pay points	Location (Distance to pay points)
Lusaka	Pay points, Electronic payment	Each PPWM area	4 km
Nkana	Pay points, Mobile, Digital Banking	16	-
Kafubu	Pay points, Mobile	Each PPWM area	5km
Mulonga	Pay points	2	500m
Lukanga	Pay points	2	200m
Maputo	Utility office, Electronic, Pay points	Multiple	Nearby
Kampala	Electronic	Remotely	-
Nairobi	PPWM Operator	165	
Nakuru	Utility Office, Mobile Money	6	2km
Kampala PSP	Pay points, Handheld devices	75	2km

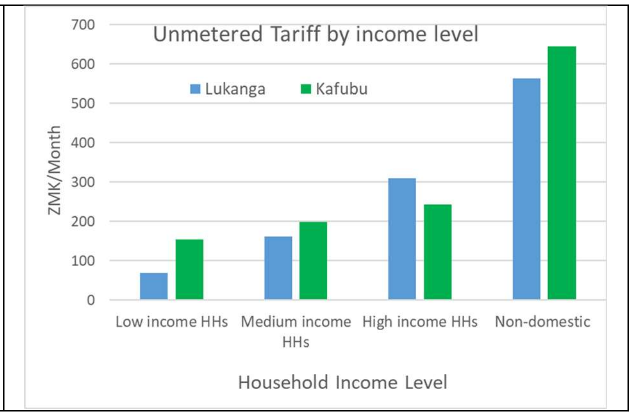
Table 2 above outlines different types of vending method, the number of pay points and location of such pay points in the surveyed utilities. Credits are loaded into customers token via handheld devices at designated pay points as shown in Photo 1. Individual PPWM connections also offered programmable options to recover customers debt including installment payment. Debts are recovered as a portion of the payment a customer makes for water credit with 40% in all the Zambian utilities and 50% in Maputo.

Photo 1 Loading credits into a token via handheld device

2.5. PPWM as a system favoring in-need customers

Poverty alleviation measures such as maintaining low tariff was adopted in most of the surveyed utilities. A such example of low tariff in metered and unmetered connections in Lukanga and Kafubu is shown in Figure 4. In Kampala, improving access to safe water such as by introduction of PPWM was considered as key to the welfare of individuals and a step further towards poverty alleviation.





Note: ZMK (Zambia Kwacha: 1 ZMK =about 5.7 yen)

Figure 4 Subsidized tariff of metered and unmetered connections for low-income households in Lukanga and Kafubu

Similar consideration for low-income users found in other cities such as:

- In Nakuru, customers from low-income areas whose monthly consumption is 1-6 units are protected by a low-rate pro-poor tariff under the government regulation.
- In Lukanga, PPWM tariff for the low-income categories are cross subsidized by differences in usage by those in high income customers categories.
- Maputo and Mulonga reported that PPWM customers can manage their own consumption and water expenses which prevents from accumulating debts.
- In Nkana, customers who had huge debts and were disconnected for long periods have been able to buy PPWM units using minimal amounts. The PPWM is also pre-programmed to recover accumulated debts gradually at a lower percentage providing them sufficient time to pay their debts.

None of the utilities in the surveyed cities reported any experience of customers not being able to afford payment. While there were no specified measures, for any cases utilities reported that they would either:

- Request customers who cannot afford to pay for PPWM to either seek help from well-wishers.
- Provide affordable kiosks.
- Suspend debts.
- Provide first token for free.

2.6. Public consensus, willingness to use and awareness

Majority of the surveyed utilities consulted with the prospective PPWM users and conducted awareness campaigns both prior and post PPWM installations. Consultations were conducted through community meetings, stakeholder meetings, public hearings, and door to door consultations. Awareness campaigns and information dissemination methods utilized by the surveyed utilities are listed in the following table.

There was very minimal refusal to install PPWM in the surveyed cities, yet some residents were reluctant to leave post-paid meters. In Maputo and Nkana, customers refusing to install individual PPWM installations were left with the postpaid system. Such refusal was minimal or absent in Lusaka, Kafubu and Lukanga. If a landlord refused to allow public PPWM in his land, utilities looked for other location.

Table 5 Public Awareness Raising Method

	Methods of Public Awareness Creation	
City	**Prior to PPWM Installations**	**Post PPWM Installations**
Lusaka	Radio, TV, printed advertisements	
Nkana	Radio programs, Engagement meetings	Quarterly awareness meetings
Kafubu	Community Meetings Radio	
Mulonga	Drama, Flyers	Door to door sensitization
Lukanga	Radio advertisements, Brochures, Online, Community Meeting	Radio
Maputo	No	No
Kampala	Support of Accounting Officers	On premise training of users
Nairobi (PSP)	Campaigns on advantage of PPWM, level of service and quality of water	Training to use PPWM
Nakuru (PSP)	Landlords, Tenants	Demonstration the use/draw water from PPWM, Report abnormality
Kampala Public (PSP)	Public Hearing, Stakeholder meeting, Community meeting, Individual consultation	

Post installation campaigns focused on assisting customers how to use/draw water from PPWM and detect any abnormality, though not all utility carried out such campaigns. Nkana conducted post installations campaigns on a quarterly basis. Except Kafubu and Lukanga, all the surveyed utilities conducted satisfaction survey and found the customers to be receptive and satisfied with the PPWM services. In Nakuru, tenants were happy to be able to access water at any time unlike before where landlords controlled their consumption by locking taps. PPWM users in Maputo, Lusaka and Mulonga recognized that they had full control over their consumption and water expenses and did not have to pay higher rates of water to the intermediaries. Utilities also reported that the customers were worried at the beginning to accept PPWM, but after installation, they considered PPWM as fair.

2.7. Regulations

PPWM was introduced in the surveyed cities as early as 2006, yet most utilities lacked specific regulations and policies guiding PPWM procurement, installation and operation and maintenance. Some of the regulations are listed below:

- In Zambia, the National Water and Sanitation Council (NWASCO) provides guidelines to safeguard utilities financial viability, protect customers from being exploited, achieve 100% metering policy, and ensure transparent PPWM installation.
- The Zambia Information Communication Telecommunication Authority (ZICTA) also requires conformation on the use of radio frequency.
- In Kenya, the government body, Water Services Regulatory Board (WASREB) ensures that PPWM tariff match the gazetted tariff for water kiosks in low-income areas.

2.8. Illegal cases and complaints

Except Kampala (public PPWM), all utilities reported experiences of illegal water use in PPWM which were mainly meter bypass, PPWM unit or battery removal, illegal connections, and meter tampering.

Bypass means customers cutting pipes before the PPWM. Illegal cases, detection methods and actions taken towards such illegal uses varied among the utilities which are outlined in the following table.

Table 6 Illegal uses, method of illegal use detection, measures against illegal uses

City	Illegal uses	Detection	Measures
Lusaka	Meter bypass Meter tampering	Physical inspection	Inform the police
Nkana	Meter bypass Meter tampering Stealing PPWM fittings	Routine inspections	Penalty plus fees for their bills Prosecuted by law
Kafubu	Meter bypass	Tamper detection system	Charged, penalties
Mulonga		Extensive inspection	Fine of USD 50 equivalent to 3 months usage fee and reconnection fee of USD 3.75
Lukanga		Inspectorate under audit	Penalty and replacement cost Police report for non-compliance
Maputo	Meter bypass Meter tampering Battery removal	Consumption analysis, Those who do not buy water often are suspect cases	Legalized
Kampala	Removal of meter	Field visit, system reports	Fine (400,000 UShs and equivalent fee of 2 years use)
Nairobi	Meter bypass	Routine inspections	Arrests, fines
Nakuru		Informers, Consumption trend analysis, Regular monitoring	Disconnection, Fine (20000 Kenyan shillings)

Major complaints in PPWM reported by the utilities include battery problem (Lukanga, Nakuru, Kampala, Maputo), failing to recharge or load tokens (Lusaka, Kafubu, Mulonga), In addition, Lusaka also reported problems such as units running out quickly, customer unable to load token into meter, meter turning off, meter failing to close etc. whereas Kafubu reported leakage at the meter and valve failing to open.

In Nairobi, residents also complained of unable to access water when water pressure was low. A typical complaints list, and handling efficiency by the utility for Lusaka is shown in Table 3. Overall, it has addressed 51 out of 62 complaints most of which were related to leaks at meter (21) and desire to install PPWM (18).

Table 7 List of complaints and handling efficiency in Lusaka

Item	Reported	Resolved	Pending	Efficiency
Water Leaks at Meter	21	19	2	90%
No Water	11	10	1	91%
Pre-paid not Installed	18	11	7	61%
Low Pressure	4	4	0	100%
High Consumption	2	2	0	100%
Customer Interface Unit (CIU)/ Meter communication	3	3	0	100%
Damaged Meter	0	0	0	0%
Stolen meter	1	0	1	0%
Meter not recharging	2	2	0	100%
Total	62	51	11	82%

2.9. Operation and maintenances

All the utilities had a dedicated team for operation and maintenance of PPWM system. This team consist of one or more of the following:

- Customer care staff
- Sales technicians for vending control
- Plumber, IT technicians and engineers for technological issues.
- Sociologist to collect customer data during enrolment (in Kampala)

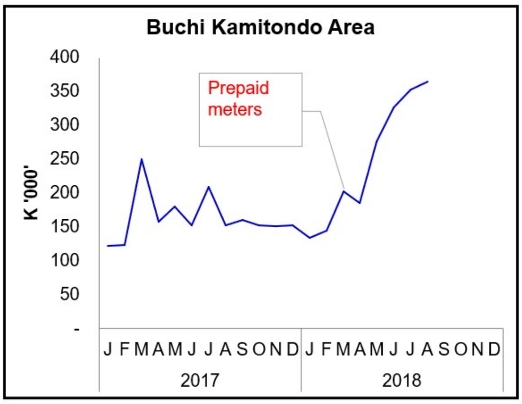
None of the utilities provided any incentives for accepting a PPWM installation, however the PPWM, fittings and first token were provided for free. The ownership of the PPWM remained with the utility in all the cities. The utilities were also responsible for the costs of PPWM and fittings, for regular checks, maintenances, repairs, and replacements. Besides this, Nkana also assisted its customers to recharge. Malfunctions were treated as utilities responsibilities; however, customers were liable to pay for any damages and tampering of PPWM units. In Kafubu, ageing meters were replaced by the utility whereas damaged meters were customers responsibility. If PPWM malfunction was found to be caused by customers negligence, Lukanga charged partial to full cost of replacement to the customers.

O&M, and monitoring policy of PPWM differed among the surveyed utilities as listed below:

- PPWM monitoring was conducted monthly (in Nkana), quarterly (in Lusaka), daily (in Nakuru) or periodically (Nairobi, Mulonga, Lukanga and Maputo).
- Lusaka has a metering policy which dictates meter replacement.
- In Nkana if a meter malfunctions, investigations are carried out to determine the cause. If it is a failure, a meter is replaced without any charge to the customer.
- In Mulonga meters are replaced after the attainment of the life cycle, however, all meters which are not repairable are replaced and this is done in accordance with the metering policy.
- In Nairobi, all malfunctioning PPWM are either repaired or replaced, whereas in Nakuru, replacement is only done if a component of the machine is faulty and beyond service.

2.10. Impacts after introduction

All the utilities reported increase in revenue collection after the introduction of PPWM. For instance, as shown in Figure 5, revenue collection sharply increased in the following months after the PPWM was introduced in two service areas of Lukanga. In Lusaka, when technical failures were encountered on a large scale, the revenue started to decrease.



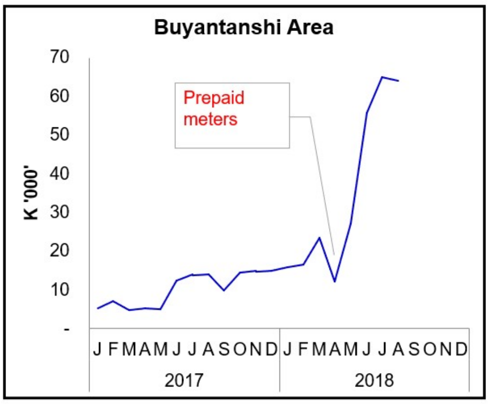


Figure 5 Revenue collection in two service areas in Lukanga

Overall, PPWM reduced various costs for most utilities as shown in Figure 6. There was a decrease in billing and collection and customer management costs for a majority of the utilities. Contrary to that, operation and maintenance costs increased for 4 utilities. Logistics costs either decreased or was unchanged for majority of the surveyed utilities.

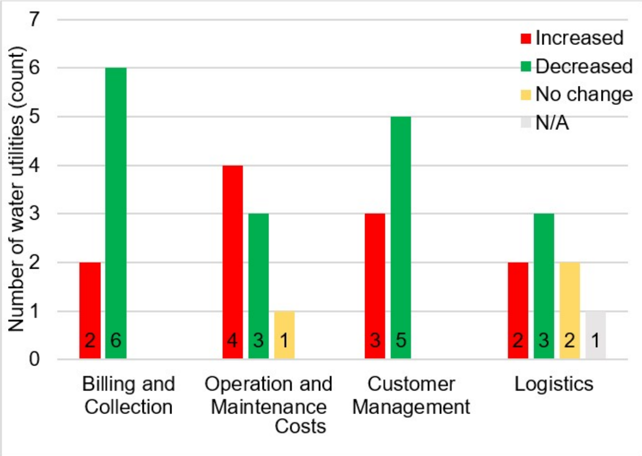


Figure 6 Impact of PPWM on various utility costs

Other impacts of PPWM are listed below:

- **Human Resources**: Most utilities reported no change (no additional recruitment) in the number of staffs. In Kafubu and Mulonga some staffs were transferred to other duties.

- **Water Consumption:** Water consumption decreased by 66% in Nkana and 10% in Maputo where consumption went back to the previous levels soon after. In contrary, water consumption in Mulonga increased by 50%.

- **Water Loss:** Water loss decreased in 6 of the surveyed utilities but increased in Nkana.

- **Water supply hours:** PPWM installations were too few to affect supply hours in Kampala and Maputo. However, in 6 other utilities, the supply hours increased after PPWM introduction.

- **Number of Customers:** None of the utilities reported substantial increase in the number of PPWM customers except for Nakuru and Nairobi. In Nakuru, the rate of annual new installation was about 5,000 units which probably increased customers count.

2.11. Problems in O & M

Some of the problems in O&M of PPWM in the surveyed utilities are:

- Meter failed to close or meter is off (in Lusaka).
- Theft of prepaid meter fittings (Nkana)
- Leaks at the meter and token swap (Kafubu).
- Product malfunction rates were as high as 50% a year (Lusaka) and 40 % a year (Nakuru and Lukanga). Malfunctions were mainly caused by product failure (Lusaka, Nakuru), electrical components failure (Mulonga and Nkana), mechanical failures (Mulonga, Maputo), and battery failure (Kampala and Lukanga).
- None of the utilities received supplier's training except Kafubu.

- Only five of the nine utilities reported having a workshop for repair and maintenance works.
- Maputo and Mulonga did not receive any service after sales from the manufacturer.

Some of the after-sales services provided by the supplier were:

- In Nakuru, battery depletion and solenoid valves problems are handled by the suppliers.
- Software support was provided by the supplier in Lusaka, Kampala, Lukanga, Nakuru and Nairobi.
- Nkana received remote support and free replacements from the supplier.

Besides, spare parts were not easily available in the local market of the surveyed cities except Nkana which stocked spare parts such as batteries, customer user interface and infrared tools from the manufacturers. In Nairobi, the local agent of the manufacturer had spare parts availability whereas Kampala had stock of spare batteries.

Lusaka, Maputo, and Kampala had either no meter test bench or did not perform any meter accuracy test. Whereas Nkana, Mulonga, Lukanga and Nakuru possessed meter test bench. Nakuru, Nairobi and Nkana have caretakers in authorized areas to attend all prepaid matters for security and credit vending purposes.

2.12. Issues and challenges in PPWM

Some of the issues and challenges reported by the surveyed utilities are itemized in the table below under different categories.

Table 8 Issues and Challenges of PPWM

S. N	Items	Issues
1	Policy	- Lack of guidelines, manuals on procurement, installation, and O&M - No standardized data capture protocols - Lack of tariff structure. Post-paid tariff applied to prepaid - Land tenure system – Landlords control over installation space for PSP - Little or no interoperability of PPWM brands - Some STS systems disadvantage customers who purchase large amounts of water at once but consume it over several months. - Lack of standard penalty limits utilities to prosecute the customers further
2	Procurement	- Difficulty in preparing and evaluating specifications for PPWM tender - Limitation of suppliers in the local market compared to post-paid - Limited experience of most bidders - Difficulty to choose from brands with different functionalities - Delivery periods are long - Warrantee period are short - Most PPWM brands need to be imported which incurs procedural obstacles and delays
3	Technology/ Products	- Technology can only be proven to be reliable by piloting - Lack of adequate local technical support - Actual battery life is much shorter than marked battery life - Constant malfunctions of the PPWM unit
4	Software	- Require a lot of customization - Setting up tariffs and billing calculation is complex - Poor reporting and constant gaps in availability - Information consistency errors - High maintenance costs - Takes long time to upgrade

S. N	Items	Issues
5	Water supply conditions	- Air intrusion in intermittent supply leads to error in measurement - PPWM may not operate in low pressure condition - Sand intrusion may break impellers
6	Costs	- PPWM is 3-4 times more expensive than post-paid system - Extra components such as Customer Interface Unit, Automated Meter Reading (AMR) device and spares are costly - Unreliable technology increases costs substantially - High costs at introduction and benefits come in the long term - High O & M costs - Installation costs and license fees are also high
7	Installation	- No proper installation manual is provided by suppliers - Requires special protection from vandalism - PPWM is susceptible to water ingress if slightly damaged
8	Tariffs	- The tariff may be too low which can discourage further investment
9	Credit vending	- Different PPWM requires integration for vending - Customers require 24-hour access to credit vending - Difficult to access remaining credit from a malfunctioned token - Internet failure causes the system to delay in crediting
10	Social aspects	- Incoherent messages reaching the public about PPWM (tariff, breakage) - Low-income customers need continuous sensitization - Poor people may not always afford advance payment - PPWM should be located at convenient locations -less commuting time for target customers - Location of the PPWM should be such that it is accessible even at night - Being an advanced payment technology, complaints should be addressed on time otherwise it risks losing customers - Payment of penalty charge limits the utility in prosecuting the clients - Difficult to detect illegal uses remotely
11	Data collection	- Inefficient AMR systems - Low range radius of data transfer - Cost is high for real-time data transfer - Battery issues in meters affect data capture - Failure of meters due to bad weather and vandalism - Valve glitch as it stays open when it should close and vice versa
12	O & M	- Inadequate system reports - Lack of technical skills/competencies - High cost of spares - Unavailability of spares in local market - Lack of computerized test bench

2.13. Lessons learnt

Lessons learnt by the utilities is outlined in the table below.

Table 9 Lessons Learned on PPWM

City	Lessons learned
Lusaka	- All the stakeholders including utility staff should be made aware of the PPWM system - A reliable technology in PPWM should be procured
Nkana	- PPWM should be targeted in areas with stable supply and pressure and high debt

City	Lessons learned
Mulonga	- The project was not adequately supervised. - PPWM brand was poor which were non-serviceable - Utility staff lacked training - PPWM can be effective in low-income areas and Government properties
Lukanga	- Constant inspection of customer properties
Maputo	- PPWM specifications should be well prepared, and not purchased on price basis - Batteries do not last the reported time in years
Nairobi	- Promote use of PPWM which can run by solar power
Nakuru	- Provision of meters which are cost effective and technological compliance
Kampala	- Need to have good specifications - Ensure installations are done as per instructions - PPWMs are expensive but the social economic benefits outweigh the cost - Top utility management support is helpful

2.14. Recommendations

Despite several issues and challenges as highlighted above, all the surveyed utilities considered PPWM are willing to continue and promote PPWM. The surveyed utilities have the following recommendations to other utilities for a successful PPWM.

Table 10 Recommendations to other utilities for a successful PPWM

City	Recommendations
Lusaka	- Supply of water should be continuous. If intermittent, air valves are necessary - Well planned target areas such as having DMA - Extensive public sensitization both prior and after installation - Supplier's training to utility staff to install, repair, customer service, data management is advantageous. - PPWM should be introduced in separate areas than post-paid to recognize its actual advantages.
Nkana	- Dedicated team for PPWM is needed. - Availability of spares should be ensured before purchasing PPWM. - Replace all leaking pipes in the area.
Mulonga	- Meter Management Unit (MMU) and IT team should explore a good PPWM brand - The supplier should adequately train MMU and IT team in handling various prepaid meter challenges. - The two units should be integrated for the supervising and monitoring all PPWM.
Lukanga	- PPWM is best for revenue collection when applied to customers with huge debt - Sensitization and good customer service.
Maputo	- PPWM should be installed considering the water supply situation in the target area - The management of the meters should be delegated to a full team. Full teams should consist of multidisciplinary responsibilities consisting of engineering, commercial, IT, and administration personnel. - Training in the installation process - Include other technologies such as GIS for management
Nairobi	- Community sensitization and participation is very crucial
Nakuru	- Development of PPWM battery with a long lifespan and solenoid valve which does not dispense water free - Proper awareness & sensitization - Availability of spare parts should be ensured before purchasing PPWM units

City	Recommendations
Kampala	- Protection of PPWM is very important for their longevity - Stakeholder involvement at all stages - Community involvement before commencement

2.15. Major findings from the utilities PPWM experience

<u>Prior to Installation</u>

- Utilities mainly introduced PPWM with the objective of increasing revenue, controlling NRW, reducing staff load, and supplying water at pro-poor tariff through PSP.
- PPWM decision were mainly based on pilot projects, market study, benchmarking visit, or cost benefit analysis.
- Various public consultation and awareness raising programs were conducted prior (and even after) to installation, such as stakeholder meetings, public hearings, individual consultation.

<u>Implementation</u>

- Majorities of the utilities lack proper guidelines/policies on procurement, installation, O &M, monitoring and repairs.
- PPWM were mostly targeted in areas with high debt, stable water supply hours, and low-income.
- Installations were mainly done in a project basis. Utilities seldom made regular additions.
- In general, one public standpipe was installed to serve 25 – 150 households.

<u>Products</u>

- Selection of a PPWM brand was mainly based on availability of funds, product price, and availability of supplier.
- Premature battery failure was the major technological issue.

<u>Data Management</u>

- Not all utilities possessed automatization/web-based transfer. They still used handheld devices.
- PPWM accounting system was not integrated with the billing software, instead manual entry of sales using Excel was common.

<u>Issues</u>

- Illegal cases in PPWM were detected using field inspections, tamper detection system, and analysis of consumption trends. Actions against such illegal cases (fines, police charge) differed among the cities.
- Utilities mainly faced complaints of water leaks, no water during low pressure, and difficulty in credit charging/loading.

<u>Impacts</u>

- PPWM reduced utility costs for majority of the utilities mainly the billing and collection costs, customer management costs and logistics costs.
- There was either no change or staff’s responsibility was redistributed in majority of the surveyed utilities.
- PPWM helped to decrease water loss in 6 of the surveyed utilities.

3. Summary of Face-to-face Survey of Water Users

3.1. Case study in Kampala, Uganda

A face-to-face survey of water users was carried out among 16 respondents who used public standpipes PPWM, selected randomly from various parts of Kampala PPWM service area. Two focus group discussions were also carried out to collect additional opinions about the PPWM system. The results of the face-to-face survey and focus group discussions are presented below.

3.1.1. Characteristics of respondents

Nine of the 16 respondents were female. The average family size of the respondent household was 6 people (except 3 respondents who were business customers). The monthly income for the households ranged from Shs 100,000 (USD 27) to 900,000 (USD 246) with an average of Shs 226,250 (USD 62)[2]. Majority of the survey participants utilized ordinary meter stand post (50%) and other forms of piped water (38%) as main source of water prior to using public standpipes PPWM. One person fetched water from a borehole and another from a spring well. Twelve respondents (75%) reported receiving water 24 hours while the remaining participants received water intermittently from once a week to night only (7.00 pm to 6.00 am every night).

3.1.2. Community sensitization and PPWM installation

The installation of PPWM was preceded by community consultations and sensitization. Working with community leaders, residents were mobilized and informed about the proposal to introduce PPWM. The operation of the PPWM as well as the rationale for PPWM introduction was explained. The community was also trained on how to use it and assigned the responsibility to protect the PPWM. According to National Water and Sewerage Corporation (NWSC) the first credit tokens were given free. But to enlist commitment and enhance value of the token to the holders, each customer was registered and charged some UShs 5,000 (USD 1.4) for the token. The charged fee was put on the token as water credit. Community engagement continued even after the installation of the PPWM. When asked about how they came to know about PPWM, user respondents indicated that they had heard from the utility (56%), from community leaders (38%) and other community members. This confirms the sensitization carried out by the utility.

