

# **Beyond leakage control: Significant non-revenue water reduction through commercial-loss management in Khan Younis Municipality, Palestine**

Hatem AbuEltayef

*Urban Planning and Building Permits General Directorate, Gaza, Palestine*  
*e-mail: Hatem.tayef@gmail.com*

**Abstract:** Non-revenue water (NRW) remains a major challenge for water utilities particularly in water scarce areas where losses affect not only the efficiency of the services but also their financial sustainability. This study evaluates the effectiveness of a targeted NRW reduction program implemented by Khan Younis Municipality, Gaza Strip, Palestine, with a special focus on commercial losses. The study aimed to identify and quantify the components of NRW, develop an intervention plan targeting authorized but unbilled consumption and apparent losses, and assess its impact on the performance of the utility. An analytical descriptive approach was adopted based on historical operational records, billing databases, field surveys, water balance analysis and post-intervention performance monitoring. The intervention strategy was focused on three main categories: unbilled metered consumption in housing projects, administrative subscriptions for service facilities, and authorized unmetered consumption in municipal and governmental facilities. The results demonstrated that the intervention plan recovered approximately 609,496 m<sup>3</sup> of previously unbilled water per year, contributing to an overall water network efficiency increase of 7.07% and helping to reduce NRW from about 33% to 27%. The findings indicate that NRW reduction can be achieved without major infrastructure investment, simply through low cost administrative and commercial-loss interventions. The study highlights the significance of systematic monitoring, customer registration, metering and consumption tracking as pragmatic means of enhancing water utility performance and improving water resource sustainability in developing regions.

**Key words:** non-revenue water; commercial loss; water loss; Khan Younis city; Palestine.

## **1. INTRODUCTION**

Non-revenue water (NRW) is one of the most constant challenges facing water utilities around the world. NRW includes physical losses from leaks, apparent losses resulting from unauthorized consumption and metering inaccuracies, and authorized but unbilled consumption. High NRW levels lower operational efficiency, increase financial burdens on utilities, and add pressure to already scarce water resources (Kingdom et al., 2006; Wyatt, 2010). Global estimates show that NRW makes up a significant share of produced water, especially in developing countries. In these regions, aging infrastructure, weak governance, limited financial resources, and poor monitoring lead to elevated loss rates (FAO, 2021; Makaya, 2015; Mvongo et al., 2024).

Previous studies have extensively investigated NRW assessment methods, water balance analysis, and leakage management, and technical approaches for reducing physical losses (Alegre et al., 2016; Farley et al., 2008). However, there's less focus on administrative and commercial loss reduction strategies, especially in developing countries with limited funds for large infrastructure solutions. In many water utilities apparent water losses resulting from unauthorized consumption, billing errors, unregistered users, and unmetered public services may represent a significant share of total NRW. Yet, these losses remain difficult to quantify and monitor.

There are many challenges facing the Palestinian water sector, including: water scarcity, rapid population growth, infrastructure challenges, and severely restricted development of water resources, making it increasingly important to increase water use efficiency and reduce the amount of water not accounted for in utility operations (PWA, 2016b; WSRC, 2018), as a low-cost means of improving the availability of water and the performance of utilities. In 2016, the volume of water

not entering from utility sources into the water supply system in Palestine was over 58 million m<sup>3</sup>, or almost one-third of the total volume of water supplied. NRW levels in the Gaza Strip were over 36% (WSRC, 2018), meaning that there are lost revenue opportunities, as well as higher operating costs due to high NRW levels, for water service providers.

Khan Younis Municipality is an important case study because of its high NRW levels and the availability of detailed operational and billing records. Unlike many NRW reduction programs that mostly focus on physical losses and fixing infrastructure, the municipality chose a targeted approach to reduce commercial and administrative losses. This intervention included water balance analysis, systematic identification of unregistered consumption, managing administrative subscriptions, monitoring municipal and government facilities, and ongoing performance tracking using billing and monitoring databases. The novelty of this study is in creating and using an integrated administrative intervention model for reducing NRW that targets commercial losses instead of physical losses. The study offers a measured assessment of the impact of various commercial loss categories. It shows how monitoring and billing management tools can aid in reducing NRW. The effectiveness of these interventions is evaluated through a real municipal case study in a water-scarce area.

Accordingly, the objectives of this study are to: (1) present the NRW reduction strategy used by Khan Younis Municipality; (2) identify and measure the impact of commercial-loss components on total NRW; (3) evaluate how effective targeted administrative actions are; and (4) offer practical advice for water service providers who want to improve NRW management and operational efficiency. The findings provide considerable reductions in NRW can be achieved through relatively low-cost administrative steps without requiring major investments in network repairs.