3.1.3. Use of PPWMs

Most of the respondents reported to have been using the PPWM for more than five years (56%). They were able to reach the nearest PPWM stand within 3 minutes, and some reported that half a minute is enough as the stands are just outside of their premises. Only 3 of the 16 respondents reported queuing every time at the stand post with one queuing for up to 15 minutes. The majority however 7/16 reported that there was no need to line up while 6/16 reported lining up occasionally.

Respondents reported that in most homes (38%) a male adult collects the water, followed by a female child (in 19% homes). Households reported collecting water from the tap stand between once in about 2 days to about 10 times a day. Some people reported collecting water more than 30 times a day, but these were reporting both for domestic use and for their nearby businesses (restaurant and hair salon). Typical households therefore collect water an average of 4 times a day.

[2] Exchange rate at UShs (Ugandan Shillings) 3,650 for one USD (United States Dollar)

Majority of the respondents (69%) reported an increase in water consumption in PPWM system, while others reported a constant rate of water use. Monthly expense on water ranged from UShs 3,000 (USD 0.8) to UShs 100,000 (USD 27) with an average of UShs 34,313 (USD 9.4). This expense on water had been decreasing for majority of the respondents (63%) though it had increased for some few (37%). In Kampala (and Uganda in general) customers do not receive any free water as also confirmed by all the survey respondents.

3.1.4. Paying commission to the standpipe attendant

Prior to PPWM, attendants at the postpaid standpipes used to sell water at a price above the tariff of the utility, making the markup as their income. This made water expensive for the poor people living in the informal settlements. However, at the PPWM none of the respondents reported paying a commission to the PPWM attendant implying that they received water from the stand tap at the utility tariff. However, in the focus group discussion, it was reported that some fake tap attendants who have tokens with loaded credits wait for customers with no tokens. Such fake tap attendants charge a commission fee but still provide convenience to the customer with no token. It was noted that this arrangement is made possible by rigidities in the availability of tokens and credit loading facilities. Such tap attendants charged up to UShs 500 for 20 litre jerry can which costs only UShs 25 at the PPWM with a token.

3.1.5. Functionality of the PPWMs

When asked about the frequency of break down, 94% respondents reported that the PPWM stands that they use had broken down between 1 and 6 times a year with an average of 3 times a year. The cause of the break down in almost all the cases was the battery. One respondent reported mishandling as the cause. The study team noted several malfunctioned PPWM standpipes including a damaged token receiver in one of those PPWM as shown in Photo 2.

Most of the respondents reported that they had not heard of either theft or vandalism of the PPWM near them. However, this study noted several PPWM with contraptions designed to prevent vandalism and misuse as shown in Photo 2.

Photo 2 Improvisations for the protection of PPWM

Also important in the perception of functionality of the PPWM is the efficiency with which lost or dysfunctional tokens can be replaced. When asked if they had ever lost or broken their token, 14/16 of the respondents replied that they had. This is an indicator that the problem of damaged or lost tokens is real and serious and the mechanisms for the replacement need to be efficient. One respondent reported losing or damaging his/her token five times. All but one of those 14 people who reported losing their tokens reported that the owner is responsible for the replacement. The cost of replacement named ranged from UShs 8,000 to UShs 35,000 (USD 9.5) with average of UShs 18,303 (USD 5)

Photo 3 A PPWM public stand tap token in hand and in use

3.1.6. Access to credit vendors

For the smooth operation of the PPWM system, the recharge of the token should also be convenient. Respondents reported that they recharge their tokens with credit vendors who are not always available, and they had to visit the utility office in Kisenyi, in some cases some 7.5 kms away. For some respondents, the vendor comes to their home regularly. Overall, the average distance to travel (walking or motorcycle) to the vendor is 3 km and the average time to the vendor is 29 minutes.

3.1.7. Emergency options

Respondents were also asked if they ever were in a situation of not being able to afford advance payment for water. Half of them (8) responded that they faced such situation and resorted to either borrowing a token 5/8, free but possibly unsafe sources e.g. spring well 1/8, and buying water from private vendors 2/8.

Besides lost tokens, 69% (11/16) of respondents reported that they did not have any problems accessing water from the PPWM. The 31% who reported having problems such as intermittent supply (3/5), low pressure (1/5) and battery failure (1/5). When asked if they would like to quit using the PPWM, the majority of respondents (81%) indicated that they would not want to, while the rest 19% would like to upgrade to private house connections with PPWM.

3.1.8. Satisfaction and recommendation by users

Respondents in the study were asked to rate their level of satisfaction on a scale of 1 to 5 where 1 represents very dissatisfied and 5 represents very satisfied. A high level of satisfaction with the services of PPWM was found. None of the variables scored less than 4. Those with lower scores of 4 were for water availability – perhaps due to intermittent supply in some places and availability of vending stations.

3.1.9. Main challenges and issues

Participants were also asked to identify and rank three main issues and challenges associated with PPWM on a scale of 1, 2 and 3 where 1 is the most important. Issue most frequently named as number 1 was the location of credit vending stations followed by the breakdown of the unreliability of the

PPWM machine. Further, the issue that was named most times among the top 3 was not being able to access water without money followed by the issue of location of vending stations.

3.1.10. Method of communication

Respondents were also asked to rank the method of communication that should be used in sensitizing new customers about PPWM on a scale of 1-3 with number 1 being most important (or most recommended). From the analysis the method of communication most frequently recommended as the best is "Door to door explanation". This is followed by "Public meetings". The method that appeared the most among the top three was that of "Public meetings". These two methods "Door to door explanation" and "Public meetings" therefore, are the ones seen by the users as being the most effective.

3.1.11. Suggestions for improvement

Respondents were also asked to rank a range of recommendations for improving the PPWM service. The recommendation most frequently ranked as number 1 is "Increase number of prepaid public stand posts" followed by "Increase the reliability of prepaid water meters (less break down). The suggestion named most frequently among the top three were a) Improve reliability of prepaid water meter (less breakdown) and b) Increase number of vending stations. Following closely on these two is the recommendation to "Increase number of prepaid public stand posts" Thus the number of the PPWM stand posts, the support framework in terms of the vending stations and the reliability of the PPWM stand posts are all high priority recommendations by the users.

3.1.12. Satisfaction with the services of the utility

Respondents were asked to rank some of the utility's services on a scale of 1 to 5 with 1 being very dissatisfied and 5 being very satisfied. It was found that the respondents were most satisfied with the water quality with 14 people scoring it at 5. On the other hand, water pressure had a significant dissatisfaction with only 7 people scoring it at very satisfied and one person scoring it at very dissatisfied. The utility should improve water pressure in order to gain more positive perception of its service level from the customers.

3.2. Case Study in Lusaka, Zambia

3.2.1. Summary of perceptions of users of Public Tap Stand/Kiosks

A total of 10 questionnaires were distributed to customers using public tap stands (PTS) or water kiosks using prepaid meters distributed across 3 Peri-urban Communities of Lusaka namely (Kamanga, Chazanga, Kanyama). 9 questionnaires were received fully completed by responder households.

(1) Respondent characteristics

The majority of the sample respondents (7/9) lived in rented housing. Their average monthly income ranged from K250 – K1,000[3] per month. One resident who had a private house had a higher income of K5,000 per month. Prior to using PPWM, the water sources for majority of the respondents were vendor supplied water whereas a few also used borehole water. Five respondents reported receiving 24/7 supply whereas supply was intermittent (ranging from 5 to 13 hours daily) for the remaining respondents.

(2) Prepaid Public Stand Posts

Many of the respondents reported using PPWM for less than one year and indicated that they spent 2-30 Minutes to collect water with occasional queuing at the PTS/Kiosks point. Adult female members were the common responsible person to collect water from PTS/Kiosks in all the respondent households.

[3] K= Zambian Kwacha. 1 USD= 22.4 Zambian Kwacha (K)

They collected water 1-2 times a day from the PPWM. Four respondents reported decrease in water consumption, 3 respondents reported constant water consumption and 2 respondents reported increase in water consumption after using PPWM. However, for 6 respondents, water expenses increased more than before with an increasing expense in the range of K2 – K100 per month.

None of the respondents reported receiving any free water and neither had to pay any commission to PTS/kiosks operators. All but one reported not experiencing PPWM breakdown. One respondent who reported breakdown of PPWM cited vandalism / theft as the cause and stated that the utility usually bears the cost of repairs or replacement.

(3) Satisfaction / Recommendations
Although one respondent reported dissatisfaction, the majority of the respondents reported great satisfaction with the PPWM at PTS/kiosks.

Issues and challenges cited by the respondents in order of priority are (1) no water without payment (2) lack of information on the tariff / operation or charging procedures (3) high water tariffs (4) sudden stop of water supply and (5) distance to PTS/Kiosks and credit recharging points.

Most respondents preferred the following awareness creation system in order of priority: 1) door-to-door explanation 2) neighborhood committee 3) community leaders 4) public meetings 5) workshops/seminars and 6) utility website / facebook.

The respondents had the following suggestions to the water utility in order of priority: (1) improve reliability of prepaid water meters (less breakdown) (2) increase water supply hours' / service reliability (3) increase number of prepaid PTS/Kiosks and (4) change recharge payment system and (5) improve customer service / awareness information

In conclusion, all respondents were very satisfied with the prepaid meter system at PTS/Kiosks. They were very satisfied with the services in terms of 1) good water quality 2) adequate supply pressure, and 3) satisfied with supply hours. However, they were least satisfied with the supply reliability meaning water was not supplied at pre-scheduled hours.

3.2.2. Summary of perceptions of private prepaid meter users
A total of 10 questionnaires were distributed to private customers using prepaid meters distributed across low-income and urban areas communities of Lusaka namely (Matero, Chainda, Chilenje). 9 questionnaires were received fully completed by responder households. Below is a summary of the results:

(1) General Characteristics
The majority of the sample responded lived in rented housing with income ranging from K3,000 – K5,000 with an exception of 1 household with income of K46,000 per month. Prior to using PPWM, most respondents had unmetered connections or used post-paid system.

Respondents reported that they received information about the PPWM from the awareness campaign launched by the utility or its project staff at the onset of the project. Majority of the respondents have been using the PPWM for 1 to 3 years. On average, they spent 10-30 minutes to reach pay points to recharge their credit. Water consumption levels were the same in PPWM and previous system yet experienced some increase in cost of water reaching almost 30-50% of previous expenditure. None of the respondents received any free water. Some respondents reported breakdown in the prepaid meter system due mostly to mechanical faults and stated that the utility usually bears the cost of repairs or replacement. On contrast, two respondents reported they spent money on installation of PPWM.

(2) Satisfaction / recommendations

The majority of the respondents reported high satisfaction with the prepaid water system at private connections. Amongst the issue and challenges sited by the respondents in order of priority were 1) lack of information on the tariff / operation or charging procedures, b) poor customer service by the utility/ lack of 24/7 service, and c) charging system / card failure.

Respondents' preference for awareness creation method in order of priority was reported to be 1) door-to-door explanation 2) neighborhood committee, 3) radio / TV and 4) utility website/facebook.

They also made the following suggestions to the water utility in order of priority: 1) improve reliability of prepaid water meters (less breakdown), 2) increase water supply hours / service reliability, 3) increase number of prepaid recharge pay points, 4) change recharge payment system, and 5) improve customer service / awareness information.

Overall, all respondents were very satisfied with the prepaid meter system at private connections. The households were very satisfied with the water utility services in terms of 1) good water quality 2) adequate supply pressure, 3) satisfied with supply hours, and 4) satisfied with supply reliability.

4. Summary of Utilities and Users Responses

4.1. Comparison of utility and users' perception

The following table outlines similarities and differences in the perception of PPWM among the utilities and users based on the survey responses.

Table 11 Similarities and Differences in Perception of PPWM Between the Utilities and Users

Similarities in Perceptions		
City	Utility	Users
Kampala	PPWM was successful and widely accepted by community	PPWM provided satisfying service level
	PPWM were installed at convenient locations	Located within 3 minutes with no or very less queuing time
	Tariffs favouring low-income	Less water expense under PPWM
	Had no complaints of illegal use in PPWM	Never experienced PPWM theft/vandalism
	Provided 15-20 pay points for 1500 public PPWM as reported by utility	Customers hoped for additional vending stations
	Agreed to frequent battery failures	Experienced PPWM breakdown (avg. 3 times/year)
Lusaka	Water consumption by PPWM customers has decreased due to water saving behaviors.	7 out of 9 public PPWM users and all private PPWM users reported that their consumption did not increase in PPWM. Such situation created more reserve water in the system to be distributed to other places.
	Water supply hours have increased because of customer saving on water wastage and more water is available to be distributed.	
	PPWM was successful as it brought improved service delivery/water demand management PPWM.	All respondents of both private and public PPWM were highly satisfied with PPWM services except for reliability.
Differences in perception		
City	Utility	Users
Kampala	Unaware of people who could not afford to pay	50% of the customers reported facing such situation
	Pro-poor policy – free initial token	Replacements costs of token was as high as USD 9
	Conducted public awareness program (prior and after PPWM)	5 respondents reported lack of information on tariff, operation, and charging process
Lusaka	Water tariffs are low under PPWM	6 public PPWM users and some private PPWM users reported increase in water expense in PPWM.

4.2. Points to note and recommendations

(1) In PPWM, affordability is an important issue and so is to identify a social case (vulnerable group) involving a customer who cannot pay for water. Utilities may create their own criteria for poor as in many cases there are several people who fall under the poor category as per the government guidelines (i. e. below poverty line).

(2) If poor people cannot afford advance payment, they revert to other sources. The cumulative effect of such cases creates revenue uncertainties. To support such cases, provisions for loan water with condition (if the user is a regular user of PPWM) can be programmed in PPWM. Temporary subsidized rates or certain emergency/ free water can also be devised in the PPWM system.

(3) Those who cannot afford payment in PPWM occasionally avert to other sources as water vendors. This is probably because water vendors may not always require advance payment (if they are known contacts) and also provide water at the users door. However, it is because of the incentives of PPWM such as water quality, the amount of water that can be procured at one time, and the distance to the water supply location could be the reason users return to PPWM after they can manage to purchase credit.

(4) While designing pro-poor tariff rates or other mechanisms to support the poor, financial stability of the utility should also be considered so as not to discourage further investments in PPWM.

(5) Care should be taken when taking actions for illegal cases. Fines need to be adopted considering the balance between charging the illegal users and maintaining customers positive attitude towards PPWM. Charging huge fines and/or legalizing illegal cases may risk losing customers.

(6) Complaints immediately after switching to PPWM (for example, how to operate PPWM, initial failure of PPWM etc.) are temporary. These complaints can be prevented to some extent by giving sufficient advance explanations such as usage and payment methods. However, utilities should be prepared to handle other complaints that can occur specially for PPWM such as meter failing to close, meter turning off, leakage at the meter, valve problem, and battery failure.

(7) In most cases, revenue increases after the introduction of PPWM, yet consecutive technical failures caused a decrease in revenue, as was the case in Lusaka. Utilities should not be discouraged in such a situation instead manage better O & M services.

(8) Users of sources other than PPWM limit their consumption as it is costly (overcharged by intermediaries) so they may want to use more water under PPWM. Also, in PPWM, users can manage their own consumption and payment, so they opt to use optimum amount of water. This situation is beneficial for the utility as it can collect more revenues. However, in semi-arid areas where water is scarce, it is also necessary to raise awareness of saving water.

(9) In PPWM, customers usually waste less water either while drawing or when using it for daily purposes (due to fear of extra payment). Such token holders have developed a responsibility of water saving which in turn increases availability of water and thus supply hours.

(10) It was also observed that PPWM did not reduce the number of customers, at least, if not increase. As for the domestic customers, even if groundwater such as wells is used as water source, residents are likely to choose PPWM for its better quality, reliability, and no risk of being legalized/limitations. Also, using a publicly supplied water as the PPWM will reduce resident's resources and time to care for their wells and mechanism to draw water.

(11) Resistance in further expansion of PPWM (increasing customers) may be caused by those who advocate water as a free source and some landlords and intermediaries. Continuous sensitization is

needed to make customers understand that landlord's objection to installation of PPWM compels them to fetch water from distant sources and intermediaries supplied water will be too costly.

(12) In Kampala, 14/16 users reported that they had at least once lost their token and it was costly (as much as USD 9.5) to replace it. It is thus important that utilities develop methods to increase the efficiency with which lost or dysfunctional tokens can be replaced with less financial burden to the users.

(13) For the convenience of the users, not only the location of the PPWM but also token recharge should be convenient. This includes the commuting distance to the vending station. Increasing vending stations, setting up vending stations closer to the PPWM users, or regular home visits by the vendors could be employed.

(14) Post-paid tariff applied to prepaid can be a problem as it not always pro-poor and is targeted at residential connections with their own homes (installation space) with some level of financial stability. However, target area of PPWM is mainly low-income residents as in the surveyed utilities. To manage PPWM effectively and sustainably for this categories of customers, post-paid tariff should be revised and subsidized. Such tariff usually subsidizes customers with lower consumption per month (usually in the range of 6 m^3).

(15) As with the local technical support, how much support can be obtained from a PPWM manufacturer was beyond the control of water utility. The utilities should prescribe required technical support and training in the specifications of their bidding documents. Additionally, training by suppliers, easy availability of spare parts and replacements during warranty/guaranty period must also be well ensured while selecting a PPWM brand.

5. Key Findings of the Survey

5.1. Features of the products

Individual type PPWM brands included Utilimeter, Baylan AK311, Laison, Precision Meters, and Electromed brands whereas for public PPWM type SUSTEQ, Elster Kent, and WAARI brand were adopted in the surveyed utilities. The features of these PPWM brands are highlighted in the table below.

Major suppliers of PPWM are located in Kenya (Maji Milele, KABS, Nairobi Iron Mongers) and Zambia (MS Carbon, SARO, JARASH Investments and Global Water Resources) and Mozambique (Triana, and Wihananahm Kasulo). In Uganda there are no suppliers, so they import PPWM from Kenyan suppliers.

The results of a survey of PPWM manufacturer information on the internet are compiled in the table below.

Table 12 Characteristics of PPWM Brands used in the surveyed utilities

Brand	Price (USD)	Type	Vending method	Guarantee Period	Product Life (Actual)	Battery Life (Actual)	Malfunction Rate	Function	After sales service
Utilimeter (Lusaka)	200	Velocity	Token/ Coin	1	5 (Still in use)	5 (2.5)	50%	A B C D E F G H	Software support Technical support Spare provision
BAYLAN (Lusaka, Lukanga)	188	Inferential (MultiJet)	Token/ Coin	2					Software & Technical support, Spare provision
LAISON (Nkana, Lukanga, Maputo)	266	Velocity	Smart Card/ STS	1.5	5 (5)	5 (3)	0.5%	A B C D E F G H	Smart card to STS
Precision Meters (Kafubu)	145	Volumetric	Token/ Coin	1	7 (5)	3 (3)	New system	A B C D E F G H	Supply of spares Total solution
Utility Systems (Lukanga)	150 (DN 20	Volumetric	Smart Card/ STS	2	4-5 (3)	5 (1)	10% (2 yrs) 40% (4 yrs)	F G H	Software
Electrometer (Mulonga)	250	Volumetric	Smart Card	0	12 (10)	5 (3)	2%, 5%, 20% (every 2 yrs)	B F G H	N/A
Electromed (Kampala)		Velocity		3	10 (Still in use)	10 (Still in use)	<10% (after 3 yrs)	A B C D E F G H	Software management Guarantee of spares
SUSTEQ (Nairobi, Kampala)	1064, 1216 and 1367 for 1,2 and 3 outlets	Volumetric	Token	3	Still in use	Still in use	10% (after 1 yr)		
Elster Kent (Kampala)	1000	Velocity	Token/ coin	1	10 (Still in use)	5 (1)			
WAARI (Nakuru)	2700	Volumetric Ultrasonic	Smart Card	1	8 (4)	10 (4)	40% (after 3 yrs)		

Note:
Function: Realtime clock (A) Remaining Credit (B) Reserve for emergency (C) Low credit alarm (D) Friendly credit (E) Tariff setting (F) Debt recovery (G) Consumption limit (H)

Source: Prepared from the answers of the questionnaire.

Table 13 PPWM Manufacturers Information

No.	Product name	Manufacture	Office location	Local Agent	Area of sales (including PPWM)	Source (website)
1	UTILIMETER	Inzalo Utility Systems	Westmead, South Africa	Global Water Resources Limited (Zambia) MS Carbon Zambia Limited (Zambia) Matra Manufacturing and Trading Investments Limited (Zambia)	South Africa, Zambia	https://utility-systems.co.za/
2	BAYLAN AK311	Baylan Water and Energy Meters	Izmir, Turkey	Fury Trade （Palestine）	90 countries in 5 continents,including most Sub-Saharan African countries	http://www.baylanwatermeters.com/en/
3	LAISON	Laison Technologies, Hangzhou Ltd	Hangzhou, China	SARO (Zambia) MS Carbon (Zambia)	18 countries worldwide including Zambia, Malawi, South Africa, Mozambique Angola in Africa	http://www.laisongroup.com/
4	PRECISION METERS	Precision Meters	Cape Town, South Africa	JARASH (Zambia)	South Africa, Zambia	https://precisionmeters.co.za/
5	SUSTEQ	SUSTEQ Netherlands	Enschede, Netherlands	Maji Milele (Kenya and Uganda)	Kenya, Uganda, Tanzania	http://www.susteq.nl/
6	ELSTER KENT	Elster Kent Metering Private Limited	Johannesberg, South Africa	Nairobi Iron Mongers (Kenya) Maji Milele (Kenya) KABS (Kenya)	Offices located in 36 countries in all 5 continents including South Africa	https://www.elster.com/en/index

Note: Surveyed in July 2021

Figure 7. Baylan, Susteq and Laison Brand PPWM (in order from left to right)
(Source: Respective brand homepage)

Majority of the PPWM brands possessed functions of real time clock, remaining credit, and tariff setting, whereas low credit alarm, friendly credit, consumption limit, and debt recovery were present only in some brands. Similarly, shut-off valve, tamper protection device, built-in strainer, non-return valve and sealing were common fittings applicable to all the prepaid meter types. Air valve was included in only a few brands. Manufacturer provided the server and software, vending station, and handheld units along with the PPWM units. Upgrades in technology was limited to payment system (from token/coins to smart card). Except Maputo, all the PPWM in the target cities were covered by box.

Some of the common functions available in PPWM and their explanation is provided in the table below.

Table 14 PPWM Functions

PPWM functions	Explanation
Anti-water shortage (purchase limitation)	Credit purchase are restricted to deal with water shortage and curb users who spent large amount of water
Arrears payment facility	A certain percentage of credit is used towards payment of debt of that token holder
Consumption limit	Limit on the volume of water that a token holder can consume.
Daily limit	Users can only use a fixed amount of water each day
Emergency water (overdraft)	A certain amount of water provided to use at emergency periods
Free basic water	Customers can receive certain amount of water for free (usually once every month)
Friendly credit	Credit that can be used in certain situation to purchase water but need to pay it in next recharge
Low credit alarm	A warning when the customers credit reaches a minimum level
Monthly consumer consumption profile	Shows a history of daily water consumption for the entire month
Real time clock	Displays the current time
Remaining credit	Displays the balance remaining in the token/coin/smart card
Tamper detection	System that informs the service provider if the PPWM is physically tampered
Tariff setting	The tariff can be programmed to be set for different categories of customers/zones
Zoning	Only users in that particular zone can purchase water from that PPWM

5.2. Innovations for consideration of the low-income residents

(1) In PPWM, affordability is an important issue and so is to identify a social case (vulnerable group) involving a customer who cannot pay for water. Utilities should create their own criteria of low-income residents.

(2) To support customers who cannot afford advance payment, provisions for loan water can be programmed in PPWM. Such loan water can be offered to certain users only (e.g. a low-income but a regular user of PPWM).

(3) Temporary subsidized rates or certain emergency/ free water can also be devised in the PPWM system.

(4) In Uganda, the government's pro-poor policy is directed at providing water at an affordable tariff for the low-income people. Such pro-poor tariffs are subsidized in rates and/or cross-subsidized by other categories of customers (e. g. commercial, institutional, domestic or large consumers).

(5) Those who cannot afford payment in PPWM occasionally avert to other sources as water vendors. This is probably because water vendors provide water at users doors and may not always require advance payment. However, if other incentives of PPWM such as water quality, the amount of water that can be procured at one time, and the distance to the water supply location are provisioned, it could be the reason for the users to return to PPWM after they can manage to purchase credit.

(6) Although tokens were issued free for the first time, subsequent replacement cost were as high as USD 10 in Kampala (including token vendors commission when token recharge at users home). It is also important to consider the efficiency with which lost or dysfunctional tokens can be replaced and at low costs.

(7) Prospective users of PPWM who have been fetching water from vendors (at high prices) or free water from natural sources (poor quality) need to be made aware of the benefits of PPWM such as the tariffs, water quality, convenience etc. Sensitization should continue even after the installations.

5.3. Challenges and countermeasures in O&M

The main challenges and countermeasures in O & M of PPWM are presented in points as below:

Table 15 Challenges and Countermeasures in O & M of PPWM

Key Issues	Mitigation Measure
Meter related billing errors	Regular tests by meter test bench
Knowledge on how credit uploads on PPWM, how a card is read, and other customization	Staff should be well trained, if possible, by the supplier
Problems such as meter locks due to errors in code, failure to read smart card, token breakage	Troubleshooting guidelines and manuals should be sought from manufacturer
Illegal cases of theft, bypass	Extensive field inspections in addition to consumption trend monitoring
Vandalism – cutting of cables, covering meters using magnets, or iron shielding leading to meters not closing	Anti- tamper warning devices like seals to make use in litigation whenever tampering is apparent

Key Issues	Mitigation Measure
CIU / meter communication failures Meter not recharging	Good meter management (proper meter installation)
Penalizing poor customers	Well-defined penalty system should be established by regulating body
Reduced consumption by opting for alternative sources such as boreholes	Enact specific legislation on drilling of boreholes
Lack of spares to repair / or replace defective meters or units with problems	Information on whether suppliers sell the assembly parts should be collected from the supplier prior to procurement.
Malfunction of the external unit after submersion or flooding of the meter chamber on the bulk meter	Need to ensure installation are as per guidelines that avoids entry of water into the unit
Apparent discrepancy between sales and consumption	Investigate and record meter history
Stuck mechanical meters on prepaid meters due to grit ingression from leakages	To provide clean strainers and pressure relief valves in the network and periodic flushing of networks
Negative attitude towards the PPWM project by utility Staff	Extensive staff awareness campaigns
Information related to consumption cannot be transferred or is not consistent when the PPWM is replaced.	Suppliers should investigate if consumption information from a previously damaged PPWM can be transferred to a new PPWM.
Apparent reduction in sales on properties with prepaid meters	Confirm on a case-by-case basis

5.4. Organizing successful cases

PPWM was successful for all the surveyed utilities, and it was further supported by users opinion in Kampala and Lusaka that the level of services provided by PPWM was satisfactory. Each of these utilities had their own stories of success, yet majority of them considered efficient debt recovery and reduction of NRW as the major advantage of PPWM.

In the individual PPWM type:

- Nkana could increase its sales and there was no growth in debt.
- Lusaka improved its service delivery and water demand management in PPWM. There was an immediate change in customers behaviour leading to significant reduction in wastage of water. Water pressures also improved in the network. Disconnections were fewer or even unnecessary. If any, disconnections were smoother through electronically controlled valve.
- Mulonga could manage its debt and reduce NRW.
- Lukanga reported that cashflows were more predictable under PPWM, billing was easier and revenue collection was consistent.
- In Maputo, PPWM promoted rational use of water and reduced water loss.
- In Kampala, debt recovery from public institutions (in Uganda) was efficient and service continuity could be ensured.

In the public PPWM type stories of success include:

- PPWM was widely accepted by community as informal settlements could receive water at more affordable rates.
- Utility could increase water access to more users in Nakuru as revenues increased due to advance collection.

- In Nairobi, customer data management, credit dispensing, and consumption measurements were easier in PPWM systems. In addition, NRW also decreased.

5.5. Public awareness activities for introduction of PPWM

Public participation and acceptance are an important aspect in the introduction of PPWM as applied by all the surveyed utilities who conducted public sensitization activities before introducing PPWM. The results of the face-to-face survey also showed that individual (door-to-door) consultation would be more effective as users could be more open to questions when consulted individually. However, they are costly and may require extensive resources. Probably as a reason, utilities (as in the surveyed cities) adopt public hearing, community meetings and stakeholders meeting to make the users aware about the PPWM. Media advertisements, flyers, brochures, drama, radio, TV could also help to some extent to inform the public about the PPWM, however, such approach can be used to complement the above-mentioned methods of public hearings and community meetings. Another important inclusion in the awareness campaign is to include landlords, water vendors and intermediaries who are also an integral part of a water supply distribution chain in many African countries.

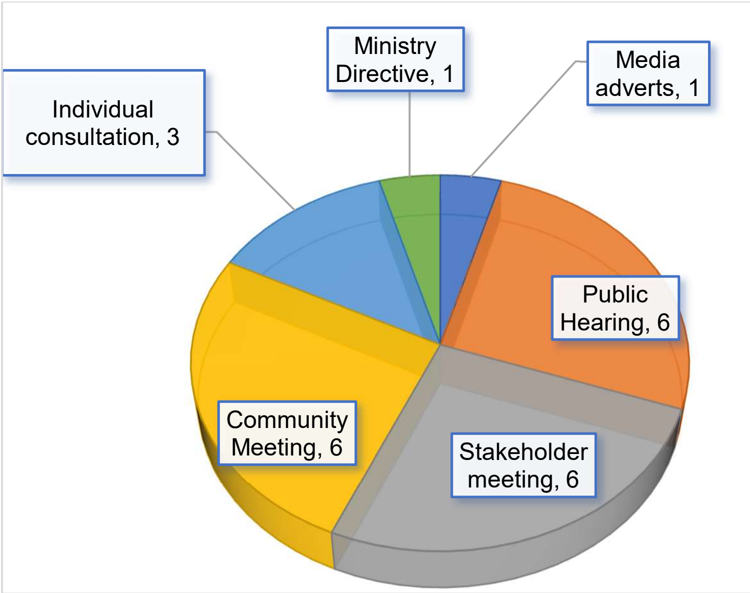


Figure 8 Method of consultation (Numbers indicate count of survey participating utilities)

5.6. Checklists and conditions for introduction of PPWM

Based on the above case studies and responses of utilities and users, the following checklists and conditions are recommended for introduction of PPWM.

Table 16 Checklists and Conditions for Introduction of PPWM

S.N.	Checklist	Conditions
1.	Regulation (Guidelines/Manuals)	1. Procurement, Installation and O & M guidelines/manuals should be established.
2.	Clear target area	1. Based on the objective, target areas should be selected such as areas with high debt, stable water supply, areas that are well planned (such as DMAs), and low-income areas (for public PPWM)

S.N.	Checklist	Conditions
3.	Internal resources (manpower, training, facilities)	1. A dedicated team for PPWM is necessary 2. Such team should at least comprise electricians, plumbers, IT technicians, sales officer, and customer engagement officer
3.	Public sensitization	1. Public consultation is a must before introduction which can be chosen from a wide range of approaches as described in Part 2. 6. 2. Allocation of appropriate funds for consultation 3. Well trained staffs to engage with community
4.	Tariff	1. If PPWM is targeted for the poor, the tariff should be pro-poor and subsidized. 2. Utilities should realize that low tariff will require long cost recovery period and that should not discourage further investment.
5.	Decision Making	1. Wherever feasible, one or more of the following should be conducted: pilot project, market study, benchmarking visit to other PPWM cities 2.Cost-benefit analysis should be conducted
6.	Funds	1. Utilities should plan how funds can be managed to expand PPWM. PPWM introduction on a project basis will leave the utility hanging between two post-paid and prepaid systems.
7.	Brand Selection	1. Price vs. durability 2. Warranty period and items covered 3. Availability of local supplier 4. Supplier's training facility 5. Spare parts availability (in local market) 6. Battery life (minimum 5 years)
8.	Software Selection	1. Easy customization 2. Better user interface 3. Ability to upgrade into web-based data transfer (automatization)
9.	O & M	1. Ensure that there are proper guidelines and manuals for procurement, installation and repairs 2. Staffs should be well trained to handle installation, repairs and complaints redressal
10.	Pro-poor strategy	1. Tariff rates should be affordable by the low-income customers 2. Measures to support such users when they cannot afford water should be devised in the PPWM system
11.	Token recharge method	1. Number of vending stations should be sufficient 2. Distance to vending stations should be convenient 3. Cost of token replacement should be minimal and efficiency with which token is replaced should be improved

Annex 1: Survey Summary- Individual Case Studies

Case 1: Lusaka Water and Sanitation Company in Zambia

Background

Lusaka Water and Sanitation Company (LWSC) was incorporated in 1988 and begun operations in 1990. LWSC is wholly owned by the city of Lusaka, and local authorities of Kafue, Chongwe, Luangwa, Rufunsa, Chirundu, and Shikabeta. The total service population of LWSC is 2,716,780 who are connected by 121,470 customer connections. Water coverage in the LWSC jurisdiction is 87.5% while the metering coverage is only 70%. LWSC produces 226,039 m^3/day of water and supplies in average 17 hours of piped water every day.

Objectives to introduce PPWM

Prior to installation of PPWM, LWSC faced a lot of challenges with the post-paid metering technology. Some of the major challenges were:

- High debt accrual on customer accounts
- Inefficiency in manual disconnections and reconnections and meter reading
- Demand management (wastage of water by customers who do not pay bills on time)
- Poor customer service – complaints of high/erratic bills.

LWSC is the pioneer of PPWM introducer in Zambia. The decision to introduce PPWM was made to attain financial viability for the utility because of customer's failure of timely payment for water services. The PPWM was perceived to offer the possibility to automatically stop water supply when previously purchased credit exhausted; thus, forcing the customer to purchase more units from the utility without the use of collection reinforcements like reminders and disconnections.

LWSC also aimed at other goals from the PPWM project such as:

- To reduce staff involvement in enforcing activities necessary for improved revenue collections eliminating collusions between customers and staff as well as eliminating related billing costs and activities.
- To improve water supply service provision to the customers through redistribution of the available water resource.
- To enhance customer awareness of how they use water.
- Provision of water to poor households at subsidized tariff that are more cost-effective.
- To achieve a 100% metering policy set by the government.

PPWM Implementation

LWSC initiated a pilot PPWM project in 2009 which achieved 100% collections and debt recovery. Debt was recovered by deducting a pre-agreed amount or preset percentage from every purchase of water units. In 2013, LWSC launched PPWM installations across a) public standpipes, b) individual connections and c) institutional customers, with the intention of making PPWM the default technology wherever possible.

In addition to the pilot project, LWSC also conducted bench marking visits to other utilities that had implemented PPWM(International), established an in-house PPWM team, provided pre-implementation training and capacity building in installation, O & M of PPWM, and conducted sensitization of the target community. Public sensitization was mainly conducted through branding, radio and TV and printed adverts on prepaid meters, which included information on how to use them and their benefits.

Customer Selection Criteria

LWSC adopted the following criteria to select target customers for PPWM installation:

- Properties and locations with good pressure and reliable hours of supply
- Areas with low collection efficiency and high arrears
- Government facilities
- Unmetered satellite towns (Kafue, Luangwa, Chongwe)

Regulations

LWSC is regulated by National Water and Sanitation Council (NWASCO) which has provided guidelines on prepaid metering to ensure transparency when implementing, protection of consumers from any form of exploitation by service providers, and financial viability of the utilities. NWASCO requires that each water utility must improve the metering ratio to 100% using both post-paid and prepaid options. The standard NWASCO approved water tariff is the same for both pre-paid and post-paid customers.

PPWM Products

LWSC has used three different models of PPWM, namely:
1) MATRA supplied by Infotron
2) UTILIMETER supplied by Infotron (now defunct) and MS Carbon
3) BAYLAN- AK311 supplied by Global Water Resource and MS Carbon (supplies other models as well)

LWSC has a total of 13,110 PPWM connections out of a total 121,470 customer connections. PPWM customers consists of residential (12,113 connections), commercial / industrial (789 connections) and public institutions (72 connections). In the past, LWSC conducted in average 4,500 PPWM installations including replacements, annually.

PPWM Team

LWSC has arranged a dedicated, multi-disciplinary PPWM team composed of technical, commercial, IT and administrative personnel who have received pre and post installation training and Capacity Building training on O&M and sustainable management of the PPWM system. The commercial team analyses purchasing and consumption trends, IT team fixes problems of PPWM and other software issues, and the technical team resolves leakages and fix meters.

Impacts of PPWM

PPWM had a significant impact on revenues as there was an initial increase in revenue, followed by a reduction and then a plateau probably due to large scale technical issues with the meters which impacted the revenue collection negatively. Debt recovery was seamless and accelerated however, it also reduced as technical issues with the meters increased. Water supply in Kafue improved dramatically as water stressed areas begun to receive water normally. The impact on NRW was largely negative after technical issues with the meters. Due to the low tariffs, even low-income customers could purchase tokens.

Issues and Challenges

LWSC encountered many challenges in implementing the pilot PPWM program. These challenges included requirement for extensive inspections to all customer properties and problems of pipe bypasses which requires physical inspection. In case where a customer has huge debt, the debt recovery is slow as the customer only pays a percentage of his water bills for debt. Water consumption by PPWM customers decreased due to water saving behaviors.

Other challenges faced by LWSC on using PPWM system are:

- Physical parameters in the network like the water quality and network pressures likely caused failures of the meters.
- Technological failures where most meters failed to close automatically for varied reasons.
- Some customers could not afford advance payment compared to the convenience of getting the service on credit and paying for it when they are ready.
- Most of the utility staffs were not confident in PPWM technology at the onset of the project and had weak motivation towards PPWM.
- Low technical support from the meter suppliers.

LWSC also obtained positive outcomes by introducing PPWM such as improved service delivery/water demand management, significant reduction of wastage at customer premises, improved revenue and debt collection, elimination of billing related complaints, less need for disconnections, smoother disconnection through electronically controlled valve and reduced leakages at meter point. However, there were also some negative outcomes of the PPWM such as revenue increase plateaued after consecutive technical problems, and new types of complaints emerged on the use of PPWM. Such complaints were meter failing to close, leakage at the meter, battery failure and no water when pressure is low.

Key messages for successful PPWM

LWSC, based on its experiences, suggests the following points for a successful PPWM:

- Commitment from senior management
- PPWM roll out plan should be well planned
- PPWM technology should be reliable
- Big savings are likely for the utility with PPWM systems
- Network should be verified before starting PPWM installations
- Wherever possible, network should support 24/7 service
- Building customer consensus for prepayment requires significant resources
- Particular attention should be given to explain charges and tariff structure to customers

Case 2: Nkana Water and Sanitation Company in Zambia

Background

Nkana Water and Sanitation Company (NWSC) was incorporated in 1998 and begun operations in July 2000. It operates in three towns in Zambia, namely Kitwe, Kalulushi and Chambishi. NWSC has 67,223 customer connections, a water coverage of 96% and a metering coverage of 80%. It produces in average 180,000m^3/per day and supplies water for 17 hours daily.

Prior to introduction of PPWM, NWSC had major problems of high customer arrears, low metering ratio, high NRW, illegal connections, and weak balance sheet/inadequate liquidity. To address these issues, NWSC developed a 5-year corporate plan and specific performance improvement plans which included organization restructuring, mass disconnections, road shows, opening more pay points and piloting PPWM.

Objective of introducing PPWM

Although NWSC's review of available literature criticized PPWM technology for its i) Technical unreliability, ii) High capital and maintenance costs, and iii) a system that penalizes poor customers, it still introduced PPWM with the objective to enhance billing and revenue collection, reduce non-recovery of revenue (NRR) and consequently NRW, and consequently improve the liquidity situation to cover O&M costs.

PPWM Implementation Stages

Prior to installation of PPWM, NWSC also conducted benchmarking visits to other local and international water utilities that had implemented PPWM, initiated pilot PPWM projects, established in-house PPWM team, and conducted pre-implementation training and capacity building for installation, and O&M of PPWM.

Sensitization of the target community and public was also conducted via community engagement meetings with customers and community leaders, stakeholder engagement and public announcements, appearance of state and community radio programs to raise awareness. Quarterly post implementation public awareness meetings were conducted in all prepaid areas.

The PPWM program began in the Year 2012 with the first pilot in Buyantanshi township and further rolled out a second phase in 2015 and 3rd phase in 2018 as detailed below:

Table 1: Phasing of PPWM Pilot projects by NWSC

Year	Area of PPWM Pilot	Customer Type	Coverage
Phase- 1 2012-2015 Token Type	Buyantanshi Township	Medium income households – reliable supply, high customer base, low collection area, and many debtors	240 HHs
Phase 2 2015 Smart Card	Kwacha East (2% NWSC Customer base)	Low-income households, reliable Supply, High customer base, low collection area, and High number of debtors	1,500 HHs
Phase 3 2018	Roll Out to other PPWM Target Areas - Buchi, Kamitondo,	Low-income Households - Reliable supply, High customer	13,900 HHs

STS Type	Kwacha Chimwemwe, Bulangililo and Buyantanshi	base, low collection and High number of debtors	

PPWM Pilot Customer Selection Criteria

The following points were considered to select customers for the pilot PPWM project:

- Properties and locations with good pressure and reliable hours of supply
- Areas with low collection efficiency and high arrears
- Government institutions - e. g. Police camps
- Reluctant payers in the commercial category

PPWM Team

NWSC PPWM team was composed of technical, commercial, and administrative personnel who had received pre and post installation training on O&M. Their responsibilities were similar to those described for Lusaka Water.

Regulations

Similar to that of Lusaka Water.

PPWM Products

NWSC used PPWMs manufactured by Laison Technologies, Hanghzou Ltd of China; Model LXSZ LoRa STS Prepaid Split Meter which was supplied by MS Carbon. These meters are mechanical velocity type with smart card, STS, and token as vending method.

Impacts after Introduction of PPWM

NWSC encountered many challenges in implementing the PPWM pilot program. These challenges included requirement for extensive inspections to all pilot customer properties and problems of pipe bypasses which required extensive inspections. Also, for customers with huge debt, the debt recovery was very slow.

Other impacts included increased revenue. Water consumption however decreased by 66%. Utility was able to supply water for longer hours because of customer saving by reducing wastage.

Issues and Challenges

Some of the issues and challenges faced by NWSC in the introduction of PPWM are listed below:

- Procurement: Compared to initial phases NWSC now has a more reliable source (supplier) for procurement of PPWMs.
- Cost & benefit: The initial investment cost is high but improvement in collection is instant.
- Installations: The meters are supposed to be installed off the ground to avoid water logging.
- Technically unreliable: premature battery failure, CIU/meter communication failures, and meter not recharging, discharge is also affected by intermittent supply.
- Credit charging and vending: Once the token is dispensed, it cannot be cancelled.
- Public awareness: Satisfying all customers who have complaints is a big challenge.
- Social aspects: Not all customers can purchase units. Some customers may reduce consumption by migrating to alternative water supply source such as boreholes or illegal bypasses
- Customer service: It is difficult to monitor meters without data concentrator units and there is no robust complaint handling system.

- O&M: The system reports are inadequate, no strong evidence to prosecute illegal cases, lack of technical skills/competencies, high cost of spares, unavailability of installation space and lack of computerised test bench
- Data Management: Migration policies

To solve the key issues NWSC suggests the following as solution:

- Technically unreliable: Good meter management such as proper meter installation, installations only in areas with good water supply, competent and skilled staff
- Penalizing poor customers: Need to have well established justifiable actions and penalty rule
- Migrating to alternative water source: NWSC will advocate for specific legislation to control drilling of boreholes.

Key Messages for successful PPWM

- Dedicated PPWM and well-trained staff
- Seek support of police during inspections of illegal cases
- If e-billing is adopted, the agent will handle complaints, disconnection and other technical repair works
- To counter battery failure, it is better to set a purchase limit
- Vending system should be upgradable (token > smart card > STS)
- Availability of spare prepaid meters, cards etc must be well ensured before introduction of PPWM.
- PPWM should have automatic valve operation
- The system can load credit or disconnect the customer from the office upon installation of Data Concentrators Units (DCU)
- All reports should be easily exported to excel for analysis
- Customization of debt management and recovery tool
- Availability of newer and convenient payment methods e. g. mobile money and digital banking
- Local hosting of the system is more advantageous and enhances compliant management

Case 3: Kafubu Water and Sanitation Company in Zambia

Background

Kafubu Water and Sanitation Company (KWSC) Ltd. was established in the year 2000 by three local authorities, namely Ndola City Council, Luanshya Municipal Council and Masaiti District Council to provide water and sanitation services in their respective service areas. There are 66,798 connections in Kafubu and water coverage is currently at 86%. The metering ratio is at 71% and water average supply duration is at 23 hours per day. The daily water production capacity of KWSC is 190,000m^3.

Objectives to Introduce PPWM

In the quest to improve service delivery and manage customer queries related to billing errors KWSC decided to introduce PPWM. Other major objectives of PPWM introduction were:

- To achieve a 100% revenue and arrears collection
- To reduce Non-Revenue Water
- To improve metering ratio
- To reduce errors in billing

KWSC also conducted mini research with similar companies to understand PPWM. Three companies who had piloted PPWM (including Lusaka Water) were visited. KWSC took advantage of the lessons learnt from their study visit to other water utilities and projected to procure about 30,000 Prepaid meters. About 10,000 prepaid meters have since been installed in Pamodzi, Lubuto, and Mushili, Police camps. KWSC prepared a step-by-step process to implement the PPWM installations which followed the order of selection, stakeholder management, installation, software management and monitoring activities.

The following formed the main criteria of target areas for PPWM installations:

- Areas with high NRW
- Areas with good water pressure and reliable hours of supply
- All target properties needed to have a fence and meters installed in secure locations
- Existing unmetered connections in project area in order to reduce NRW and increase metering ratio
- Customers with huge debts as to increase collection efficiency and reduce on debtors.

Regulations

Similar to that of Lusaka Water

PPWM Products

KWSC entered into a contract with a vendor and procured "Precision Meters" which was supplied by JARASH Investments, a local supplier. The manufacturer was Zambia Electrometer. The Precision Meters were mechanical volumetric type and credit vending method was token/coin.

Issues / Challenges of PPWM Implementation

The following issues were observed during PPWM implementation:

- Intermittent water supply may affect the PPWM performance and accuracy
- Management of the prepaid installations requires extensive inspections specially to solve problems such as a) stuck meters and b) bypasses
- Premature failure of batteries in electronic device means that utility has to temporarily switch back to post-paid till meters are replaced
- PPWM are more expensive than ordinary post-paid meters – (approx. 4 times)

- Debt recovery is slow because the customer only pays a certain percentage of his usage.
- Sensitization and good customer service are a constant requirement.

Conclusion

The PPWM in KWSC progressed well with some minor challenges as highlighted above. The biggest benefit was the 100% revenue collection in PPWM areas. A dedicated prepaid meter team is critical to management and physical meter reading and inspection is important. The success of the PPWM project may only be determined after sufficient monitoring and evaluation has been done and lessons learnt.

Case 4: Mulonga Water and Sanitation Company in Zambia

Background

Mulonga Water and Sanitation Company (MWSC) commenced a pilot Prepaid Metering Project in Chililabombwe town in 2015. Under this project 300 meters were installed at a total cost of USD 75,000. The project was implemented by MWSC and is still managed by MWSC. The meters were installed on both new connections and existing connections.

Objectives to introduce PPWM

Prior to PPWM, MWSC faced several issues of erroneous bills, huge debt accrual by customers, high NRW, and intermittent supply. Likewise, supply pressure was also low due to uncontrolled usage of water. In addition, pressure from top management and board to improve metering ratio to meet NWASCO guidelines was always present.

To solve these issues, MWSC decided to introduce PPWM specifically to increase revenue collection and to reduce workload of meter reading, billing, and revenue collection processes. Donors provided the initial funding for initial PPWM pilot projects at MWSC. Prepaid metering was to be introduced in low-income areas, especially areas with reliable water supply of adequate pressure and areas with high debts.

MWSC started a pilot implementation in 2015 and piloted 300 PPWM in Kasumbalesa (a transit town) because it is a low-income area with total customers base of 60,000. Customers charge credit or purchase tokens from designated pay points determined by MWSC. The PPWM is installed in customers premises in a covered box and all residents were consulted. At first it was difficult for customers to accept but after installation was done, customers welcomed PPWM and thought it was fair to use it than the post-paid meters.

The implementation process followed was:

- Bench Marking visits – local and external
- Procurement and signing of contract agreement
- Establishment of in-house prepaid team
- Pre-implementation training
- Customer consultation in target localities - i) drama was conducted amidst community sensitization; ii) flyers were distributed to community and iii) door to door sensitization
- Installation of domestic PPWM
- Post installation training – meter inspection, minor repairs, operation and maintenance. Almost all the challenged faced with the PPWM are now resolved by the utility
- Installation of bulk prepaid meters
- Monitoring and evaluation

The following formed the main criteria of target areas for PPWM installations:

- Properties and locations with high NRW
- Areas with good water pressure and reliable hours of supply
- All target properties needed to have a fence and meters installed in secure location
- Existing unmetered connections in project area in order to reduce NRW and increase metering ratio
- Customers with huge debts as to increase collection efficiency and reduce on debtors.

Regulations

Similar to that of Lusaka Water

PPWM Products

MWSC entered into a contract with a Vendor, Zambia Electrometer to oversee and manage the pilot PPWM project. The PPWM were supplied by a local supplier SARO with the latest LAISON prepaid meters from China. The PPWM were mechanical velocity type.

Impact after Introduction of PPWM

Initially the O&M costs increased, billing and collection costs and customer management costs decreased whereas logistics costs remained unchanged. The PPWM made it easier to collect debt without much effort. There was a reduction of bill printing and distribution costs and workload of some employees (e.g., meter readers) reduced and were assigned to other duties. The company has also put in place the Meter Management Unit. The Transact Prepaid Management system offers a lot of reports for easier analysis. The PPWM has a temper mode which responds to physical tempering of the meter by closing the electronic valve, a feature that is missing in post-paid meters. This helps in Non-Revenue Water reduction. In addition, most customers became water wise and in turn reduced wastage. PPWM contributed to NRW improvement especially in areas with unmetered properties and high wastage. Overall, metering ratio was also improved after PPWM introduction.