## 2. NON-REVENUE WATER SECTOR SITUATION IN PALESTINE

Challenges to water resources management in Palestine are compounded by its inherent scarcity, accelerated population growth, limited infrastructure, financial constraints, and institutional complexities, which put more pressure on the service providers. This enhances the need for improving the operating efficiency and lowering the rate of non-revenue water (PWA, 2016b; WBG, 2018). The Palestinian water sector struggles with a big gap between water demand and water supply. Limited access to water and restricted infrastructure growth makes providing consistent services even harder (PWA, 2016b; World Bank, 2009). Thus, making water use more efficient to reduce NRW is now a strategic goal for the Palestinian Water Authority (PWA), and water service providers.

In 2016, the Water Sector Regulatory Council (WSRC) reported that NRW was around 58 million m<sup>3</sup>, which is 33.6% of total water supplies. The Gaza Strip especially had high NRW levels over 36%. Clearly, there's a need for actions to improve system efficiency and maintain financial sustainability (WSRC, 2018). Given the scarce water resources, and the high cost of developing new supply sources, NRW reduction represents one of the most-effective approaches for improving water service delivery.

Table 1 shows that NRW levels in Palestine remained high between 2014 and 2016 despite an increase in the demand for water. As such, improvements to utility performance through systematic technical, administrative, and managerial interventions are needed.

The application of NRW reduction programs requires substantial investment since the suggested measures are aimed at reducing NRW in the most effective way possible. From the point of view of the cost-benefit analysis, the reduction of NRW from 38% to 35% is expected to generate extra revenues in the amount of \$20 million in a decade (PWA, 2012). As demonstrated in Figure 1, the total amount of water consumed in 2014, 2015 and 2016 was evaluated according to its source (from wells or desalinated water). It is important to note that the current report contains comprehensive information on domestic consumption and the total losses in percentages.

Table 1. Consumed domestic water quantities in Palestine by year

| Item                                                           | 2014        | 2015        | 2016        |
|----------------------------------------------------------------|-------------|-------------|-------------|
| Quantity of water consumed - West Bank (m <sup>3</sup> /year)  | 60,926,000  | 77,730,000  | 84,660,000  |
| Quantity of water consumed - Gaza Strip (m <sup>3</sup> /year) | 84,660,000  | 88,060,000  | 94,100,000  |
| Quantity of water consumed - Palestine (m <sup>3</sup> /year)  | 145,586,000 | 165,790,000 | 172,300,000 |
| Annual NRW - West Bank (m <sup>3</sup> /year)                  | 18,277,800  | 22,304,199  | 24,620,782  |
| Annual NRW - Gaza Strip (m <sup>3</sup> /year)                 | 32,170,800  | 34,152,123  | 33,389,494  |
| Annual NRW - Palestine (m <sup>3</sup> /year)                  | 50,448,600  | 56,456,322  | 58,010,276  |
| Annual NRW rate - West Bank                                    | 30.00%      | 27.67%      | 30.54%      |
| Annual NRW rate - Gaza Strip                                   | 38.00%      | 37.01%      | 36.19%      |
| Annual NRW rate - Palestine                                    | 34.65%      | 32.66%      | 33.56%      |