Issues / Challenges of PPWM Implementation

Some of the issues faced by the MWSC are as follows:

- For illegal cases, the payment of penalty charges limits the utility in prosecuting the clients any further.
- There are limited suppliers of PPWM compared to postpaid in the Zambian market.
- Management of the PPWM installations requires extensive inspections specially to solve problems such as a) stuck meters and b) detect bypasses.
- Premature failure especially of batteries in PPWM units leads to switching back to postpaid till replacements are made.
- Prepaid Meters are 3-4 times expensive than ordinary post-paid meters.
- For customers with huge debt, the recovery period is significant as the customer only pays back a certain percentage in each recharge.
- Data management: i) Failure of meters due to bad weather and vandalism ii) Poor battery life of PPWM iii) Valve glitch as it stays open when it should close and vice versa.

Conditions to Success of PPWM Introduction

MWSC has the following recommendations for success of PPWM.

- A proper selection of PPWM brand will ensure success particularly in the low-income areas and public institutions.
- A proper corroboration between the Meter Management Unit and IT is needed for the purposes of monitoring PPWM.
- Wherever possible, utility should seek training from the supplier in the meter management and software of the PPWM.

Case 5: Lukanga Water and Sanitation Company in Zambia

Background

Lukanga Water and Sanitation Company Limited (LgWSC) is a private Company established under the Companies Act CAP 388 of the Laws of Zambia. It was incorporated on 21st March 2006 as a Commercial Utility (CU) limited by shares but wholly owned by the local authorities in Central Province. The CU was established as part of the Government of the Republic of Zambia (GRZ) water sub-sector reforms to improve delivery of Water Supply, Sewerage and Sanitation Services to the Urban and Peri-urban population in Central Province.

Technical Data 2020	
Customer Connections	29,655
Annual Water Production	12,952,608m3
NRW	48.8%
Hours of Supply	18.5
Metering Ratio	85%
Total population	456,494
Population Served	380,718
Water Coverage	83.4%

Objectives of Introduction of PPWM

Prior to PPWM introduction LgWSC faced problems of low revenue collections, high NRW (above 50%), and in some areas high pressure resulted in erratic bills. Thus, the utility board decided to introduce PPWM specifically:

- To increase revenue collection
- To reduce workload of meter reading, billing, and revenue collection processes
- To reduce NRW
- To improve metering ratio improvement
- To achieve 100% revenue and debt collection.

LgWSC provided the initial funding for initial PPWM pilot projects. Prepaid metering was targeted for low-income areas, especially areas with reliable water supply of adequate pressure and areas with high NRR (Debts).

LgWSC commenced a pilot Prepaid Metering Project in 2 towns namely Kabwe and Kapiri Mposhi in June 2016. Under this project 1,471 Domestic meters and 37 bulk meters have been installed at a total cost of Zambian Kwacha 3.8 Million. The project was implemented through a contract with Infotron limited in partnership with Utility World and Systems of RSA. It was agreed that the software system would be managed by the vendor until LgWSC could manage the system itself. The PPWMs were installed on both new and existing connections. The implementation process followed is listed below:

- Bench Marking visits – local and external
- Procurement and signing of contract agreement
- Establishment of in-house prepaid team
- Pre-implementation training
- Installation of domestic PPWM
- Installation of bulk prepaid meters
- Monitoring and evaluation

The following were the main criteria of target areas for PPWM installations:

- Areas with good water pressure and reliable hours of supply
- All target properties needed to have a fence and meters installed in secure locations
- Existing unmetered connections in project area
- Customers with huge debts to increase collection efficiency and reduce debtors.

Regulations

Similar to that of Lusaka Water

PPWM Product

LgWSC entered into a contract with a Vendor, Zambia Electrometer to oversee and manage the pilot phase of PPWM. The PPWM were supplied by a local supplier i) Utility systems – South Africa, ii) Global Water (Baylan)- German Model AK311 and iii) Laison Technology – China. The meters were mechanical volumetric type.

Impact of Introduction of PPWM

The PPWM made it easier to collect debt without much effort. There was a reduction of bill printing and distribution costs. The PPWM's tamper mode was helpful to detect physical tampering of the meter by closing the electronic valve which helped in NRW reduction to some extent. In addition, most customers became water wise and in turn reduced wastage. PPWM contributed to NRW improvement especially in areas with unmetered properties and high wastage. The metering ratio in LgWSC increased from 71% to 74% after the introduction of PPWM.

Issues / Challenges of Implementation of PPWM

Management of the Prepaid installations requires extensive inspections specially to solve problems such as a) stuck meters and b) detecting bypasses. Due to premature failure of 50 Batteries in electronic device meant, LgWSC had to temporarily switch back to post-paid mode for affected meters till replacements were sent under warranty. LgWSC is still awaiting the fault report on failure analysis from vendor. The PPWM are very costly (3-4 times the postpaid meters). In addition, recovery period of debt is slow and sensitization and good customer service always warrants extensive resources.

Conclusion

The PPWM project progressed well with some minor challenges as highlighted above. The biggest challenge was the wrong programming of the bulk meters which under registered but was quickly identified and rectified. A dedicated PPWM is also suggested to effective management. Extensive inspection will also help to identify illegal cases quickly and reduce NRW.

Case 6: Águas da Região de Maputo (AdeM) in Mozambique

Background

Águas da Região de Maputo (AdeM) is a water supply utility in Maputo, Mozambique. Adem currently has 250,000 customers out of which only 1% are connected to pre-paid system (2500 taps). Out of the prepaid customers, 2400 are residential customers whereas 100 are commercial customers. Installation was carried out in one phase in 2017, and the rate of installations is decreasing.

Objectives of Installation of PPWM

AdeM faced numerous complaints from its customers who did not agree with the billing of their consumption. In addition, AdeM also struggled with low collection, and high non-revenue water (NRW). Water supply was intermittent (12 hrs a day) however supply pressure was good.

Implementation

In 2015, AdeM hired INTELLICA to prepare a Strategic and Business Plan 2015-2019, one component of which included a market study. It was reported that invoiced amounts were the crucial factor leading to conflict between customers and AdeM. Assuming that under prepaid system, customers can control their consumption as well as save money, AdeM, introduced prepaid water meters in Maputo in 2017. The funds were managed through donors and recovery period was calculated to be 5 years.

O & M

Replacements of meters by AdeM is according to the malfunctions. Customers purchase credit at the company's stores, through electronic platforms (Mpesa and RecargaAki). There are numerous vending machines located throughout the city. Prepaid meters are usually installed in customers premises and are not covered by box. No incentive is provided to replace or install the meters. All the newly installed PPWM are at the cost of the utility. AdeM has dedicated teams for O and M and customer management of PPWM. It consists of project manager, sales technicians, and plumbers.

Public Awareness

Prior to introduction, customers were individually consulted, and their opinions were also considered. Yet, there were no public awareness campaigns launched neither before nor after the introduction of PPWM. In a satisfaction survey conducted by the utility, customers reaction in general was found to be good mostly because they could manage their own consumption. If any residents refused to install pre-paid meters, they were not forced against their will and left with the post-paid meters.

Regulations

PPWM by AdeM is regulated by AURA, which also regulates the post-paid meter system in the country. The tariff system is also the same used for post-paid customers.

Products

Prepaid water meters used by AdeM are manufactured in China and South Africa. The supplier of such prepaid meters in Maputo are Triana, Wihananah, Kasulo, Mixuene, Sotux, Mozzelec, and Tsenane. All the PPWM were mechanical velocity type. These meters are operated by token/coins. There are no after sales service provided by the supplier. The approximate malfunction rate is 16%. Valve lockouts, and battery failures are the main problems. The utility however is not capable of repairing the malfunctioned meters. Spare batteries are available in the market, though other parts are not available.

Customer service

The PPWM is owned by the utility however a customer must pay for any thefts or damage to the PPWM. AdeM conducts regular checks, repair, and maintenances, and replaces meter or batteries wherever necessary. In case of malfunction, the utility replaces the unit at no cost to the customer. The same is the case when the PPWM unit expires. The utility has also been collecting its debts at the rate of 50% each time a customer tops up the token. There are also illegal use problems such as bypass, meter damage, battery removal etc. Such illegal connections are found by judgement and thorough analysis of customers who do not often buy water. Such illegal use cases are subjected to be legalized. Besides, the utility also performs routine checks of consumption against purchased volume. The major complaints received from PPWM customers are constant meter and CIU failures, frequent battery discharges, and vague tariff rates, which is difficult for the customer to understand. AdeM has no problem where a PPWM customer is unable to pay bills. However, for customers facing problems to pay for PPWM due to COVID-19, the utility has provisions for suspension of debt collection.

Data Management

Customer database for PPWM is separate from post-paid system. AdeM uses web-based data transfer and customer management system. There are no gateway and LORA technology to transmit customer data from PPWM. Monthly reports are extracted with information about sales.

Impacts after introduction

After the introduction of PPWM, AdeM's revenue collection has increased. Costs related to operation and maintenance, billing and collection, customer management, and logistics have decreased. There was no change in the number of employees after PPWM was introduced and neither did the number of customers changed. On the other hand, water loss decreased, because customers repair the water leaks immediately and reported other leaks in the network. Daily water consumption rate has also reduced by 10% in the beginning however, it went back to previous consumption levels. Despite this, there is no change in the water supply hours.

Issues and Challenges

AdeM has used postpaid tariff to prepaid water meters which is a challenge to persuade customers. Procurement costs are relatively high. Likewise, constant malfunctions of prepaid meter unit is also a major challenge. Poor reporting and constant gaps in availability, information consistency errors, poor user experience are issues in software of PPWM. Payback period is very long due to high costs at introductions. AdeM also has the following O&M issues:

- Management system improvements
- Inclusion of a resource planning in the sales system
- Ongoing training
- Availability and high price
- Creation of local workshops
- Introduction of meter calibration

Recommendations

AdeM considers the introduction of PPWM in Maputo successful because PPWM reduced billing claims, promoted rational use of water and reduced water losses, ADEM is keen to continue and promote PPWM. Through its experience of PPWM, AdeM feels it is necessary to buy meters considering the specific situations in each target area. It also realized the importance of long-lasting batteries to avoid frequent breakdown of PPWM units. A dedicated PPWM team would also be an important factor in achieving customers will. The meter prices do not dictate the quality. AdeM also recommends that the desired specifications of PPWM should be well listed and decision should not be made on the basis of price alone. To make PPWM successful, training by supplier would be a crucial advantage especially for installation process. PPWM coupled with GIS would be effective to manage PPWM.

Case 7: Nakuru Water and Sanitation Company in Kenya

Background

Nakuru Water and Sanitation Company (NWSC) is a water supply utility in the city of Nakuru, Kenya. PPWM was introduced in 2012 with 15 units as a pilot project before upscaling. There are a total 46,389 customers under Nakuru Water. Number of standpipe/public standpipes with PPWM is 155 which serves about 3875 households. Annual additions of PPWM are not continuous in Nakuru and mainly installed on a project basis.

Objective of Introducing PPWM

Nakuru city in Kenya introduced PPWM mainly to:

- Increase revenue collection
- Reduce workload of meter reading, billing, and collection processes
- Supply water to low-income people through public tap stand
- Efficiently distribute available water and improve hygiene in low-income areas
- Reduce commuting time to fetch water through water kiosks
- Eliminate the intermediaries who overcharge

Prior to installation of the PPWM, Nakuru faced problems of low revenue collection because of water malpractices in low-income areas (LIAs). So, most landlords of those low-income areas could not afford/sustain a connection. Even those with a connection were reluctant to pay their bills. Non-revenue water was also high prior to PPWM introduction because many customers illegally drew water by puncturing water mains which also lead to major physical losses. Water supply before PPWM was also intermittent with many LIAs receiving water only for 12 hours, 3 days a week. Network pressure was low due to water malpractices and physical losses due to water infrastructure vandalism.

Implementation

For the implementation of PPWM, the water utility realized that they were collecting very less in water bills compared to the amount of water supplied. So, considering water accessibility and pricing the PPWM was initiated. Also, the utility considered that customers from LIAs usually consumed 1-6 units of water per month which fall under the category of pro-poor and was also protected under the WASREB regulations. The main donors were USAIS, WSTF, U.E and VEI. The utility also performed a cost benefit analysis and found out the recovery period as three and a half years.

Public Awareness

The residents were consulted before the introduction of PPWM through public hearing/stakeholder meeting and community meeting. Prior to the installations, public meetings were also held with the landlords of the LIA and then subsequent meetings with the landlords plus the tenants. After installation, the utility demonstrated the use/withdrawal of water from the PPWM and taught customers how to report abnormality. In a satisfaction survey conducted after the installations, customers were found to be satisfied and had positive. Tenants were able to access water at any time unlike before when landlord's-controlled water by locking taps.

Regulations

The tariffs and operational standards are controlled by the national regulator and the only guidelines are the ones delivered with the PPWM as manuals.

Products

Nakuru utilizes Elster Kent brand prepaid meters (2012-2015) and Tag meters (2016) and WAARI-Smart meter vending machine (2020). The major suppliers are Nairobi Iron Mongers, Maji Milele and KABS. Both volumetric and ultrasonic type prepaid meters are used. Vending method included token (until 2018) which has been upgraded to smart card system since 2020.

Customers recharge their token/smart cards from the utility office, though newly installed PPWM have an option of purchasing from MPesa, a local e-pay system. There are a total of 6 vending stations which are almost at a commuting distance of 2 km. Most of the PPWM are installed in landlord's premises while 52 PPWMs are installed in water kiosks. All the PPWMs are covered by box. Customers do not receive any incentive apart from the water kiosk vendors who buy credits from the utility in half price.

Customer service

The utility owns the PPWM which is also responsible for regular checks, repairs, and maintenances. Meter replacement and battery replacement are also the responsibility of the utility and the PPWM installations as well. All the cost of installation and repair and maintenance is borne by the utility. Daily monitoring is done to check the functionality of the meters and to ensure customers are satisfied. Replacement of meters is done only if the meter is faulty and beyond service. Major complaints from the customers are about battery lifespan and solenoid valve.

There are also cases of illegal bypasses which are detected mainly by informers and through consumption trends and regular monitoring. Customers conducting illegal bypasses are disconnected from the system and fined Kenyan Shillings 30000.

Poverty alleviation

PPWM was targeted especially for LIAs with pro-poor tariffs. These customers have no individual plots for water connection thus rely totally on public PPWM. Nakuru has not experienced any cases where a customer is unable to pay or recharge the token. The utility in Nakuru does not have a debt recovery mechanism.

Issues and Challenges

Major O&M challenges in Nakuru are battery depletion, solenoid valves and supplier issues. Although software, training and some of the spare parts is provided by the supplier, there are further issues with the supplier. The approximate malfunction rate of the PPWM is about 40% after 3 years of Nakuru's experience. The major cause is the product failure. The utility has the manpower to repair the malfunctioned meters, however it lacks spare parts. Also, software issues are often referred to the manufacturer. Battery, strainers, and meters are available in the local market however the price is very high. Solenoid valves, LCD and software is not available in the local market. The utility also has a portable meter test bench and ultrasonic flow meters for calibrations. The supply is continuous in some areas though others are mostly intermittent. Air valves are installed in the water supply system due to intermittent supply bringing in air intrusion problems.

Data management

The customer database for prepaid and postpaid meters is combined. The supply area is divided into 5 zones and the vending machines are stationed and managed at the zone. Customer data are found in the NAWASSCO server office. The utility uses web-based data transfer, gateway and LoRa technology. The PPWM accounting system is automatically integrated with the utility's billing/accounting software. Average monthly water consumption is 480 m^3/month for public PPWM users.

The utility has a dedicated team of plumber for technical issues, and customer care for vending controls and IT for technological issues. However, there was no change in the total number of employees. Some special staff check the functionality of the PPWM.

Impact of PPWM

The revenue collection of the utility has increased though the billing and collection cost has also increased. Operation and maintenance costs has remained unchanged whereas customer management and logistics costs has decreased. Total number of customer's have increased to 5,200 whereas the water loss has decreased.

Elster Kent has volumetric meters which are read monthly for comparison with the token sold while the latest PPWM WAARI meters transmit readings to the server. The water consumption has doubled than before the installation of the PPWM.

Issues and Challenges

- The utility has less experience on the PPWM system and determining the effective PPWM to suite water, installation condition as well as cost effective is difficult.
- The utility also lacks technical knowhow of the product.
- Software of PPWM have high maintenance costs and so are the operation and maintenance costs of the PPWM.
- There are fewer resources to deal with public awareness of PPWM.
- Income strength of the LIA is also a major social barrier to PPWM expansion.
- If there is a breakdown of the PPWM and there is a delay in sourcing of spare parts, it brings about lots of complaints and customer dissatisfaction.
- There are network issues for data transfer and management of PPWM.

Recommendation

The Nakuru water utility considers the PPWM system a success and will continue and promote it mainly because it benefits the customers to access water and also benefits the utility to collect revenue upfront. Lessons learned were choosing PPWM battery with a long lifespan and solenoid valve which does not dispense water for free. Other recommendations include provision of meters which are cost effective and technology compliant. As per the utility, success of PPWM system lies in providing customer sensitization, cost effective meters, and easy availability of spare parts.

Case 8: Nairobi Water and Sanitation Company in Kenya

Background

Nairobi in Kenya, introduced prepaid water meters in 2017 to increase its revenue collection, reduce workload of meter reading and collection processes and also to supply water to low-income household through public tap stand. As a poverty alleviation measure, the PPWM was introduced to be programmed to provide water at the lowest tariff which can also ensure sustainability. Although it used its own funds to initiate the PPWM technology, it did not perform a cost benefit analysis.

Regulations

The PPWM in Nairobi must be supplied at the tariff approved by the gazette Water Services Regulatory Board (WASREB) tariff for the water kiosks in low-income areas. Such tariff for water kiosks is set by the national regulator WASREB.

Products

The model of PPWM used was SUSTEQ from the Netherlands supplied by Maji Milele, a local supplier in Kenya. The types of prepaid meters are mechanical, volumetric type and it operates by a token.

Implementation

Started in 2017, the main target areas were the unplanned informal settlements where incomes were low. Out of 300000 customers, there are 4018 public stand post which serves 20,090 customers. Only 165 public stand posts are connected to PPWM which serves 25000 customers. On average, 60 new PPWM are either installed (or replaced) annually and the trend of such installations is increasing.
PPWM customers can purchase the credit from the PPWM operator located at 165 points in the city. The distance from the customers to the vending stations varies from area to area. Most of the PPWM are installed in customers premises, public land and landlord's premises. The PPWM are covered by box. The customer who operates the PPWM receives a percentage of the total sales.

Public Awareness

Residents were consulted prior to installation and their opinions were considered especially about the affordability of the water and the security of the PPWM. Public hearing/stakeholder's meeting/community meetings were conducted to gain consensus. Prior to the introduction, public awareness campaigns were conducted to explain the customers the advantages of using the PPWM, its level of service and quality of water. Even after the introduction, the utility trained the customers on the use of PPWM. A satisfaction survey was also conducted after the introduction of the PPWM. Customers whose postpaid meter was replaced with PPWM were very positive as it reduced the accumulation of bills. The installations were done after sensitization campaigns, so the residents hardly refused to install.

Customer service

The PPWM is owned by the utility which is also responsible for regular checks, repair and maintenance, and replacements of meter and battery. If any malfunctioning cases arise, the utility repairs it at its own cost and replaces it if repair is not possible. There is no debt recovery system in the PPWM. The utility faces issues of bypass which is detected during routine inspections. Arrests and fines are made as per the applicable statutes for those illegal bypasses. Besides that, monitoring is also done through periodic site visits. The main complaints are that when water pressure is low customers cannot access water from the PPWM.

Poverty alleviation

All customers can afford to pay for water charge. There could be some social cases but are not documented. Some low-income areas are being offered free water during the COVID-19.

Data management

Customer database for PPWM is separate for postpaid and prepaid. Utility has a sociologist who collects customer data during enrollment. It does not have web-based data transfer and customer management system. The supplier has its own software for management of the PPWM. The billing and accounting are done separately using the software from the supplier.

Organization

The utility has a dedicated team for operation and management of PPWM which consists of electrician and plumbing artisans. Total number of dedicated staffs for PPWM is 9.

Impacts of PPWM

Revenue collection has increased after the introduction of PPWM. Operation and maintenance, billing and collection has reduced whereas customer management and logistics cost have increased. There was no change in the number of employees to help PPWM management. Supplier trained some staffs at the utility specifically for installation and maintenance. Number of new PPWM customers increase per year was 5400. Water loss has decreased after introduction of PPWM.

The PPWM are GSM enabled and transmits all data. E.g., water consumption, sales, credit, battery charge etc. automatically to the office. The PPWM was introduced in non-piped coverage areas, therefore its impact on water consumption could not be determined. However, water supply duration has increased after the PPWM were installed. PPWM are sometimes supplied with water stored in elevated tanks when water from the mains is not available.

Issues and challenges

Major challenges in PPWM system in Nairobi includes high unit cost of PPWM which takes a long period to receive return of investment. Because of low tariff, it is discouraging the investment in PPWM. Regarding credit charging, one major problem is the access any credit which a token holds when it malfunctions. Field inspections are needed to identify illegal connections. Other issues are vandalism of the PPWM. The utility repairs the vandalism, and the supplier provides the spares needed as per the contract and software support. After 1 year of introduction, the malfunction rate was almost 10% including some vandalism cases. Other malfunction causes are valves and battery failures. The utility also has a workshop to repair the malfunctioned meters. All spares are available from the local agent of the manufacturer. The utility also has a meter bench but does not check meter accuracy of PPWM. The utility has also signed a MOU with vendors mainly for security of the PPWM and credit vending. Although supply is intermittent some areas, air intrusion is not a problem.

Recommendations

PPWM implementation in Nairobi is considered a success as reported by the utility and they plan to continue installing and promoting PPWM since it is easy to manage customer data, and credit dispensing is also easier. Besides, it is easy to record volume measurements in PPWM and NRW is also reduced eventually. The utility in Nairobi has suggestions that PPWM eases management of water services especially in unplanned informal settlements. It does not allow bill accumulation thereby eliminating bad debts. However, utility must explore more affordable PPWM in the market.

One major recommendation is to promote PPWM with no power mains but by using solar power. Community sensitization and participation is very crucial in the success of PPWM use.

Case 9: National Water and Sanitation Company in Uganda

Background

Kampala is the capital and largest city in Uganda. At the time of the National Population Census 2014, Kampala had a nighttime population of 1,507, 000 (Uganda Bureau of Statistics UBOS, 2017). This is now projected to have exceeded 2 million people. National Water and Sewerage Corporation (NWSC) a parastatal of the Government of Uganda, is responsible for supply of safe piped water to Kampala as well as all urban centers in the country. NWSC serves some 315,815 metered customers in Kampala (National Water and Sewerage Corporation, 2020). There are 4,273 public standpipes in Kampala with 1,500 of them having PPWM. National Water is a leader and model of success in urban water supply in Africa and the world and the implementation of water supply approaches in Kampala have been used to inform similar implementation in many other countries.

In Uganda, PPWM were introduced in 2006 by the NWSC with the purpose of improving access to safe water for low-income household in high density areas of Kampala City (also variously referred to as informal settlements, slums, or ghettos). Prior to this, the government of Uganda through the Ministry of Water and Environment (MoWE) had articulated a pro-poor strategy which was the backbone of the policy for the provision of safe water to low-income households in informal settlements. Subsequently, government prepared the institutional infrastructure for the implementation of the pro-poor strategy through the formation of the pro-poor unit in NWSC. Once this enabling framework was in place, NWSC mobilized its own resources and was also supported by development partners (donors) and the Government of Uganda to install PPWM in pilot sites in Kampala[4]. Installation of PPWM was subsequently rolled out to additional areas in the city and beyond.

Table 1. Public PPWM installed in division of Kampala City

Division	Served wards in division	Number of pre-paid meters
Kawempe	Bwaise 1, 2 and 3, Kyebando, Tula, Kagoma, Kanyanya, Nameere, Mulago, Kalerwe	466
Central	Kisenyi, Kagugube, Kibuli, Kamwokya, Namuwongo, Katwe	252
Nakawa	Biina, Luzira, Mutungo, Kireka, Kirinya, Banda, Kitintale	261
Lubaga	Nyanama, Namungoona, Kawaala, Ndeeba, Nateete, Nabulagala, Kasubi	246
Makindye	Kibuye, Ndeeba, Nsambya, Bukasa, Namuwongo	314
Total		1,539[5]

Source: Low Income Customer Support Units. Case Study – WaterAid Feb 2016.

Subsequently and with support of more development partners PPWM were installed in many more sites in the informal settlements of Kampala. Table 1 above shows the sites where PPWN were installed. NWSC states that there are currently 1,500 PPWM in Kampala serving some 150,000 people[6].