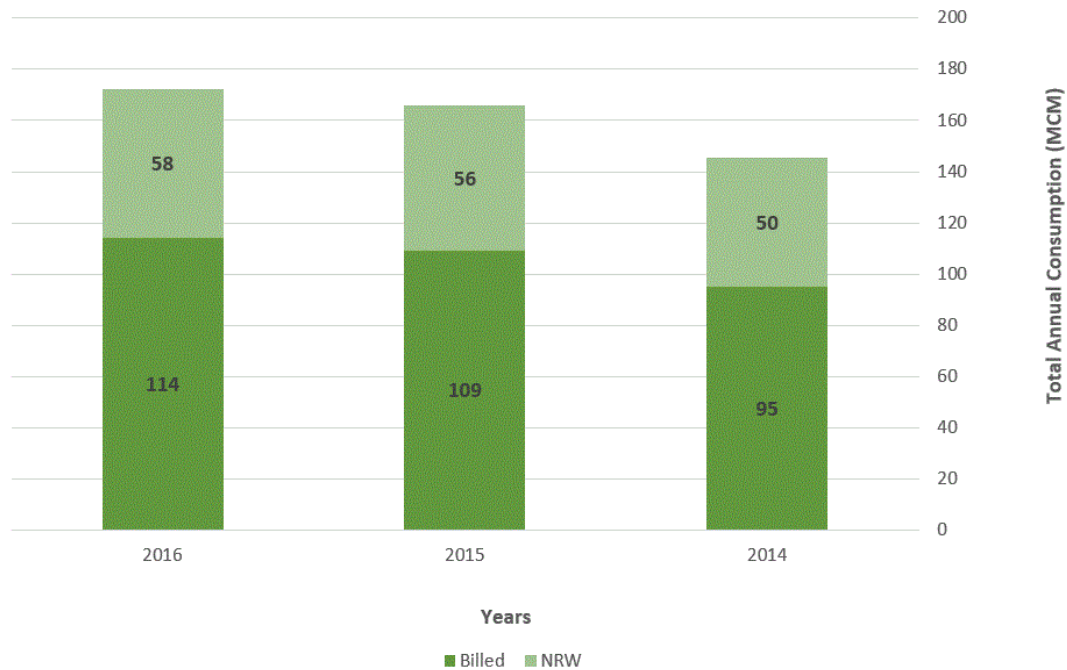


Figure 1. Billed water and non-revenue water in Palestine (2014-2016)

### 3. MATERIALS AND METHODS

#### 3.1 Study area

Khan Younis city is located in the southern part of the Gaza Strip, shown in Figure 2. It is a major Palestinian city on the east coast of the Mediterranean. It is considered the second largest city in the Gaza Strip in terms of both population and area. The city is situated within the governorate of Khan Younis, and is designated as the second core city in the Gaza Strip regional plan of 2005. The city covers a total area of 54.56 km<sup>2</sup>. It is a major commercial center and transit station on the ancient trade route to Egypt. It is considered the center of the Khan Younis Governorate (Abueltayef et al., 2023).

As illustrated in Table 2, a compendium of key statistical indicators has been assembled, encompassing data pertaining to water production, distribution, and loss rates. This comprehensive set of metrics is further augmented by ancillary operational and financial data drawn from Khan Younis.

Table 3 presents data on the quantities of water produced from the municipal wells, the actual water quantities, the loss rate, and per capita water share over the years. Evidence suggests that the Municipality of Khan Younis has successfully implemented plans and programs to reduce unaccounted-for water, thereby enhancing network efficiency.

- The volume of water produced is derived from the readings of well meters and the quantities supplied to the network, whether directly from the wells or through collection in tanks, followed by pumping via the boosters.
- The quantity of actual water is defined as the volume of water recorded through the monthly water meters readings of citizens, as part of the municipality's billing process.