[4] Starting in pilot sites was a way to test out the technology and pick lessons for implementation at a wider scale.

[5] NWSC says that the exact number of PPWM varies from time to time as PPWM are demobilised due to malfunctions or replaced by new ones.

[6] The number of public standpipes with PPWM varies from time due to some of the standpipes being decommissioned due to poor functionality and others being installed. The rate of decommissioning and

According to NWSC there is no program for increasing number of PPWM and the number of PPWM is therefore currently constant.

NWSC in Uganda faced several problems in billing, collection, and non-revenue water. Substantial manpower hours were spent in reading the meters and distributing bills. The bills which were delivered to the caretaker were often not paid. Illegal use was also high especially after disconnection. Likewise, the supply hours were totally on the caretaker availability. On the other hand, there was an increasing trend in non-payment by the private government connections. To overcome these problems, NWSC introduced prepaid water meters in 2017 with the intention of

- Increasing revenue collection
- Reducing workload of human resources
- To supply water to low-income people through public tap stand
- To enable the poor to receive water at pro-poor tariff.
- To eliminate middlemen from the water supply system who used to overcharge the poor and yet they would not pay the bills to the utilities promptly.

In the introduction of the PPWM, the government policy was to reduce domestic arrears while also improving the access of poor people to safe water as water is the key to the welfare of individuals.

The funds for the public prepaid meters were managed from the utility's own funds, donors, and government subsidies. After acquiring some prepaid meters, cost benefit analysis was carried out which was calculated to be 7 years. However private government connections were replaced by prepaid meters by the utilities own funds only which was initiated after conducting a cost benefit analysis with a payback period of 3 years.

Issues and challenges of PPWM installation

The utility faced some major challenges at this point, as described below:

- Land ownership problems – Slums are informal settlements and most residents do not own the land in which they live. Many people are tenants in makeshift tenements. Land ownership is therefore diffuse, and some landowners resisted installing PPWM on their land out of fear that they might lose their land. In practice PPWM are installed outside of a resident's premises. Even after the sensitization, some residents rejected PPWM near them in which case the utility looked for another resident who accepted the PPWM.
- Resistance from water vendors and operators of existing public tap stands – The PPWM threatened the livelihoods of water vendors by availing safe water at an affordable price. Operators of public water stands also felt that their source of livelihood was under threat. These operators make a living by adding a markup to the price of water which they pay to the utility.

installation is not always the same, neither are the locations always the same. NWSC indicates that in general the number of public standpipes with PPWM has been relatively constant for some years.

Box 1. Water price dynamics

The lowest tariff for water is that for water supplied to public tap stands – at UShs 1,060 (approximately USD 0.3) for a cubic meter or UShs 25 per 20 litre jerry can. This tariff benefits from a cross subsidy from the tariff charged on house connections. However, most people in informal settlements are not able to access water at this tariff because of the markup on this tariff by the operators of the public tap stands. In fact, customers fetching water at the public tap stands end up paying much more that those with house connections, usually between UShs 200 and Ushs 500 per jerry can depending on the situation, because of this dynamic. PPWM make the operator of the public tap stand unnecessary and therefore eliminate this mark up. Therefore, users are able to access water at the lowest tariff.

PPWM for institutions

In Kampala, PPWM were originally planned to be introduced in informal settlements for the low-income households. However, in 2017 NWSC opted to introduce PPWM for institutions to stem endemic non-payment of bills. Some institutions had accumulated such huge bills that they were undermining the financial feasibility of the utility. Moreover, this was happening while government was allocating funds to these institutions for water. The change to PPWM for such institutions was triggered by a row between a large hospital in the country. Following the disconnection of water by the utility over a huge, accumulated bill, the institution went to the media alleging loss of lives due to failure to carry out normal treatment procedures due to lack of water. The issue reached parliament which also summoned the utility. After both sides presented their case, the hospital was compelled to come up with payment for the outstanding bill. To avoid such incidents in the future, NWSC was authorized to install PPWM on key institutions that were notorious for non-payment. PPWM were therefore introduced for some institutions including major hospitals and police and army barracks. NWSC reports that there are some 200 institutional PPWMs in the country, but more are being installed.

Choice of Technology

The process leading to the choice of the model and brand of meters to use has not been availed. However, according to NWSC, two brands of PPWM are in use namely:

Elster Kent (the owning company is now called Honeywell) and SUSTEQ for the public standpipes and Elektromed – for the institutions. The PPWMs for the public standpipes use a token which is inserted by the customer to access water. When the credit on the token is used up, the customer has to load new credit with a credit vendor. The credit vendor is appointed by NWSC and usually resides in the recipient community. The vendor is trained and equipped with a handheld device which he/she uses to load credit on the tokens of users. There are 15-20 credit vendors in each area of service. (The areas are unplanned and informal in nature, so they are different in size and lay out). The goal is to have one vendor within 2 Kms of each user. The vendor collects money from customers that he uses to pay for water in advance, earning a commission of 10 percent of sales every time. The institutional PPWM use a smart card. NWSC has named the price of a PPWM at USD 1,000 and the cost of installation at USD 100.

Box 2: How credit vending works

When a credit vendor is appointed, he/she is trained and allocated a vending machine which remains the property of NWSC. At the time of selling credit, a token holder pays the credit vendor cash and hands in his/her token. The token is inserted into the credit vending machine and the credit vendor transfers a specific amount of credit to the token. The token owner then takes away his/her token with new credit. Once most of the credit on the vending machine is sold, the vendor physically banks the money on an account designated by the utility. The bank gives the vendor a banking slip with a unique number which the vendor physically takes to the office of the utility together with the vending machine. New credit is then loaded on to the vending machine. Vending machines in use now have no capacity for remote data exchange with the utility or with a token holder.

Operation and Maintenance (O&M) Strategy of NWSC

Besides manufacturing integrity, the O&M of any water facility is critical in its functionality and long tern service. This study examined the approaches to O&M of PPWM by the utility including the support infrastructure such as credit vendors as well as perceptions on functionality from the customers.

As part of its O&M strategy, NWSC formed a unit called the Pro-poor unit that is responsible for the installation and management of PPWM public standpipes as well as post-paid public standpipes. Training covered both technical and commercial and customer care aspects. In the technical area staff were trained on the operation and maintenance of the PPWM. On the commercial and customer care aspects, staff were trained on a range of competencies including community engagement, mobilization, and facilitation skills as well as handling of customers. From the trained people, NWSC created teams and allocated responsibilities for O&M and customer management of PPWM. The teams consist of IT specialists, engineers, commercial people and social scientist skilled in community mobilization. NWSC has a policy of all field staff having customer relations skills and being multi skilled. Therefore, wherever they go they are also able to deal with customer complaints and issues. NWSC therefore did not create special structures for O&M PPWM but trained existing staff to be able to manage the O&M of PPWM in addition to the O&M of post- paid meters. In the same way NWSC does not have a special workshop for PPWM but uses the same workshop for both PPWM and ordinary meters though equipment that are needed to dismantle and assemble PPWMs like special screw drivers, allen keys, special spanners and screw drivers, soldering guns, electrical testers (multimeters) and others were added to establish capacity for O&M of PPWM.

While customers have a responsibility for the proper use and securing of the PPWM, the PPWM remains the property of the utility and is replaced at the cost of the utility if it fails. But where malfunction is the result of vandalism or malicious damage, the users especially if the user is a private institution, is asked to pay for the repair or replacement.

Where PPWMs develop problems, customers call in to report problems with the PPWM. The problem is then assigned to any staff available who will visit the site, trouble shoot and carry out maintenance or repair as needed. NWSC staff inspect and read the PPWM once a month even if no problem has been reported with the specific PPWM. (The meter is read manually, and the recording recorded on paper and later input into the data scheme of the utility)

Functionality

This study inquired into the functionality of PPWMs arising either from manufacturing defects, design issues or misuse. Malfunction from design problems, for instance, can arise if the meter is designed for very clean water and then it is installed in a place with water with relatively high turbidity and grit. All PPWM installed in Uganda have a warranty period of one year for PPWM of public stand taps and 3 years for the PPWMs of private connections, to take care of manufacturing defects. NWSC reports that the functionality of the PPWM is generally good though no study has been carried out to assess the functionality rate of PPWMs. The main source of malfunction for PPWM is batteries which expire and have to be replaced from time to time. NWSC has prepared for this by having a stock of batteries for replacing the spoiled ones. For institutional PPWM, grit is also a challenge as it is reported to cause breakage of impellers.

Intermittent supply of water can lead to malfunctions in all types of meters due to air bubbles as well as grit that may seep into distribution pipes when there is no water. With the PPWMs both grit and air bubbles occasionally cause problems with institutional PPWMs. However, this is not the case with PPWMs for the Public Standpipes which are located in the informal settlements. NWSC reports that because most of the informal settlements are at the bottom of the valleys (Central Uganda's topography is characterized by flat topped hills separated by valleys dissected by streams) they never experience shortages of water that are characteristic of the higher zones of the city that are generally inhabited by the high-income residents.

Box 3: Innovations in the repair and maintenance of PPWM

With batteries being the most common cause of fault with PPWM, NWSC decided to find a local solution. NWSC engineers fabricated a battery with components sourced locally. These batteries have shortened the down time of standpipes with PPWM and obviated the need for keeping stock of expensive imported batteries. NWSC is experimenting with solar powered batteries in the PPWM so that the batteries being continuously charged do not run out. NWSC engineers are also working on improvising other components of the PPWM including the electronic module. Some electronic modules have been repaired with the replacement of some components such as capacitors and the learning process is ongoing.

Cost benefit analysis

During the introduction of PPWM in Uganda, the issue of cost and return on investment was not a major issue. The main reason for the installation of PPWM was to enable poor people in informal settlements to access safe water at the tariff set by the utility. NWSC reports that cost benefit analysis was not done at the introduction of the PPWM for public stand taps. However, it was done latter, and it showed that payback period is 7 years. For PPWM at institutions, cost benefit analysis was undertaken, and it showed a payback period of 3 years.

Efficiency of credit vending

NWSC aims to have a credit vendor within 2 km of any PPWM user and reports that there are 15 -20 credit vendors in each of the informal settlements targeted. Optimally these credit vendors should be sufficient to meet the needs of all users. In practice there are some users who still complain that they are finding it hard to get access to credit due to the unavailability of credit vendors. This issue is explored more in the section on users' perceptions.


Photo 1. A credit vending machines and a credit vendor. Note the token sticking out at one end of the machine.

Special arrangements for the poor

PPWMs have been promoted in some countries as tools for improving access to water for poor people. But in other cases, they are vilified for monetizing water and limiting access to water for poor people. In Kampala, PPWM have helped to improve access to safe water for poor people in informal settlements by facilitating access to water at the utility tariff for poor people. This is the lowest tariff, and it can only be accessed via the public standpipes. Unlike other countries however, the PPWM have not been programmed to provide a minimum amount of free water or to provide free water in emergencies. This is partly because of the prevailing policy in Uganda (water is not yet considered a right) and also because there are no house connections with PPWM. NWSC reports that no special arrangement has been put in place to help customers cope with the impact of COVID. However, at the peak of the lockdown period the government announced that no one should be disconnected due to unpaid water bills.

Data management with PPWM

With regard to data management, NWSC reported the management of the customer database for institutional PPWM is different from the management of customer data base for public stand post PPWM.

For institutional PPWM, the customer data base is integrated with that of the Post-paid customers. Customer consumption data is remotely monitored. The utility uses a web-based data transfer and customer management system using GPRS communication. NWSC reported that it uses gateway and LoRa technology (APN cards in modems) to transmit customer data from PPWM and manage it in the web base. Additionally, institutional PPWM accounting system is automatically integrated with the utility's billing/accounting system/software.

For public stand post PPWM, the customer management data base is separated from that of post-paid customers. NWSC reports that in this case there is "data downloads for handheld devices and online for vending stations" (handheld devices are used to bill post-paid public standpipes and data is relayed to the utility. For prepaid standpipes, data is relayed from the payment points, banks etc. online to the utility). Both manual and web-based data transfer and customer management systems are used. For public standpipes PPWM, NWSC does not use gateway and LoRa technology but uses internet. For public standpipe PPWM accounting data is not automatically integrated with the utility's billing and accounting system. It was explained that this is considered to be the best approach for now considering that the PPWM for public standpipes have a different objective. But aggregated outputs from this data such as monthly revenue is transferred as needed into the utility's accounting system. NWSC reported an average monthly consumption of 50 cubic meters per public standpipe.

Impacts after introduction of the PPWMs

- Costs: NWSC reports that revenue increased after the introduction of PPWM both from institutional customers and from the public standpipes. NWSC says that cost of O&M for public standpipes with PPWM increased because of the cost of components such as batteries and the need for more regular monitoring and maintenance for the PPWM.

- Human resources: NWSC reported that there was no significant change in the number of employees after the introduction of PPWMs both with the institutional PPWM and with the public stand taps. Nevertheless, existing IT and engineering staff were trained to handle PPWM matters. (NWSC reported that even though there is no billing for PPWM of public standpipes, they have to be monitored and readings taken regularly)

- Water Loss: NWSC reported that the water loss rate remained the same with institutional customers but reduced with the public stand taps. Note that NWSC also reported that institutions took measures to reduce leakage and water loss within their systems because they were paying for a lot of lost water. According to NWSC, the reduction in water loss at the public standpipes is due to reduced meter bypass and water theft (illegal activities). (Some of the water theft was by individuals who would fill tanks to resell to people. Due to the ability of everyone to access water at NWSC tariff, this practice became unviable) NWSC did not make a distinction in water loss at the Public Standpipes with PPWM and those with mechanical meters.

- Water Supply: NWSC determines the water supplied to institutional and public standpipe customers based on the bills. However, in the case of PPWM of public stand taps, the utility also carries out periodic manual meter reading as an audit. NWSC has not noticed any significant change in the water supplied to both institutional and public stand tap PPWM customers. Neither has there been any recognizable change in the water supply hours. NWSC reports that supply was already 24 hours before introduction of PPWM.[7]

Issues and Challenges

NWSC faced various issues and challenges associated with the PPWM which is summarized in the table below.

	Issue or challenge	Institutional PPWM	Public Stand Tap PPWM
1	Regulations/Legal aspect	PPWM have no clear policy yet	None noted yet
2	Procurement	It follows the normal procurement process with pilot requirements.	PPWM has be imported
3	Technical/products	Failure before the expected time especially batteries and humidity and water ingestion.	Cannot easily be upgraded

[7] While NWSC maintains a policy of 24/7 water supply, a steep increase in demand for water coupled with constant supply has led to some parts of Kampala getting intermittent supply. NWSC is due to commission a new water treatment plant at Katosi that is designed to deal with this problem.

	Issue or challenge	Institutional PPWM	Public Stand Tap PPWM
4	Software of PPWM	System down times caused by system crashes	Takes long to be upgraded
5	Cost and benefit	Installation, license fees. The technology is still quite expensive.	Cost fluctuates with the dollar rate.
6	Installation	The PPWM require special Installation protection.	Land tenure system
8	Credit charging and vending	Internet failure causes the system to delay in crediting the meters sometimes	Technical Failures of handheld devices (credit vending machines)
9	Public awareness	None	Transient population of the poor communities requires continuous sensitization
10	Social aspects	None	Culture of the people, religion and values
11	Customer service	Sometimes meter reports are not sent to the server	None
12	O&M	Shared test bench with postpaid	None
13	Data management	Internet issues that cause the delay of reports transfer	Token based data transfer requires long periods to get all data.

Success factors in the implementation of PPWM

NWSC reports that the introduction of PPWM is considered a success and the impacts of the PPWM technology have been positive. PPWM has enabled efficient arrears recovery for institutional customers and this has helped to ensure continuity of service. On the other hand, public standpipe PPWMs have received wide acceptance and are continuously used by the customers.

While PPWM are expensive in comparison to ordinary post-paid meters, the social economic benefits, especially for the public standpipes outweigh the cost.

To ensure that the introduction of PPWM is successful, NWSC makes the following recommendations.

- The protection of PPWM is very important for their longevity.
- Need to have good specifications and ensure that installations are done as per instructions.
- Community involvement before commencement
- Protection of the PPWM from water ingestion (The electronic module is very sensitive to moisture. While it is manufactured as waterproof, continuous exposure to moisture may cause condensation inside which will lead to malfunction.)
- Stakeholder involvement is needed at all stages. In addition, top utility management support is a necessity.
- It is recommended to have a dedicated team to manage and maintain PPWM installations.

Annex 2: Photographs from the Field Survey

Focus Group Discussions in Kampala

Elster Kent PPWM in Kampala


Vandalized public PPWM in Kampala


Alternative water sources in Kampala: Springs (left) and Stream (right)


Postpaid meters in Kampala (Residents often queue their jerry cans to collect water)

Despite low water tariff offered by utility, intermediaries lock the tap to sell water at higher rates in Kampala

Customers at a water kiosk (left) and a PPWM in the Kiosk (right) in Lusaka

Protecting PPWM from water logging: Off the ground (left) and Wall installation (right) in Lusaka

User Interface Unit

Customer Interface Unit

Typical Customer house connections in Lusaka

Final Report

Part 2:
Key Findings and Recommendations on Introduction of PPWM

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Part 2. Key Findings and Recommendations on Introduction of PPWM

Studied Water Utilities

After a detail review of the studied water utilities/providers in Sub-Sahara Africa in the part 1 and Jenin in Palestine, where JICA is implementation a pilot project of PPWM, this part provides an outline of the major comparative findings based on the service utilities' experience with PPWM introduction and the points to keep in mind when introducing PPWM. The outlines are summarized in 11 points.

Table 1 Summary of the Studied Utilities

Country	Water Utility	City	Type of PPWM Customers
Palestine	Jenin Municipality	**Jenin**	Residential, Commercial
Zambia	Lusaka Water and Sanitation Company	Lusaka	Residential, Commercial, Public Institutes (PI), public standpipes
	Nkana Water and Sanitation Company	Nkana	Residential, Commercial, Public Institutes (PI)
	Kafubu Water and Sanitation Company	Kafubu	Residential
	Lukanga Water and Sanitation Company	Lukanga	Residential, Commercial, Public Institutes (PI)
	Mulonga Water and Sanitation Company	Mulonga	Residential
Mozambique	Águas da Região de Maputo (AdeM)	Maputo	Residential, Commercial
Uganda	National Water and Sanitation Company	Kampala	Public Institutions (PI)
	National Water and Sanitation Company	Kampala	Public Standpipes (PSP)
Kenya	Nakuru Water and Sanitation Company	Nakuru	Public Standpipes (PSP)
Kenya	Nairobi Water and Sanitation Company	Nairobi	Public Standpipes (PSP)

1. Objective of PPWM introduction

1-1 The purpose of introducing PPWM is to increase income from water charges, but other purposes are also expected.

The issues and objectives of the water supply service before the introduction of PPWM of the water supply utilities studied are shown below. The main purpose of introducing PPWM is to increase revenue, but it was also expected to solve other issues.

Table 2 Issues and objectives of the water supply utilities before the introduction of PPWM

Item	Issues before introduction	Objectives after introduction
Water tariff income and NRW	1) Low collection rate of water tariff income 2) Large debt of customers 3) Indebted public institutions 4) Errors in bill readings 5) Illegal connection 6) Illegal intake from main pipelines 7) Large consumption due to fixed tariff rate 8) High non-revenue water (NRW) ratio	1) Increase of tariff income 2) Reduction of workload of staff (meter reading, billing, and collection) 3) Reduction of complaints of customers due billing error 4) Reduction of debt of public institutions.
Water distribution	9) Low water pressure and limited supply hours due to uncontrolled water supply 10) Water rationing supply	5) Equitable water supply
Public standpipes	11) Suspension of water supply of public standpipe due to unpaid caretakers 12) No access to public standposts due to unavailability of caretakers in standposts 13) High water tariff rate imposed by caretakers (intermediators)	6) Water supply to low-income areas 7) Water tariff rate for low-income households 8) Elimination of intermediators / caretakers 9) Improvement of sanitary condition of low-income areas
Others	14) Low customer satisfaction	

1-2 The ultimate objectives of the introduction are to improve water supply services, not to increase water tariff income.

In Jenin Municipality, several stakeholder meetings were held to introduce PPWM. At that time, stakeholders requested that the water supply situation be improved to agree to install PPWM. In addition, other Palestinian water utilities are also improving water supply conditions by improving water supply facilities before or in parallel with the introduction of PPWM. These utilities have suggested Jenin Municipality that the objectives of introducing PPWM should not be to increase income from water charges, but to improve water supply services. It is necessary to show stakeholders how the increased income from water charges after the introduction of PPWM would be utilized to improve water services.

In addition, as described in detail in 3-2, the introduction of PPWM into public standposts was also aimed at improving water supply service to the poor.

It is considered that aiming to improve the water supply service will increase the acceptability of PPWM.

2. Approach to Introduction of PPWM

2-1 Consider how to introduce PPWM.

It is necessary to start considering the introduction of PPWM after understanding the overall procedure for introducing PPWM. The following is a comprehensive list of PPWM installation procedures prepared with reference to the example in the Jenin Municipality. There are many steps to take before installation.

1. Preliminary survey / analysis
   a) Understanding the current status of existing water meter reading, billing, and collection systems
   b) Case studies of other water utilities that have introduced PPWM
   c) Available PPWM manufacturers and product surveys
   d) Social survey on PPWM (pre-installation survey)
   e) Evaluation of sustainability and preparation of strategies for PPWM (feasibility study (F/S))
2. Preparation of a PPWM implementation plan
   a) Preparation of a PPWM implementation strategy that includes pilot area selection
   b) Measures to improve water supply status (may be requested by stakeholders as a condition for installing PPWM)
   c) Preparation of a plan of PPWM system (server, credit vending station, gateway) setup
   d) Determining PPWM setup details (water tariff rate, debt collection percentage of the credit charged, use of various functions of PPWM, etc.)
   e) Operation and maintenance plan
   f) Customer service plan
   g) Public awareness activity plan
   h) Consideration of measures for socially vulnerable group
   i) PPWM operation and maintenance training plan
   j) Implementation schedule
3. Procurement of PPWM
   a) Determination of specifications
   b) Select a supplier
4. Public awareness activities
   a) Stakeholder briefing session
   b) Conducting a visit explanation survey of each house before installation (door to door survey)
5. Installation of PPWM system
   a) Installation of PPWM system (credit vending stations, server, gateways)

    b) Installation of PPWM unit to customers
6. Development of management system
    a) Development of operation and maintenance system
    b) Development of customer service operations
7. Post-installation survey (satisfaction survey)
8. Monitoring, maintenance, and complaint handling

2-2 Most utilities conducted studies and analysis prior to their decision on introduction of PPWM.

In cases of PPWM for residential customer installations, utilities conducted preliminary surveys and analysis to help them decide on introduction of PPWM. Following shows various types of surveys conducted by the Utilities:

1) Benchmarking visits (Zambia: Lukanga/Mulonga/Lukanga, Palestine: Jenin)
2) Review of the national water guidelines and regulations (Zambia: Lusaka, Palestine: Jenin)
3) Consultation with higher management/board members/City Council members (Zambia: Mulonga/Kafubu, Palestine: Jenin)
4) Test study for selection of type of PPWM (Palestine: Jenin)
5) Financial sustainability stud by cost-benefit analysis (Zambia: Nkana, Kenya: Nakuru PSP, Mozambique: Maputo, Palestine: Jenin)
6) Social sustainability study (Palestine: Jenin)
7) Social survey on introduction of PPWM (Zambia: Lusaka/Nkana/Mulonga/Lukanga, Palestine: Jenin)
8) Implementation of pilot project (Zambia: Lusaka/Nkana/Mulonga/Lukanga, Palestine: Jenin)

In Jenin Municipality, PPWM was introduced covering almost all preliminary surveys due to careful consideration of its introduction.

When implementing PPWM for public stand-posts, there are cases where the introduction of PPWM is decided without conducting a preliminary survey. In Uganda and Kenya, there is a problem that public stand-post caretakers are excessively collecting water charges by adding an additional amount to the official water tariff set by the government. In these countries because of measures to support the poor, it has been decided to install PPWM without conducting a major preliminary survey. (Uganda: Kampala PSP, Kenya: Nairobi PSP)

Box 1: Initial cost recovery period (Payback Period) for the introduction of PPWM

PPWM is an expensive meter compared to regular meters. It is necessary to check the financial sustainability by cost-benefit analysis, which is used as a reference for introduction of PPWM. Here, the initial cost recovery period is shown as an example, which indicates how many years the initial cost of introducing PPWM can be recovered by increased revenue by tariff collection. The initial cost recovery period (payback period) for the water utilities in this survey was in the range of 3 to

12 years. In addition, an example of calculating the payback period in Jenin Municipality is shown below.

Calculation conditions:

- Number of customers that meter is replaced: Approximately 9,000
- Tariff collection rate before introduction: Approximately 42%
- Tariff collection rate after introduction: 100%
- Water tariff: Approximately 1.25 USD/m^3
- Water consumption after introduction: 10% reduction
- Cost of PPWM unit (including installation cost): 170 USD/meter
- PPWM system set-up cost (including server and software): 20,000 USD/set

Calculation result:

The payback period was calculated as about 2.1 years. In the case of Jenin Municipality, the initial cost can be recovered in about two years.

Considerations:

The cost of PPWM unit influences the payback period, and at the same time, the water tariff level and the tariff collection rate before the introduction also influences it. For example, in the case of installing water meters to all customers in the target area, if the tariff collection rate in the area is higher or the water tariff is lower, the payback period will be longer, and the financial sustainability will be low.

2-3 Select the PPWM introduction target in consideration of customer characteristics and water supply conditions.

Although PPWM installation started with public sandpipes with a pro-poor strategy in 2006 in Sub-Sahara Africa (Uganda: Kampala), the PPWM targets expanded to individual residential/commercial and institutional customers in recent years for several other Utilities in the area. The Utilities, however, have been cautious in selection of the areas/targets where the PPWM should be installed.

Instead of installation for random customers or in random areas, the Utilities aimed to target specific areas or customers. Depending on the Utilities' service areas, various factors have been considered when the Utilities selected the target areas and customer groups as follow. It is desirable to target specific areas and customers selected based on the preliminary survey.

(1) Selection by customer characteristics

1) Areas with higher level of socio-economic characteristics (income and education) who are likely to accept PPWM as a pilot project (Palestine: Jenin City)
2) Previous meter is already secured in good location such as house premises (Zambia: Kafubu/Lukanga)

(2) Areas where collection rate is low and NRW ratio is high

1) High indebted areas (Zambia: Nkana/Lusaka/Lukanga/Kafubu/Mulonga, Mozambique: Maputo)
2) Unmetered satellite towns/areas/settlements with low collection rate (Zambia: Lusaka/Nkana/Kafubu/Lukanga, Kenya: Nairobi PSP, Uganda: Kampala PSP)
3) High indebted public institutions (Uganda: Kampala, Zambia: Lusaka/Nkana)
4) Areas with high NRW (Zambia: Kafubu)

(3) Low-income areas (in case of public stand-post)

1) Low-income areas (Zambia: Mulonga, Kenya: Nairobi PSP, Uganda: Kampala PSP)

2) High density areas with low-income (mostly for public standpipes) (Uganda: Kampala)

(4) Selection based on water supply facilities

1) Areas with more stable supply of water and better water pressure (Zambia: Lusaka/Nkana/Kafubu/Mulonga/Lukanga, Mozambique: Maputo)

2) Areas with established DMAs (Zambia: Nkana, Palestine: Jenin City)

In the case of Jenin municipality, public institutions are paying water charges from the government budget, and it was assumed that the prepaid budget could not be secured, so the municipality initially decided not to include public institutions in the PPWM installation target. However, later on, it was decided to install it in a public institution for the purpose of labor saving in meter reading and bill collection at the site and accurate data acquisition. For this purpose, the valve in PPWM is always open to convert PPWM into a postpaid meter and only PPWM's remote meter reading function will be used.

3. Consideration for Socially Vulnerable Group

3-1 Most water utilities have considered measures to ensure access to water for the poor, which is extremely important when implementing PPWM.

The measures taken by water utilities to deal with vulnerable groups when introducing PPWM are shown below.

1) Setting a low tariff rate
   - Customers in low-income areas with monthly consumption of 1 to 6 m^3/month are protected by a pro-poor tariff set by the government regulatory board for water services. (Kenya: Nakuru)
   - Under government policy to guarantee water supply to low-income households in informal residential areas, the government tries to curb the intermediaries of public stand post and provide water at low tariff rates. (Uganda)
   - Tariff rates of PPWM in the low-income category are cross-subsidized from water tariff rates in the high-income customer category. (Zambia: Lusaka, Lukanga)
2) Mechanism for collecting unpaid bill is not set. (Kenya: Nairobi PSP / Nakuru PSP)
3) Unpaid bill is collected from water charges at a low percentage of the credit charged in PPWM.
   - Set a low collection rate for unpaid amounts drawn from credit charged in PPWM to ensure a sufficient repayment period for unpaid bills for customers. (Zambia: Nkana)
4) Temporary suspension of repayment of unpaid bill (Mozambique: Maputo, Palestine Utilities including Jenin)
5) Temporary valve opening (Palestinian water utilities including Jenin)
   - For customers who are temporarily unable to pay for water, the municipality opens the PPWM valve for a limited period of time and records water consumption during that period as unpaid bill or debt. (Palestine Utilities including Jenin JM)
6) Use the PPWM in a postpaid manner

- Open the valve of PPWM of customers in poor households and record bills as debt (Palestinian water utilities, including Jenin) until they have the means to pay.

7) Donation by local government donation program to poor households (Palestine)
8) In some areas, water was provided free of charge during the COVID-19 epidemic (Kenya: Nairobi PSP).
9) Do not disconnect water connections during the COVID-19 epidemic (Mozambique: Maputo)

The above is the reduction or exemption of water charges after the installation of PPWM, but for the poor, connection costs are also a major barrier to water supply. Usually, when replacing an existing meter, the water utility often bears the replacement cost. However, in the case of a new connection, the customer basically bears the cost. In the case of Jenin, PPWM is about 120 USD more expensive than conventional meters, and new customers will have to bear the connection fee including the cost increased by expensive PPWM. For the poor, the barriers to connect water supply are even higher because of this cost increase. It is necessary to take measures such as subsidies or installment payment of connection fee to the poor. However, in the case of public stand post type PPWM, the initial cost is often borne by the water supply utility, so the burden of the initial cost is eliminated even for the poor. In order to promote water supply for the poor, it is necessary to promote the introduction of public stand post type PPWM.

3-2 Some utilities focused on pro-poor policy for their decision on introduction of PPWM.

As for the public standpipes, the decisions were mainly made without initial analysis and only by adopting the government's pro-poor strategies. In case of Kampala in Uganda, the government of Uganda through the Ministry of Water and Environment (MoWE) had articulated a pro-poor strategy which was the backbone of the policy for the provision of safe water to low-income households in informal settlements. Subsequently, the government prepared the institutional infrastructure for the implementation of the pro-poor strategy through the formation of the pro-poor unit in National Water and Sewerage Corporation (NWSC) of Kampala. Once this enabling framework was in place, NWSC mobilized its own resources and got support from development partners (donors) and the Government of Uganda to install PPWM in pilot sites in Kampala. Installation of PPWM was subsequently rolled out to additional areas in the city and beyond. In this case, an intermediary at the public stand post was charging users higher than regular water rates; the installation of the PPWM eliminated this intermediary and allowed users to purchase water at a lower price than before. Furthermore, non-payment of water charges by intermediaries had forced public stand posts to be shut down, which had a significant impact on the water supply of the poor. In addition, access to water supply was insecure, as water supply was only available when the intermediary was at the public stand posts. The introduction of PPWM at public stand posts has improved these conditions and enabled the poor to have a stable supply of cheaper water.

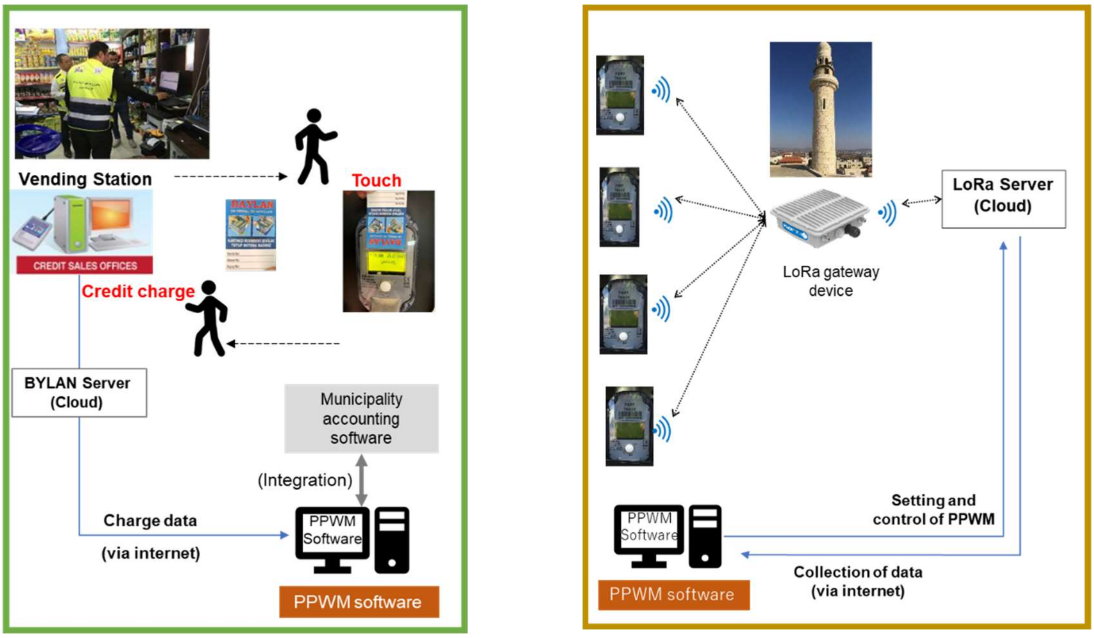
As for the Nairobi PSP in Kenya, such decision was also made by adopting the government's pro-poor service strategies for the high cost of water in low-income areas for the public stand posts. The water form PPWM in Nairobi must be supplied at the tariff approved by the gazette Water Services Regulatory Board (WASREB) for the water kiosks in low-income areas. Such tariff for water kiosks is set by the national regulator WASREB. PPWM can set rates for low-income households, thus providing low-income households with safe water at reasonable rates.

> BOX 2: Water tariff of public standpost (Kampala PSP)
>
> The lowest water tariff rate is for water supplied to public standpost, at 1,060 UShs/m^3 (about US $0.3), or 25 UShs per 20 liters of jerrycan. This tariff rate benefits from cross-subsidy from the water tariff rates of normal customers. However, most people living in informal settlements do not have access to the official rates due to the extra charges imposed by public standpost managers. In fact, customers who draw water from public standpost pay far more than normal customers. Generally, this extra amount is 200 to 500 UShs per jerrycan. PPWM eliminates payment of this extra amount by abolishing a public standpost manager. Therefore, the users are able to use water at the lowest official rate.

4. PPWM System

4-1 Understanding of Components of PPWM System

The overall layout of the PPWM and gateway systems and the components of the PPWM system are shown below.



Regular PPWM system Additional Gateway system

Figure 1 PPWM System and Gateway System

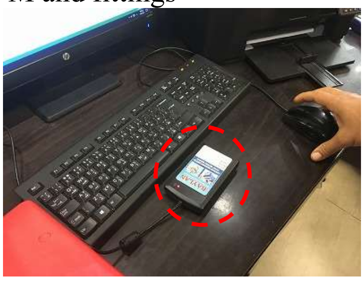
Table 3 Composition of PPWM System

Composition	Contents
① Pre-paid water meter (PPWM) and protection box	It consists of 3 main parts: a water meter that counts the amount of water, an electronic part that controls the prepaid system, and a valve that controls water supply. The electronic part has a user interface (UI) for loading credits and other data into the meter.
② Credit charging medias such as Smart card/ Token	Credits are charged by customers to this medium at the vending station, and the credits are loaded into PPWM using the PPWM UI.
③ Credit charging system (PC, card/token reader, UPS, printer etc.)	These are equipment installed at a vending station. A card/ token reader charges credit in the card. Charged credit data and other PPWM data are recoded and transmitted to the server via internet.
④ Database server and software	The server to save data of PPWM and software to control PPWM.
⑤ Internet	Collected data in vending station is transmitted to the server via internet.
⑥ Handheld unit	To read PPWM data on site, change various settings of PPWM, and acquire data. It can be operated within 100m to 200m from the PPWM. (Not required if gateways are installed)
⑦ LoRA gateway system (as necessary)	PPWM data is automatically transmitted to the server on a regular basis. PPWM settings can be changed and PPWM valves are operated remotely.
⑧ Integration of PPWM database with accounting database in utilities (as necessary)	PPWM customer data is automatically transmitted and updated to existing accounting software by integrating PPWM database with existing accounting database of water utility.

Ultrasonic type PPWM and fittings

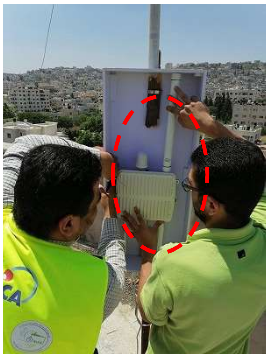
PPWM and smart card

Handheld unit



Card reader

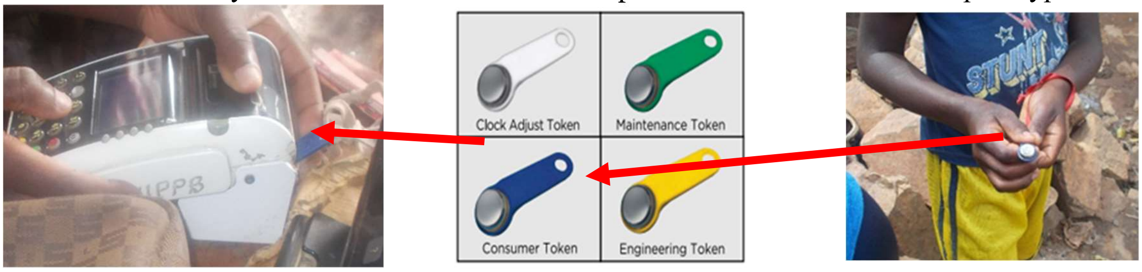
Mechanical type PPWM



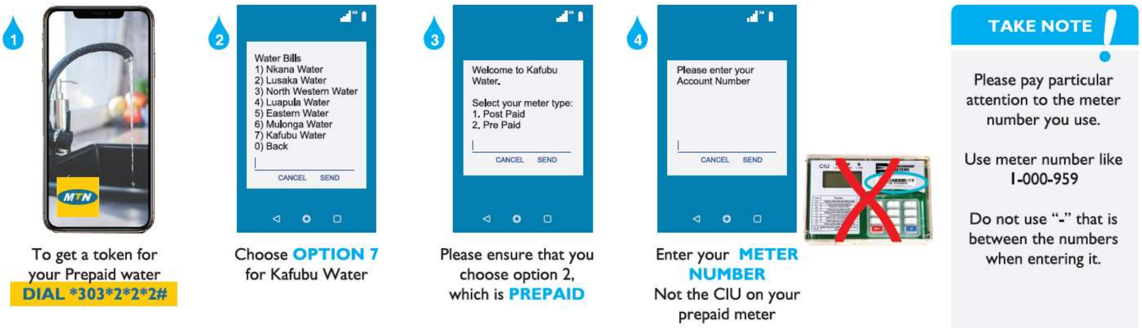
Gateway

PPWM in apartment

Public standpost type PPWM



Potable credit charger for token | Token | Token



An exapmple of charge by MTN Mobile money

Photo 1 PPWM System

4-2	**It is recommended to install a gateway to acquire PPWM data (water usage, credits used, etc.) on a regular basis.**

Credit charge frequency varies from customer to customer. It varies from week to week, once a month, once every few months, and so on. Only at the time of this billing, PPWM customer data (credits used and water usage) is sent to the PPWM database via the billing medium (card, etc.), so monthly PPWM water consumption and credit used data cannot be obtained. Therefore, monthly management indicators will not be available. For example, monthly total credit usage, total water consumption, and non-revenue water rate cannot be calculated. To obtain monthly data, a handheld unit or gateway is required. However, in the case of a handheld unit, it is necessary to be near the PPWM and work similar to traditional meter reading activity occurs. Therefore, when handling a large amount of PPWM, it is recommended to install a gateway and automatically obtain periodic data remotely.

4-3 Understand the various advanced functions of PPWM.

The functions that can be used with PPWM and their explanations are shown below. Since the functions that can be used differ depending on the brand of PPWM, it is necessary to confirm in advance what is required and decide the brand and product. These diverse functions can be used in various ways to improve water services.

Table 4 Diverse functions of PPWM

Function	Explanation
1. Tamper protection	If the customer tries to remove the PPWM from the connection fitting for the purpose of illegal connection, the valve will automatically close, and a warning will be issued. This warning is sent to PPWM's customer database if there is a gateway.
2. Debt (unpaid bill) repayment	If the customer has an unpaid bill when exchanging from the postpaid meter to PPWM, a certain percentage of credit will be used to repay the unpaid bill at the time of credit charging.
3. Friendly credit	A function that allows you to use water even if you run out of credits at preset time when the credit cannot be purchased such as at night. You need to pay for the used water amount at the next credit charge.
4. Emergency mode (Fire mode)	Even if there is no remaining credit, a preset amount of water can be used in an emergency case such as a fire. The used amount will be deducted at the time of next credit charge.
5. Free basic water	Customers can receive certain amount of water for free (usually once every month)
6. Credit purchase limit	Credit purchases will be restricted to address water shortages, reducing large water use by customers.
7. Consumption limit	Limit on the volume of water that customers can consume.
8. Daily consumption limit	Customers can only use a fixed amount of water each day.
9. Monthly consumption limit	Customers can only use a fixed amount of water each month. (Suppress the increase in water demand in summer etc.)
10. Low credit alarm	Warn when a customer's credit balance reaches a minimum level.
11. Backup mode	Warn customers of credit when the remaining credits fall below the preset credits.
12. Monthly water consumption profile	Display the history of daily water consumption for one month.
13. Water tariff setting	Tariff rates can be set for each customer and/or by area. It supports step water tariff structure of increase and decrease.

4-4 It is necessary to select the suitable PPWM meter type for the installation environment.

PPWM is mainly composed of three parts: a water meter part, an electronic part for adding a prepaid function, and an automatic opening / closing valve. The water meter section usually contains a water meter that can be purchased separately. The selection method of model/product for the water meter part, which has a large effect on the accuracy and life of PPWM, is shown below using the case of Jenin as an example.

Normally, mechanical (velocity type and volumetric type) water meters are used for PPWM. In Palestine, water supply rationing service (intermittent supply) is carried out, by which air gets intruded in the distribution pipes. Mechanical water meters count the amount of air as well as water, which is a problem because air count increases water charges. Therefore, an ultrasonic water meter that does not in principle count air was also considered in selection. The following table shows the evaluation of the three types of water meters. In the end, ultrasonic PPWM was selected because it does not count air, is not affected by foreign substances in the water, and has a long life, and the price as a PPWM is not much different from mechanical type. In addition, since there are few records of use of ultrasonic water meters for PPWM, a set of three types of water meters (velocity, volumetric and ultrasonic types) arranged in series was installed at 12 locations in the city and a demonstration experiment was conducted. The characteristics of ultrasonic type are evaluated in comparison with other types.

Table 5 Summary of evaluation of 3 types of water meter

Type	Velocity	Volumetric	Ultrasonic
Advantage	- Maintenance is simple. - Many experiences.	- Can be installed in any position. - Minimum flow rate is small. - Water meter unit is low price. - Many experiences.	- Do not count air. - Minimum flow rate is small. - No mechanical /moving parts.
Disadvantage	- Count air in intermittent supply. - Should be installed in horizontal position only. - Mechanical parts in flow can be likely damaged. - Minimum flow rate is high. Less sensitive at low flow rate.	- Count air in intermittent supply - With silty water and rust (particles), meter gets jammed and does not work accurately - Calcification occurs if water is ground water and rich calcium.	- Very less experience of ultrasonic with prepaid unit - More expensive than traditional meter.
Lifetime	- In general, 7 years or more and depend on raw water quality. - With mechanical parts, short life for accurate measurement.	- In general, 7 years or more and depend on raw water quality. - With silty water (particles) and calcification, short life or frequent maintenance.	- In general, 7 years or more. - No mechanical/ moving parts, possibly long life. - Battery life is 10 years
Price of meter unit	- Low	- Low	- High
Unit price [1] (indicative)	- Around 120~130 USD	- Around 120~130 USD	- Around 140~150 USD
Customer perspective	- Customers have negative preconception that meter counts air and more than consumption.	- Same as left	- Customer may claim it is no experience.
Evaluation	- Accuracy in low flow rate is low. - With mechanical parts, it can be damaged depending on water quality. - The accuracy is reduced according to age. - Air is counted even though it does not likely affect the measurement. It is difficult to remove customers' perception.	- Particle/dirt problems are severe. - Air is counted even though it does not likely affect the measurement. It is difficult to remove customers' perception.	- Good performance (minimum flow is lower). - Water with air and air bubble is not measured. - Without mechanical parts, life is longer. - Ultrasonic type is less likely to be blocked by any dirt or sand particles and can be utilized for a residential meter in a condition that water supply is intermittent and the dirt such as rust, sand, and calcium potentially contains in water supplied.

Note 1: An indicative price in Palestine.


Sand and particles in volumetric meter


Removed sand and particles from meter

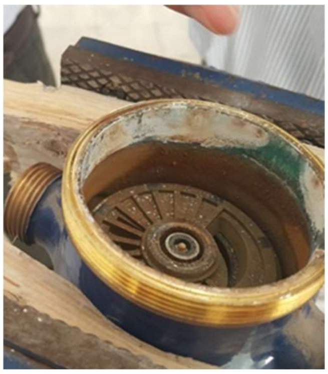

Scale adhered to meter

Photo 2 Foreign materials in volumetric meter

4-5 In order to ensure technical sustainability, it is necessary to select a product brand in consideration of maintenance.

After the introduction, there are cases where a large-scale PPWM failure occurred, and the purpose of increasing revenue could not be achieved. Since it is a complicated and expensive machine, it is very important to select a brand with few failures and high reliability. The following must be confirmed when selecting a brand.

(1) Conformity with international standards

To ensure the quality of the equipment, it is necessary to be certified with the code required for international standards. The code below is an example.

- OIML (International Organization of Legal Metrology): OIML-R49-1, 49-2, 49-3
- IEC (International Electrotechnical Commission): IEC60529 / EN60529
- ISO (International Organization for Standardization): ISO4064-1
- EN (European Norm): EN14154

(2) Availability and technical capabilities of local suppliers

Because it is a new system and there may be many problems immediately after introduction, it is necessary to rely on training and warranty services of local suppliers at the beginning of introduction. It is necessary to ensure that the local supplier has sufficient technical capabilities, including technical services, training content, and repair workshop content. If a utility plans to develop its own repair system in the future, it is recommended that it also includes the training details in the specifications of bidding documents.

(3) Warranty details and period settings

It is recommended to set the warranty period as long as possible (3 years or more) at the time of bidding. It will be possible to establish own repair system within the warranty period.

(4) Availability of spare parts

It needs to check in advance the availability of necessary spare parts. Some batteries can be used on the local market. If there are many parts that need to be imported from a foreign country, the repair cost will be high.

(5) Ensuring the required battery life

Many brands usually have a battery life of 5 years or more, but in actual use, it is often 1 to 3 years. It is recommended that the battery life guarantee be stated in the specifications. However, it is remarked that the battery usage is proportional to the credit loading frequency, gateway transmission frequency, and the like.

4-6 There are various ways to charge credit. The credit charging method needs to consider the IT environment and customer convenience.

Utilities, over several years of experience with PPWM, have made a combination of options available to PPWM customers for purchasing credit. The vending methods varies from token/coins for public standpipes to smart cards and recent method of mobile payment. In almost all studied utilities there are multiple physical vending stations in a nearby location where customers can charge their PPWM cards or buy tokens. A physical vending station is a reliable payment point that can secure purchases even in presence of other methods such as mobile payments.

Jenin has a contract with PalPay company, which has a nationwide payment network in Palestine. By installing PPWM vending machines in supermarkets where PalPay has terminals, many vending stations have been set up to improve the convenience of credit purchase for customers. Supermarkets are usually open from 8 am to 10 pm and customers can buy credit at almost any time.

Table 6 Utilities and their vending status

Utility	Utility office	Pay point	Handheld device	PPWM operator	Electronic/ mobile	Digital banking
Jenin	○	○	○ (not used)			
Lusaka		○			○	
Nkana		○			○	○
Kafubu		○				
Lukanga		○				
Mulonga		○				
Maputo	○	○			○	
Kampala					○	
Kampala PSP	○		○	○		
Nakuru PSP	○	○			○	
Nairobi PSP				○		

There are, however, some other barriers for users of public standpipes to recharge their tokens with PPWM operators/vendors. In case of the Kampala PSP Uganda, the credit vendors may not be always available at the standpipe with the handheld unit for vending credit and thus the users must visit the utility office; in some case about 7.5 kms away. In other case, the vendor comes to the users home regularly and users can buy credit at home. Overall, the average distance to travel (walking or motorcycle) to the vendor is 3 km and the average time to the vendor is about 30 minutes.

It is necessary to determine the location of the vending stations in consideration of the travel time to the vending stations by the customer and the operation hours of the vending stations.

When selecting a credit charging method, the IT environment in the area where it can be used, and the convenience of customers must be taken into consideration. Not all areas are capable of digital banking and electronic payments.

5. Public Awareness

5-1 Public/ customer awareness activities are important for improving PPWM acceptability.

Public awareness activities are conducted by the Utilities in different methods and scales before and after installation. Most water utilities provide their customers with the necessary information about PPWM and obtain their consent to install them before installing the meters. After installation, they follow up customers' use of PPWM.

In case of Jenin in Palestine, the scale of PR activities and individual awareness campaigns seems to be more expansive than other studied Utilities. Every customer in Jenin was visited in a Door-to-Door (DtD) campaign before the installation to obtain his/her consent for installation and to provide necessary information about the PPWM, and its benefits and usage. During the installation period, Jenin Municipality continued to carry out public awareness activities and provided awareness materials. Jenin Municipality also created a project video of interviews with some PPWM customers, and the customers in the video have expressed positive opinions about PPWM. This project video was posted on social media with the aim of raising public awareness.

Table 7 Type of public awareness activities by Utilities

Utility	Public meetings	Use of media	Individual consultation	Drama, movies	Printed materials	Online platforms	Post-installation campaigns	Satisfaction survey
Jenin	○	○	○	○	○	○	○	○
Lusaka		○			○		○	○
Nkana	○	○					○	○
Kafubu	○	○			○	○		
Lukanga	○	○						
Mulonga	○		○	○	○		○	
Maputo			○					○
Kampala PSP	○		○					○
Nakuru PSP	○							○
Nairobi PSP	○						○	○

In case of the studied African utilities, refusal was minimal or absent in Lusaka, Kafubu, Lukanga and most of the other studied utilities. In case of Jenin in Palestine, a small percentage of the customers continued to reject. The main reasons were mostly due to an underlying matter such as high debt or a general unhappiness with the Municipality's services. Some residents have their own private wells and do not want to use PPWM. Approaches to customers who rejected to install PPWM included:

1) Re-visit by PR staff and higher management personnel like Mayors and Council Members for obtaining their consent (Palestine: Jenin)
2) If rejecting insisted, they are referred to the Legal Unit for legal actions in case the refusal was for high debt (Palestine: Jenin). If not, they would be revisited again.
3) Remain with the postpaid system (Mozambique: Maputo, Zambia: Nkana).
4) If a landlord refused to allow installing public stand post type PPWM in his land, utilities look for other location (Uganda: Kampala PSP).

Post installation campaigns focused on assisting customers how to use PPWM and address their issues with PPWM. Nkana in Zambia conducted post installations campaigns on a quarterly basis. Jenin City utilized social media such as Facebook to publish flyers and information on how to use PPWM.

5-2 Customer satisfaction plays an important role in the successful operation of PPWM. It is important for water utilities to maintain customer satisfaction.

In the user's case study of Kampala PSP Uganda, the users were asked to rate their level of satisfaction on PPWM use on a scale of 1 to 5. A high level of satisfaction with the services of PPWM was found. None of the variables scored less than 4. Those with lower scores of 4 were for water availability – perhaps due to intermittent supply in some places and less availability of vending stations.

In the users' case study of Lusaka in Zambia, the users (PSP users and individual connections) were interviewed. They reported great satisfaction with PPWM and with the utility's services. Both groups were satisfied in terms of 1) good water quality, 2) adequate supply pressure, and 3) supply hours. However, there were some dissatisfactions with the scheduled-base water supply.

In Jenin, 10% of customers who installed PPWM were visited door-to-door after installation to measure their satisfaction with the introduction of PPWM. About 90% of the respondents were happy with PPWM. The reasons for their satisfaction are shown below.

- I was worried about PPWM before installation, but after installation I consider PPWM to be a fair method.
- I become responsible for paying water charges and reducing unpaid bill.
- There is no accumulation of unpaid bill. In the case of the post payment type, the bill collector does not come, I am absent from time to time when the meter reader visit, the payment is forgotten, etc., and the unpaid bill amount increases because the payment cannot be made regularly.

- The ultrasonic water meter is accurate.
- The meter is very good and convenient.
- The mechanism of the meter is simple.
- Understand how much water we are using.
- We can check the usage status and the remaining credit balance.
- Using PPWM streamlines water consumption. If we know we don't have enough credit, we don't need to use a lot of water.

On the other hand, the reason for dissatisfaction was not related to PPWM, but mostly due to water supply conditions such as water supply pressure and water supply hours.

Followings are requests from the surveyed customers for improvement of the Utilities services:

1) Improve reliability of PPWMs (less breakdown)
2) Increase number of prepaid public standpipes/kiosks and improve recharge payment system
3) Increase number of pay points for recharging prepaid card for customers with individual connections
4) Increase water supply hours/days, reliability and water pressure
5) Improve customer services and awareness information

6. Operation and Maintenance

6-1 Water utilities need to decide whether to handle failures independently or outsource them.

All the studied Utilities reported that they bore the initial cost of PPWM devices and fittings, etc. Malfunctions are treated as Utilities responsibilities for repair. Customers are liable to pay for any damages and tampering of PPWM units.

If the function of the water meter cannot be corrected at the site, the meter will be repaired or replaced. Malfunctions are most likely due to electrical or mechanical problems such as product failures, malfunctions of valve closure, and battery failures. In Jenin, the failure rate is as low as 4.2%[1], but some Utilities had high failure rates of 50% (Lusaka) and 40% (Nakuru and Lucanga). In some cases, the Utilities secure after-sales service and warranty period of up to 3 to 5 years to deal with breakdowns.

Among the Utilities, only Nkana in Zambia -with a longer history of PPWM- has now its own capacity for repair and a workshop and has a stock of spare parts in which they order from the manufacturer. Other Utilities still depend on the suppliers and the local agents for repair including Jenin Municipality. Before introducing PPWM, it is necessary to consider how to deal with failures or breakdown of PPWM. Water utilities may take the following options:

- Own a repair workshop and spare parts, and perform repairs on your own

[1] Ratio of the number of failed meters (numerator) to the total number of meters (denominator) up to a certain point (Jenin).

- Set a long initial product warranty period
- Make an after-sales service contract with an agency
- Set the repair range that can be done independently (for example, battery replacement, internal cleaning, etc.), and outsource the rest.

Box 2: Understand the details of the failure.
In the case of Jenin, the details of the failure are as follows. The most common failures were water leakage inside the meter, valve failure, and no counting meter. In these cases, they will be taken to the warranty agency's workshop for repair. So far, all failures have been repaired and returned. The failure rate is 4.2%.
- Leakage inside the meter
- Valve failure
- Meter failure (does not count)
- Cannot be used because the card does not match the PPWM number
- Water can be used without deducting from the credit of the card
- Count more than the actual consumption
- Battery is dead
- External damage to the meter
- Internal wiring connection problem
- Reverse flow
- Emergency mode starts automatically

6-2 By integrating the PPWM system with the existing accounting system, the water utility can effectively monitor all customer data including PPWM data and operate the accounting system with PPWM data.

Among the Utilities, only a few -including Jenin Municipality, benefit from integration between the PPWM software and the existing accounting/billing database software. Such integration is essential in saving staff time. Without integration, the staff must manually transfer the customer data of PPWM. With integration, the staff can supervise and monitor all PPWMs and post-paid regular meters for any abnormality in the database and process customer complaints, payments, and accounting in an integrated system.

6-3 LoRa gateway system can receive various customer data on a regular basis and can be used for customer service and non-revenue water management.

The LoRa gateway system introduced by Jenin can periodically receive data such as PPWM information and water consumption using low radio frequencies. The data communicated by the LoRa method can be used as an effective tool for monitoring the battery status of PPWM and the water consumption trend of customers.

In addition, it helps to efficiently monitor and detect problems such as illegal connections and leakage. For example, a customer who has not used water for a long time is suspected of having an illegal connection. Jenin is conducting a PPWM visit inspection survey focusing on these customers. In addition, the valve of the customer meter can be easily opened and closed remotely. By using this, it is possible to close all PPWM valves in the surveyed area for measures against non-revenue water and theoretically eliminate the flow of water in the water pipes in the area. In this situation, the sound of water leakage and illegal connection points are confirmed with the listening stick. In addition, from the PPWM information, it is pointed out to the customer that there is a possibility of water leakage in the customer's premises when an excessive flow rate is used. Other than the LoRa gateway, the Nairobi PSP uses GSM.

6-4 Even if PPWM is introduced, countermeasures against illegal connections are indispensable.

Even after the introduction of PPWM, illegal connections have remained a major issue for water utilities. In addition, it is assumed that customers who have not paid water charges may make illegal connections due to the change to the prepaid type. The details of illegal connections, detection methods, and countermeasures are summarized below.

Table 8 Illegal Connection

Contents of illegal connection	Detection method	Countermeasure
1. Meter bypass connection 2. Meter modification 3. Removal of battery 4. Removal of meter	1. Door to door survey (Visual inspection, regular inspection) 2. Tamper detection function of PPWM 3. Monitoring water consumption trend 4. Survey at the meter customer with 0 water consumption 5. Illegal connection information provider	1. Heavy penalty 2. Suspension of water supply and fine 3. Report to the police 4. Legal actions

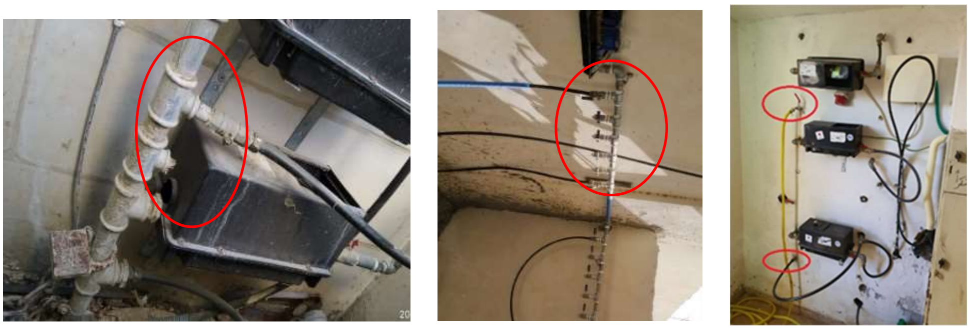


Photo 3 Illegal connections before PPWM

Although water meter reading is no longer required, regular observation of PPWM is mandatory to check meter status and illegal connections. Periodic checks of each customer's water consumption trends should be conducted for suspicious or unusual water usage. Zero or low water consumption may indicate a suspected illegal connection, while increased excessive water consumption may indicate a leak on the premises.

7. Effect of Introduction of PPWM

7-1 The biggest merit of introducing PPWM is an increase in the revenue from water charge, and other secondary effects are also expected.

The initial objective of PPWM for most of the Utilities was to improve collection rate of water charge and some for the reduction in NRW as well. The subsequent advantages, however, have been also varied and included:

(Common for individual and public standpost)

(1) Increase of water charge revenue
   1) Increase in revenue (except Zambia: Lusaka due to consecutive technical failures) (all other studied Utilities)
   2) No more debt growth and Utilities can predict cashflow (all Utilities)

(2) Improvement of customer service
   1) Reduction in billing errors and the related customer complaints (Mozambique: Maputo, Zambia: Lusaka, Palestine: Jenin)
   2) Reduction in workload of meter reading, billing, collection processes, disconnections, and reconnections (Zambia: Lusaka/Nkana/Kafubu/Mulonga/Lukanga, Kenya: Nairobi PSP/Nakuru PSP, Uganda: Kampala, Palestine: Jenin)
   3) Easier monitoring of the water usage activity of customers through the PPWM system and an easier data management (Zambia: Lukanga, Palestine: Jenin)
   4) Increase in metering ratio (Zambia: Kafubu/Mulonga/Lukanga)

(3) Water saving and equitable supply of water
   1) Better control of consumption by customers and management of water demand and increase in water supply hours (Zambia: Lusaka/Nkana)
   2) Conservation of water and reduced leakages at meter point due to replacement (Zambia: Nkana/Lusaka, Mozambique: Maputo)
   3) Efficient distribution of the available water (Kenya: Nakuru, Zambia: Lusaka)

(Only Public stand post)

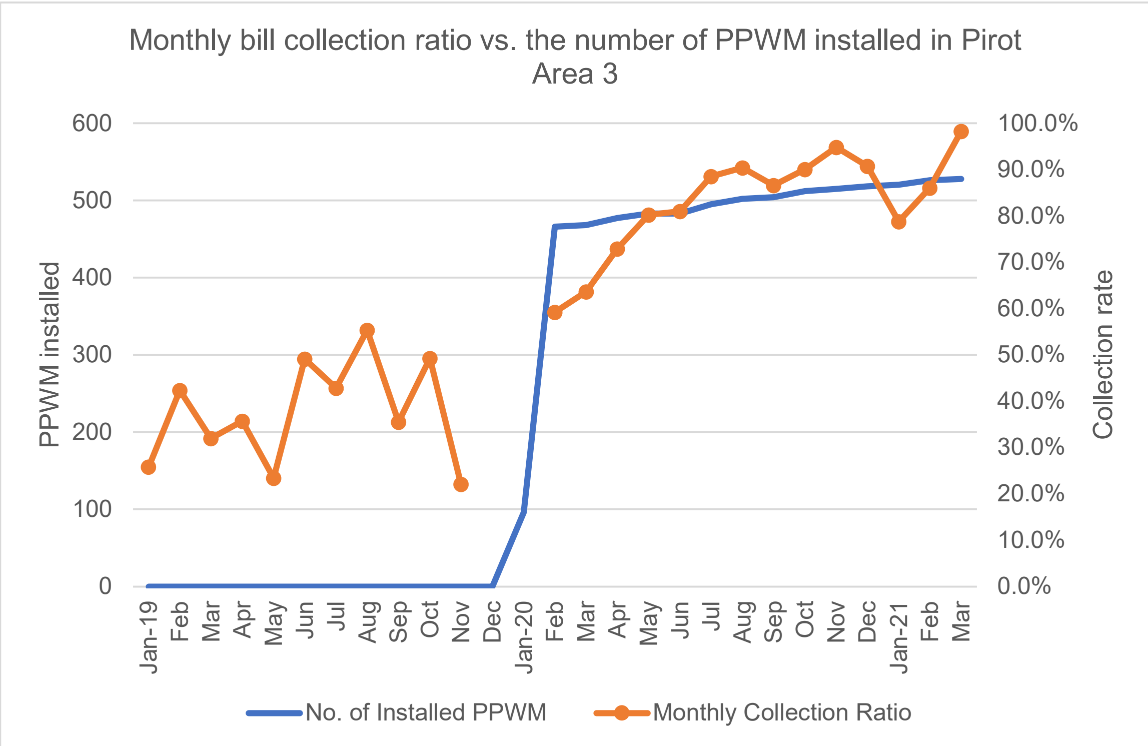
(4) Supply of water to low-income people
   1) Water supply to low-income people via public stand post type PPWM: the intermediaries who used to overcharge customers at post-paid kiosks were eliminated. (Kenya: Nairobi PSP/Nakuru PSP, Uganda: Kampala PSP)
   2) Improve hygiene in low-income areas (Kenya: Nakuru PSP)
   3) Reduce commuting time to fetch water through PPWM water kiosks (Kenya: Nakuru PSP)
   4) Ensure a steady supply of safe water to low-income households by eliminating water interruptions caused by public stand post attendants failing or delaying payment of their bills

to utilities. (Uganda: Kampala)

5) Provide clean water to low-income households at a reasonable tariff as the water tariff for low-income households can be set with PPWM. (Uganda: Kampala PSP)

7-2 The introduction increased water tariff revenue and reduced billing, collection, customer management and other costs.

All water utilities surveyed have reported increase in revenues after the introduction of PPWM. Based on the example of Jenin, the following shows how the water tariff collection rate increased according to the installation of PPWM in the pilot area. The tariff collection rate before the installation of PPWM was about 20% to 50%, but after the installation, it has reached about 100%. This means that almost all customers have replaced their regular post-pay meters with PPWM.



Note: PPWM started installation in January 2020.

Figure 2 Monthly tariff collection rate according to increase of PPWM installation in pilot area (PA3)

In addition to increase in tariff revenue, water utilities have reduced various costs by introducing PPWM. Most water utilities have reduced billing and collection, and customer management costs. However, on the contrary, there are cases where operation costs have increased for four water utilities surveyed. The detailed reason is unknown in this survey, but in the case of Jenin, the availability of detailed customer data from PPWM has stimulated customer service operations and increased customer service-related operation activities.

7-3 Customers' water consumption has leveled. PPWM promotes fair water use.

Many water utilities surveyed reported that water supply hours have increased after the introduction of PPWM. Here, using the pilot area of Jenin as an example, the effect of PPWM on the customer's water consumption was studied by analyzing the change in the customer's water consumption before and after the introduction of PPWM. The following table shows the statistical data that analyzed the monthly water consumption of each customer before and after the installation of PPWM. The average total amount of water consumption by all customers and per customer are 9,602 m^3/month and 15.9 m^3/customer/month when using the postpaid meter, and 9,142 m^3/month and 15.2m^3/customer/month after installing PPWM, which are almost the same. However, the customer's maximum water usage has been reduced by about half.

Table 9 Comparison of Water Consumption before and after installation of PPWM

Item	Water Consumption Before PPWM	Water Consumption After PPWM
Total customer (m^3/month)	9,602	9,142
Per customer (m^3/month)	15.9	15.2
Maximum water consumed customer (m^3/month)	167	88

A comparison of the customer's average water consumption before and after the installation of PPWM is shown in the following figure. The blue bars show the monthly average water consumption of customers in each group by arranging the customers in descending order of water consumption (from largest to smallest) when they were using post-paid water meters and dividing the total number of customers into groups of 60 customers each. The red bars show how much the same customer group consumed on average per month after the installation of the PPWM. It shows that even though the total water consumption of all customers is the same, the water consumption of each customer group has changed significantly. While many customers use large amounts of water during post-paid metering, many customers also use little or no water at all. On the other hand, after the same group of customers switched from post-paid meters to PPWM, customers who used large amounts of water reduced their consumption (about by 50%), while customers who used minimal or no water increased their consumption. It indicates that reduction of water consumption of high consumption customers has been transferred to customers who previously did not have access to sufficient water. These customers who did not have access to sufficient water probably reside in hydraulically disadvantaged areas in the distribution network.

From the above, it can be said that the introduction of PPWM has equalized the water consumption of each customer, and PPWM plays a role in promoting equitable use of water. It is assumed that some of the customers who consumed large amount of water did not pay water charges. As PPWM need to be charged in advance according to the amount of water consuming, it seems that these customers were conscious of saving water.

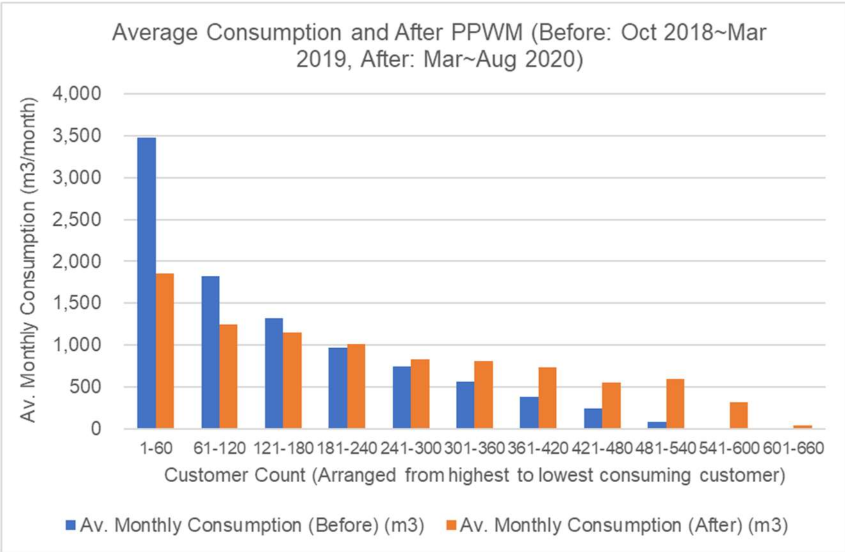


Figure 3 Average water consumption by customer consumption group before and after introduction of PPWM

7-4 Customers' water bill payments have been leveled

Similarly, using Jenin as an example, changes in customer water bill payments before and after the installation of PPWM were analyzed. The same customer's water tariff collection data for the same period as the water consumption above are used for analysis. The following table shows the data statistics of the amount of billed and collected charges before the installation of PPWM (by postpaid meter) and the amount of credit charged after the installation of PPWM. The average water billing amount for all customers is 55,004 NIS[2] before installation, of which the amount collected is 22,102 NIS. After installation, the total credit charged amount (collected amount) increased to 50,389 NIS. The total credit billed amount after installation is almost equal to the total tariff billed amount before installation. The amount collected/credit charged per customer increased significantly from 36.7 NIS to 83.6 NIS before and after the installation.

Table 10 Comparison of water tariff before and after PPWM installation

Item	Billed amount (before installation)	Amount collected (before installation)	Amount charged (after installation)
Total (NIS)	55,004	22,102	50,389
Customer Average (NIS/Customer)	91.2	36.7	83.6
Maximum	1075	430	650

[2] Currency unit of Palestine

A comparison of the pre-installation PPWM billing and collection amounts and the post-installation credit charge amounts for the same customer groups with the water consumption as mentioned above is shown in the next figure. In all groups, the amount of credit charged after PPWM installation increased over the amount of bill collected before PPWM installation. It means that many customers who had not paid their bills before PPWM installation are now being billed/credit charged by PPWM. In the group with the highest water tariff charge (1-60), the collection rate was about 40% of the billed amount. This group's post-installation credit billed/credit charged amount (11,722 NIS) is about 62% of the pre-installation billed amount. It also means that this group has greatly reduced their water consumption. The previously non-paying customers in this group may have reduced their water consumption and paid less for water because they have to pay 100% of their water bills in advance after PPWM installation. It is considered that after installation, customers with high water consumption became more aware of water conservation.

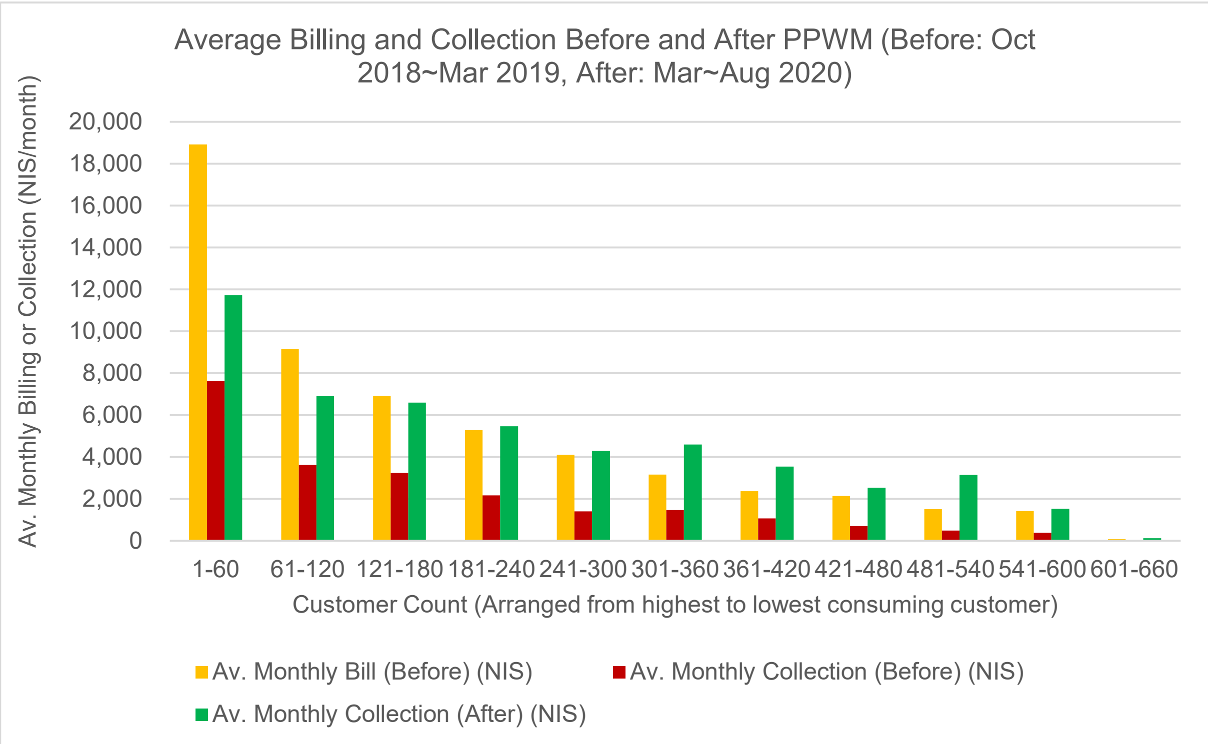
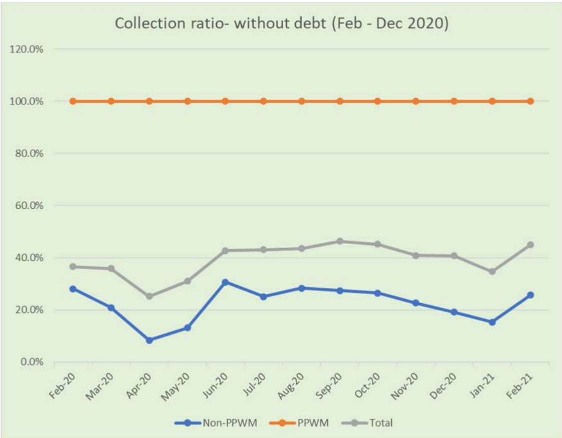


Figure 7-4 Water tariff (billed, collected, and credit billed) before and after installation of PPWM for each customer group

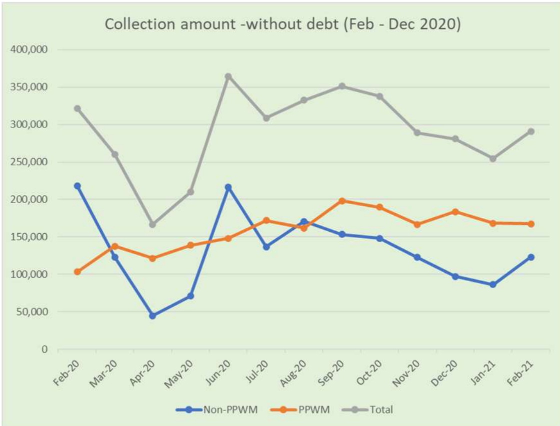
7-5 The charge collection from PPWM was stable even under the COVID-19 pandemic.

Based on the example of Jenin, the following figure shows the collection rates by postpaid meter and PPWM before and after the COVID-19 epidemic. At the beginning of the COVID-19 epidemic (March-May 2020), water tariff collection dropped significantly. This was mainly due to the COVID-19 epidemic affecting customer payments for postpaid meters. On the other hand, there was no impact on payments by PPWM customers.

On the other hand, when the COVID-19 pandemic became more critical, many complaints (requests) were received as to how to activate the fire mode. There is a desire to use water without charge. This seems to be a request for either running out of cash due to lockdown or not being able to go to a vending station. In addition to the fire mode, PPWM allows the valve to be remotely opened and converted to a postpaid type for water use without a visit by utility staff. The PPWM function can be used in various ways even under the influence of COVID-19, and it can be said that it is a water meter that is also strong against COVID-19.



Tariff collection rate



Tariff collection amount

Figure 7-5 PPWM and post-paid meter tariff collection amount and collection rate before and after the COVID-19 epidemic

8. Change of Utility and Customers after Introduction

8-1 Solved issues for postpaid water meter systems after the introduction of PPWM

Taking Jenin as an example, the solved problems of the postpaid water meter system after the introduction of PPWM are summarized below. The only problem that PPWM cannot solve is illegal connection.

Table 11 Solved issues with postpaid water meter systems after the introduction of PPWM

Problem before PPWM		Solved	Condition after PPWM
Meter Reading	1. It was necessary to visit customers every month for meter reading, which was expensive, time consuming and staff required. 2. Meter reader cannot access to a meter. Many meters are difficult to read. 3. Revisit was required because the customer was absent on the meter reading day.	○	- There is no need to perform meter reading work on site. - All the works and expenses related to meter reading are eliminated. - No meter reader is required.

	Problem before PPWM	Solved	Condition after PPWM
	4. Since the activity was paper-based, human error could occur when reading the meter or processing the data.	○	- There are no meter reading errors or posting errors to the database.
	5. In many cases, bill is issued by estimation without reading the meter.	○	- No longer need to bill with estimates. - Customer water consumption data is accurate.
Billing and collection	6. Paper-based meter reading data had to be entered into the billing system, and the bill had to be printed and delivered monthly. 7. Bill printing costs are incurred, and there are printer problems. During the monthly bill printing period, it was necessary to suspend the operation of the customer database system. These were time-consuming tasks, so the bill was delivered one month late.	○	- No longer need to manually enter billing and collection data. - Eliminates the need for bill printing and delivery. - There is no time lag between water use and billing / collection. On the contrary, it was paid in advance.
	8. The collector had to collect the money from door to door even if the collection rate was very low, because the customer sometimes paid at the door.	○	- All billing and collection issues are resolved. - No on-site billing and collection work. - The bill collection rate of customers who installed PPWM is 100%.
	9. Protection for meter readers and collectors from some aggressive customers dissatisfied is required.	○	- Staff no longer meet customers during meter reading and collection.
Illegal connection	10. There are many illegal connections.	×	- PPWM has a tamper detection function aimed at finding illegal connections, but many illegal connections are still found.
	11. Water consumption data is inaccurate due to illegal connections in addition to water meter damage and unauthorized removal. 12. Due to labor shortages and inaccurate estimated consumption data, grasping meter status and finding illegal connections is inefficient.	○	- PPWM can monitor the customer's accurate water consumption daily. - Regular monitoring of accurate customer water consumption data makes it possible to estimate illegally connected customers more efficiently.
Increase in unpaid bill	13. Due to the low bill collection rate, the amount of unpaid bill has swelled to a huge amount.	○	- Since the collection rate is 100%, the unpaid bill does not increase any more.
	14. The utility fined for late payments or sent unpaid customers to the court, but the solved speed is slow. The number of staff members who treat unpaid customers is also small. For this reason, they are facing a low recovery rate of unpaid bills.	○	- If PPWM's debt (unpaid bill) collection function is used, some of the credits charged is automatically used for recovery of unpaid bill. The recovery rate can be set arbitrarily. In the case of Jenin, it is set to 10%. - For commercial customers with a large amount of unpaid bill (high ability to pay), PPWM is installed to set a high recovery percentage.

Problem before PPWM		Solved	Condition after PPWM
Monitoring water meter	15. There are many unread meter customers, and many meter reading are estimated values. 16. There are many water meters whose status is unknown. Many meters are removed or damaged. 17. The amount of water consumption is not accurately known.	○	- Accurate data of all PPWM is transmitted daily. - With continuous monitoring of PPWM, including water consumption, it has become possible to efficiently detect illegal connections and cases where customers attempt to modify or destroy PPWM. - If PPWM is removed, the tamper detection mode will warn the customers. - Even if the meter is damaged, the water consumption value of 0 is sent, so it can be dealt with.
Staff	18. The utility faced a labor shortage for staff reading, billing, collection, and monthly data entry.	○	- There is no need to hire additional personnel. It also reduced working hours (no need for meter reading and bill collection, no need to manually enter data and print invoices). - Staff members related to postpaid meter system can be moved to other departments or tasks for more efficient use of staff.
Customers	19. There was an unfair distribution of water, such as some customers receiving sufficient water supply, while others did not receive water at all. 20. There are many illegal connections, and such customers are less conscious of saving water.	○	- Customers with high water consumption decrease water consumption. As a result, more water becomes available for previously water-scarce customers so that more equitable water supply is achieved. - With the introduction of PPWM, the utility contracted with a new water source (private well) and increased the amount of water supply by promise with stakeholders.

8-2 Changes in customer behavior after the introduction of PPWM

Taking Jenin as an example, the changes in customer behavior after the introduction of PPWM including assumptions are summarized below.

Table 12 Changes in customer behavior after the introduction of PPWM

Indicator	Before introduction PPWM	After introduction of PPWM
Awareness of water bill payment	It is difficult to understand what customers think of the water supply service. If customers are not satisfied with their water services, they are less willing to pay for water. And it is difficult for customers to understand that a large amount of unpaid bill hinders the improvement of water services.	Some customers found that paying water bills and repaying unpaid bill can improve water services in the city.
Acceptance and satisfaction with PPWM installation	Prior to the door-to-door visits and awareness campaigns for PPWM, PPWM acceptance was low.	In the post-installation satisfaction survey, customer satisfaction was high, and acceptance was greatly improved.
Water consumption	It is possible for customers not to pay water charge. Since there is no link between water consumption and charge for unpaid customers, they were not very conscious of water usage.	Water consumption equals credit, and customers are conscious of water use (credit charge) and control the amount of water used in a rational way.

Indicator	Before introduction PPWM	After introduction of PPWM
PPWM reliability	Customers had negative preconception that meter counts air and more than consumption due to intermittent water supply.	Ultrasonic PPWM has improved the reliability of customers' meters, such as not measuring air.
Handling of water meters	Customers thought the traditional meter system was easier, and the ultrasonic PPWM was an advanced technology and awkward to handle.	Customers realize that PPWM is easy to handle. It is a good impression that there is no meter reading, and customers can manage the amount of water used by themselves.
Payment of charge	Payment of the bill was troublesome and had to be paid to the city hall teller window or the collectors.	It is easier to charge the credit to the prepaid card directly at the vending station. There are many vending stations, so it doesn't bother customers. It is also a good impression that the unpaid bill does not increase.
Payment of unpaid bill	Customers needed to pay unpaid bill to the city once or in installments.	Automatically 10% of each charged credit is paid for unpaid bill. Customers can reduce debt without much awareness of repayment.
Water services	The water service was bad impression by customers.	Many customers feel that the service has improved with the introduction of PPWM.

9. Issues after Introduction

9-1 PPWM system brings new set of challenges and issues.

1) Implementation

- In pilot/early stage it required extensive initial inspections to all customer properties for customer data collection. Dealing with the discovered pipe bypasses can add to the time consumed for physical inspection (Zambia: Lusaka/Nkana/Kafubu/Mulonga, Palestine: Jenin)
- The initial investment cost is high and cost recovery is long especially where the tariff is low or pro-poor (Zambia: Nkana/Kafubu/Mulonga/Lukanga, Mozambique: Maputo, Kenya: Nairobi PSP, Uganda: Kampala PI, Palestine: Jenin)
- The maintenance cost/license fee of PPWM software system is high (Kenya: Nakuru PSP, Uganda: Kampala PI)
- Requires land for installing public stand post type PPWM (Uganda: Kampala PSP)
- Limited number of local suppliers of PPWM (Zambia: Mulonga, Kenya: Nakuru PSP)

2) Technological issues

- Valve closes unexpectedly or fails to open automatically (Zambia: Lusaka/Mulonga, Mozambique: Maputo, Kenya: Nakuru PSP, Palestine: Jenin)
- Battery failure, CIU/meter communication failures, and meter fail to charge (Zambia: Nkana/Kafubu/Mulonga/Lukanga, Mozambique: Maputo, Kenya: Nairobi PSP/Nakuru PSP, Uganda: Kampala PI/Kampala PSP)
- Hard to upgrade the PPWM of the public stand posts (Uganda: Kampala PSP)
- Once the token is dispensed, it cannot be cancelled. Credits cannot be reissued even when lost (Zambia: Nkana)

- It is necessary to repair not only the mechanical part but also the electronic part. There is a lack of local/utility workshop, a need for constant training, and meter calibration (Mozambique: Maputo, Palestine: Jenin)

3) Operation and management
   - High cost for spare parts. (Zambia: Lusaka/Nkana, Kenya: Nakuru PSP)
   - Needs to motivate and enhance confidence and skills of the staff in using new metering system especially in early stages (Zambia: Lusaka/Nkana, Palestine: Jenin)
   - Continuous customer awareness is required, for which human resources are required (Zambia: Lukanga, Kenya: Nakuru PSP, Palestine: Jenin)
   - New types of complaints emerged on the use of PPWM. Such complaints were meter failing to close, failure of electrical part due to leakage in the meter, and battery failure. (Zambia: Lusaka/Nkana/Kafubu, Kenya: Nairobi PSP, Palestine: Jenin)
   - Low technical support from the meter suppliers especially after the guaranty period (Zambia: Lusaka)
   - Utilities need to be prepared for PPWM maintenance after expiring of warranty period. (Palestine: Jenin)
   - System integration is needed for data monitoring and handling customer complaints efficiently (Zambia: Nkana)
   - Needs continues field check of the PPWM for vandalism, illegal connections, or malfunction (most Utilities)
4) Revenue recovery
   - Debt recovery is slow especially from customer with huge debt (Zambia: Lusaka/Nkana/Kafubu/Mulonga/Lukanga, Mozambique: Maputo, Palestine: Jenin)
   - Large scale of technical issues with the meters can have negative effect on the revenue collection. (Zambia: Lusaka)
5) Low-income customers
   - Not all customers can pay in advance. Consideration of social safeguard must be in place. (All Utilities)

10. Recommendations based on the lessons learned

10-1 Recommendations for successful PPWM implementation

Despite several issues and challenges as highlighted above, all the surveyed utilities considered PPWM successful and are willing to continue and promote PPWM. Some of the recommendations made by the utilities for a successful PPWM is outlined below.

Table 13 Recommendations for successfully PPWM introduction

No.	Item	Conditions
1.	Conducting a preliminary survey	Water utilities are conducting various preliminary surveys when deciding to introduce PPWM. In particular, if there are already precedents for water utilities in the same country, it is effective to conduct a visit survey to analyze issues, lessons learned, and success factors and use them for introduction.
2.	Following the success factors	The success factor of the introduction is not to aim at increasing revenue, but to improve the water supply service and customer service with the introduction of PPWM. This increases customer satisfaction and improves PPWM acceptability.
3.	Political backup	The introduction requires the commitment of local government politicians (mayors and city councils) and top executives. The participation of top management in stakeholder meetings and preparation of implementation plan will improve the implementation environment and enhance the social sustainability of PPWM.
4.	Selection of target area	The target area needs to be selected based on the purpose of introducing PPWM and its acceptability. For example, areas with a large amount of unpaid bill, areas with stable good water supply that is expected to be highly receptive of PPWM introduction, and areas with low income (in the case of public standpost PPWM). In addition, it is recommended to select the target area by specific area, which makes it easier to streamline the number of vending stations, handle customer management, and collect data statistics (non-revenue water ratio, collection rate, etc.). do.
5.	Consideration for vulnerable groups	By installing PPWM in public stand posts, there are cases where intermediate interveners were eliminated, reducing water charges paid by the poor and enabling stable water supply. Other measures for the poor include setting water charges for the poor, converting PPWM to a postpaid function, and subsidizing programs through fund-raising.
6.	Installation fee (initial cost)	If customers want to replace an existing conventional meter with PPWM, the water utility usually bears the replacement cost. In the case of a new connection, the water supply connection is made by the customer paying the connection cost including the meter. PPWM is more expensive than conventional meters, and the water utility must decide whether to use the water connection fee including the increased amount or the same connection fee as the conventional meter. Payment methods include lump sum payment and installment payment. PPWM can treat connection fees as unpaid bill and allows customers to program installments. A part of the credit purchased at the time of each charge will be used for repayment of the connection fee. Since the repayment rate can be set arbitrarily, it can be set after discussion with the customer. If the repayment rate is raised, the customer can repay in a short period of time, and if it is lowered, the customer can repay in a long period of time with less burden. Regarding the ownership of the meter, there are cases where it is owned by the customer and cases where it is owned by the water utility. Not limited to PPWM, it is possible to maintain water meter in a normal condition at all times by owning and managing the meter by the water utility. In the case of Jenin, when PPWM was introduced, the customer contract for new customers was changed, and the owner of the meter was clearly specified as the city. In the case of public standpost type PPWM, the initial cost is borne by the water utility or donor, so the initial cost is not borne by the users. The owner of the meter is basically a water utility.
7.	Credit vending method	There are various credit charge methods, but when selecting a charge method, the IT environment in the target area and the convenience of customers must be taken into consideration. Digital banking and electronic payments using mobile phones are convenient, but they cannot be adopted in all areas. When deciding the location of the vending station, it is necessary to consider the convenience of the customer, the travel time of the customer to the station, and their service hours.

No.	Item	Conditions
8.	Residents' consensus building (Awareness)	Raising public awareness of the introduction of PPWM and the role of continuous public relations are important factors for the success of PPWM. Activities to raise customer awareness and gain the trust of the people need to be planned to encourage customers to install PPWM. Most water utilities provide their customers with the necessary information on PPWM and obtain their consent to install them before installing the meters. After installation, they conduct follow-up activities for customers using PPWM.
9.	Customer satisfaction	Customers' requests for PPWM improvement are as follows, and these need to be thoroughly considered before introduction. • Improved reliability of PPWM unit (less failure) • Convenience of credit charge (increase of vending stations, improvement of credit vending system) • Increased installation of public standpost / water kiosks type PPWM • Improvement of water supply reliability (water supply hours / days, water supply pressure) • Improved customer service • Enrichment of information to be disseminated through public awareness activities
10.	PPWM team formation	A dedicated team is required to install and maintain PPWM. The required team structure consists of water connection technicians, IT engineers, public awareness personnel, and customer service personnel. In particular, unlike the installation and maintenance of conventional meters, IT engineers are required.
11.	Water tariff	Basically, PPWM's water tariff uses the same water tariff system as the postpaid type. If PPWM targets the poor, it is necessary to consider subsidized water tariffs that take the poor into consideration. Water utilities need to understand that low tariff extends payback periods for PPWM initial costs and hinders further PPWM investment.
12.	Selection of water meter model	It is necessary to select an appropriate water meter type that suits the installation environment. PPWM consists of a prepaid function part and a water meter part. In order to ensure technical sustainability, it is first necessary to select an appropriate type of water meter part. When adopting the mechanical type, it is necessary to check whether particles and calcium in the water pipe is low or high. Particles destroy and clog mechanical parts, and calcium content leads to calcium condensation to the inside of the meter in dry time in the pipe with intermittent water supply. In the intermittent water supply, there is a possibility that the count of the amount of water used is increased due to the intrusion of air into the pipe. Ultrasonic PPWM can solve the above problems, but the problem is that there are few brands in the market and there is little competitiveness in procurement.
13.	Selection of product	Consider the following for product selection. • Meets the required international standards • Check the technical capabilities of local suppliers • Clarify the warranty details and period, and the period should be 3 years or more. • Check availability of spare parts • Ensure battery life (minimum 5 years).
14.	Maintenance (failure response)	The failure rate of PPWM units can range from a few percent to 50%. If the failure rate is high, it is a mistake in brand selection. Even with a low failure rate, the equipment is expensive and needs to be repaired and used. At this time, there are almost no cases where the water utility can make all the repairs. In particular, there is no utility that can repair electronic parts. Therefore, it is necessary to consider a failure handling method. The easiest way is to sign an after-sales service contract with a meter agency to repair all faulty meters. This requires a service fee. In order to reduce this, there is a method of setting a

No.	Item	Conditions
		range that can be done by utility (for example, battery replacement, cleaning the inside of the equipment, etc.), and outsourcing other than that.
15.	Improvement of maintenance ability	At the beginning of installation, there may be many equipment malfunctions and many customer complaints. Staff must be well trained by the meter supplier to install, repair and handle complaints. It is also necessary to prepare appropriate manuals for meter maintenance and repair. The preparation of these trainings and manuals should be described in the specifications as the service content of the supplier.
16.	Use of LoRA gateway data	One of the success factors of PPWM in Jenin is the use of gateways. With the introduction of the gateway system, accurate customer data can be remotely obtained and monitored daily. PPWM can also be controlled remotely. This has improved customer service such as complaint handling and follow-up. It is also used for illegal connection exploration. It also raises the awareness of the staff of the customer service section. Complaints are also quickly and 100% resolved.
17.	Illegal connection	Although PPWM cannot solve the problem of illegal connections, it is possible to efficiently search for illegal connections with an accurate customer database. Periodic site observation of PPWM is essential to check the meter status and illegal connection. At the same time, it is necessary to regularly check each customer's water consumption trend to check for suspicious or abnormal water use.

11. Introduction Trend and Needs of PPWM

11-1 In Sub-Saharan Africa, PPWM has not been installed as originally planned, but installation in public institutions and diversification of billing methods have been promoted.

Introduction trend in Kampala, Lusaka, Maputo, Nairobi and Nakuru cities were compared based on World Bank's data in 2014 and this study.

According to a World Bank report, at that time Kampala had plans to install 3,000 public standpost-type PPWM, Lusaka had plans to install 69,000 individual-type PPWMs, and Nakuru had plans to install 1,000 additional public standpost-type PPWMs. However, as a result in this survey, the water utilities were unable to add PPWM as planned.

Maputo added 2400 individual PPWM and 100 commercial PPWM although it started with 220 public standpost PPWM. In Lusaka, individual PPWM decreased by almost 2,000 whereas more than 500 institutional PPWM were added. Public standpost PPWM were increased from 38 to 72.

Besides those in the table below, Nkana reported an increase trend in PPWM installations and upgraded the credit vending methods – 250 tokens compliant PPWM in 2012, 1400 smart card compliant PPWM in 2015 and 13,816 STS[3] complaint PPWM in 2018.

Table 14. PPWM Introduction trend

City	World Bank Report*				This Study	
	PPWM installation type	**Year**	**Total installations**	**Population served**	**Current Installations**	**Population/ Households served**
Kampala	Public Standpipes Institutional	2007 2014	>1,599	200,000	1,500 200	150,000 population
	Planned	2017	3000			
Lusaka	Individual Public Standpipes Institutional	2014	14,000 38 203		12,113 72 789	13,110 HH
	Planned Individual	2018	69,000			
Maputo	Public Standpipes Individual Commercial		220		 2,400 100	2,500 HH
Nairobi	Individual	2008			165	25,000 population
Nakuru	Public Standpipes	2012	95		155	3,875 HH
	Planned standpipes		>1000			

*Source: The Limits and Possibilities of Prepaid Water Meter in Urban Africa-Lessons from the Field, World Bank Report, 2014

Although the utilities and users both considered PPWM as successful and satisfactory services, none of the cities (except Nkana) showed an increasing trend in PPWM introduction. Instead, cities like Maputo changed course to individual and commercial PPWM after their first experience with public standpost PPWM. On the other hand, Lusaka and Kampala who began PPWM with individual/public standpipe users prioritized PPWM for institutional customers which justifies the problem of arrears accumulation in public institutions. Ambitious plans of PPWM additions made by Nakuru, Kampala and Lusaka were incomplete likely due to issues in fund management, cost benefit analysis and insufficient target setting. Nonetheless, PPWM still served a significant number of households, particularly in Nairobi (25,000 households), Lusaka (13,110 households) and Kampala (150,000 people).

11-2 PPWM introduction is still very limited in other parts of the world.

Introduction of PPWM in the other parts of the world was searched through internet. Only a limited number of utilities introduced or plan to introduce PPWM.

The introduction of PPWM is different according to the objective of introduction and the status of utility, water supply conditions and customers socio-economic status. Some examples of PPWM applications in other parts of the world is briefly described below.

[3] STS: Standard Transfer Specification refers to a standardized and secure message protocol for transmitting information between POS billing terminals and meters.

1. Palmas, Brazil: SANEATINS, a local company tested PPWM in 100 households for 4 years and planned to install 10,000 connections.

Its main objective was:

- To eliminate utility costs, reduce complaints, and reduce data processing.
- For users, it would provide reduced tariffs, more control of consumption, immediate leak detection and use of water according to financial capacity.

For pro-poor consideration

- A social card would be provisioned which provides free water to the low-income population.
- Every month, after credit expires, a user is granted a loan water for 3 days which will be deducted in the next recharge.

2. Brunei: Brunei government proposed in 2019, a phase wise plan to introduce PPWM to curb high water usage and reduce wastage. Brunei has one of the highest per capita water use of 380 liters per capita per day. It also has high arrears of USD 30 million in water services in 2016. The production cost (90 cents per m^3) was much higher than selling price (11 cents per m^3). The PPWM plan will consider that the people are not burdened and do not experience difficulties, especially those with low incomes.

3. Muscat: Oman's public water authority installed 90,000 smart meters (which also works with prepaid system) in Muscat Governorate to reduce water loss. It has plans to install 270,000 smart meters by 2021 in partnership with the private sector. Target customers were those currently connected to the system. Benefits to the customers was the control over consumption and to detect any leaks by comparing consumptions. The utility bears the meter costs and replaces it for free. Prepayment is available 24 hours and will notify customer of the expiration of the credit. Tariff is same as postpaid system.

4. Solomon Islands: Solomon Water, a water utility in the Solomon Islands has introduced CashWater Meter, a form of prepayment system in water. In 2020, it had 5,000 CashWater customers. It allows users to reduce payment risk, improve cash flows, and manage their water consumption. Users can top-up their credits using user interface units or mobile payment.

11-3 Needs for applying PPWM to public institutions with a large amount of unpaid bills, billing by online or mobile payment, and adopting solar batteries for PPWM for public standpost may increase.

Based on the survey in Sub-Saharan Africa and other parts of the world, the following additional needs of PPWM are identified:

- Utilities, based on the objective, can adopt either public standpost PPWM for people without connections, institutional PPWM for public institutions with high arrears or commercial PPWM for business purposes, in addition to individual domestic PPWM.
- In many developing countries, water utility is not always able to take action against the tariff defaulters. For instance, in Kathmandu, Nepal the water utility KUKL can neither disconnect public institutions nor stop water supply despite their huge accumulations of debts. Institutional PPWM as in Lusaka and Kampala could prove effective here.
- Online payment of utility bills including water is taking its pace throughout the world. It would be easier to introduce PPWM in such areas where customers are aware of such online technology.
- Feasibility and effectiveness in the use of solar power to run the PPWM units needs to be assessed as a measure of battery problem, especially for public standpost PPWM. If the number of credit loading to PPWM is large, battery consumption will increase.
- Upgrading from tokens/coins by introducing ICT technology and STS in payment methods is a need to ease credit vending process in PPWM.