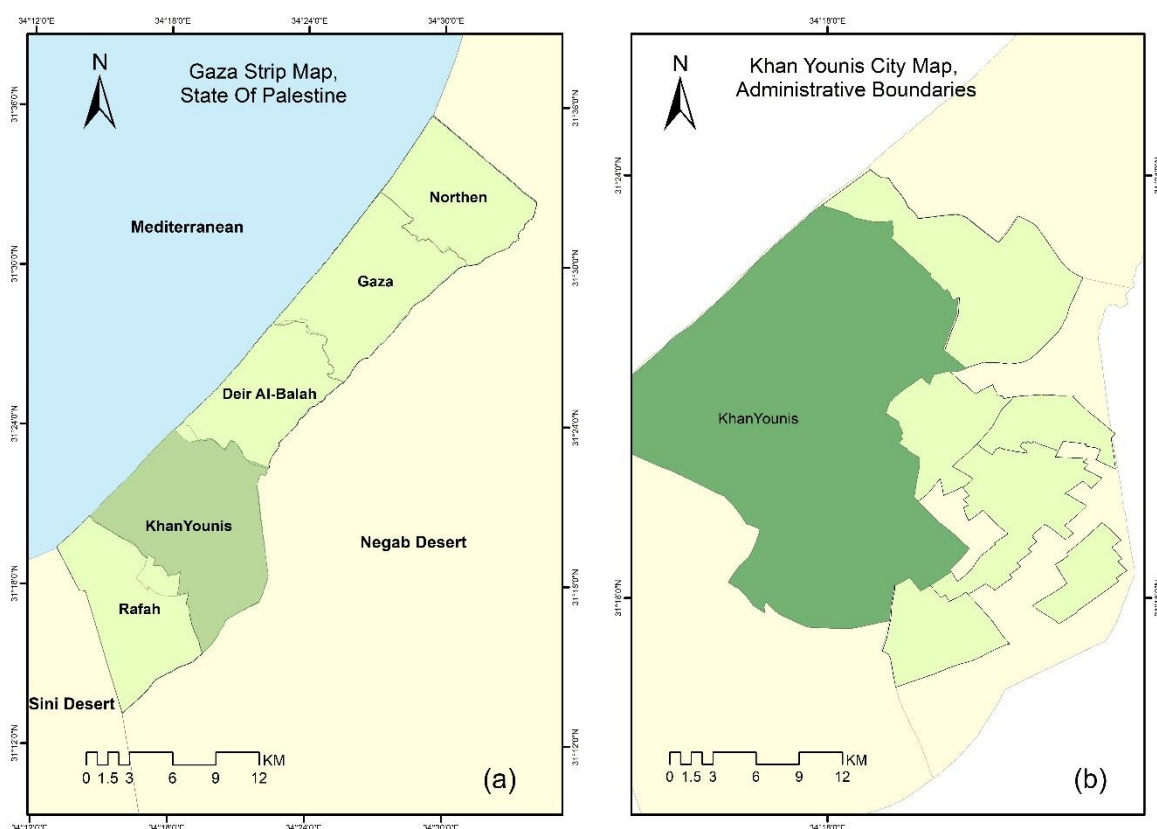


Figure 2. (a) Gaza Strip location in Palestine, (b) Khan Younis location in Gaza Strip

Table 2. Khan Younis water sector selected indicators (AbuEltayef & Leham, 2017)

| Indicator                                                                | Value                                                       |
|--------------------------------------------------------------------------|-------------------------------------------------------------|
| Population                                                               | 249,000                                                     |
| Quantity of water produced and supplied (million m <sup>3</sup> /year)   | 8.6                                                         |
| NRW rate (%)                                                             | 27.06                                                       |
| Estimated per capita share (liters/day)                                  | 96                                                          |
| Actual per capita share (liters/day)                                     | 70                                                          |
| Number of bills (residential and non-residential)                        | 27,000                                                      |
| Number of residential bills (subscriptions)                              | 20,939                                                      |
| Length of water network (2 inches and above) (km)                        | 514                                                         |
| Annual number of breakages (damages)                                     | 5,180                                                       |
| Number of breakages (damages) per 100 km of pipeline per year            | 1,008                                                       |
| Amount of water lost per m <sup>3</sup> per km per year                  | 4,527.94                                                    |
| Amount of water lost per subscription per day                            | 26                                                          |
| Number of existing water tanks                                           | 5 + 2 under construction                                    |
| Capacity of water tanks (thousands m <sup>3</sup> )                      | 14 + 10 under construction                                  |
| Number of employees working directly in water (employees)                | 70                                                          |
| Number of employees working directly and indirectly in water (employees) | 95                                                          |
| Cost of a m <sup>3</sup> of water for the consumer (USD)                 | 0.52                                                        |
| Diesel consumption (liters/year)                                         | 408,020                                                     |
| Average daily pumping hours                                              | 9 hours per well with an average of 90 m <sup>3</sup> /hour |
| Number of distribution zones                                             | 10                                                          |
| Average daily pumping volume (m <sup>3</sup> /day)                       | 26,000                                                      |

Table 3. Historical sequence of water network efficiency in Khan Younis

| Year | Annual Water Production (m <sup>3</sup> ) | Annual Actual Billed Water Quantity (m <sup>3</sup> ) | Annual NRW Quantity (m <sup>3</sup> ) | NRW (%) | Population | Per Capita Share of Produced Water (l/day) | Per Capita Share of Actual Water (l/day) |
|------|-------------------------------------------|-------------------------------------------------------|---------------------------------------|---------|------------|--------------------------------------------|------------------------------------------|
| 2012 | 9,278,072                                 | 5,056,747                                             | 4,221,325                             | 39%     | 216,580    | 117                                        | 64                                       |
| 2013 | 9,459,266                                 | 5,894,734                                             | 3,564,532                             | 36%     | 224,160    | 116                                        | 72                                       |
| 2014 | 8,676,380                                 | 5,520,901                                             | 3,155,479                             | 30%     | 231,781    | 103                                        | 70.9                                     |
| 2015 | 8,473,265                                 | 5,660,753                                             | 2,812,512                             | 33%     | 239,429    | 97                                         | 65                                       |
| 2016 | 8,948,124                                 | 5,996,673                                             | 2,951,451                             | 33%     | 241,198    | 101                                        | 68                                       |
| 2017 | 8,607,651                                 | 6,278,842                                             | 2,278,809                             | 27%     | 249,160    | 96                                         | 70                                       |

Figure 3 presents the monthly distribution of water consumption in 2017. It has been observed that water consumption tends to increase during the summer months, primarily due to the increased demand for water resulting from higher temperatures.

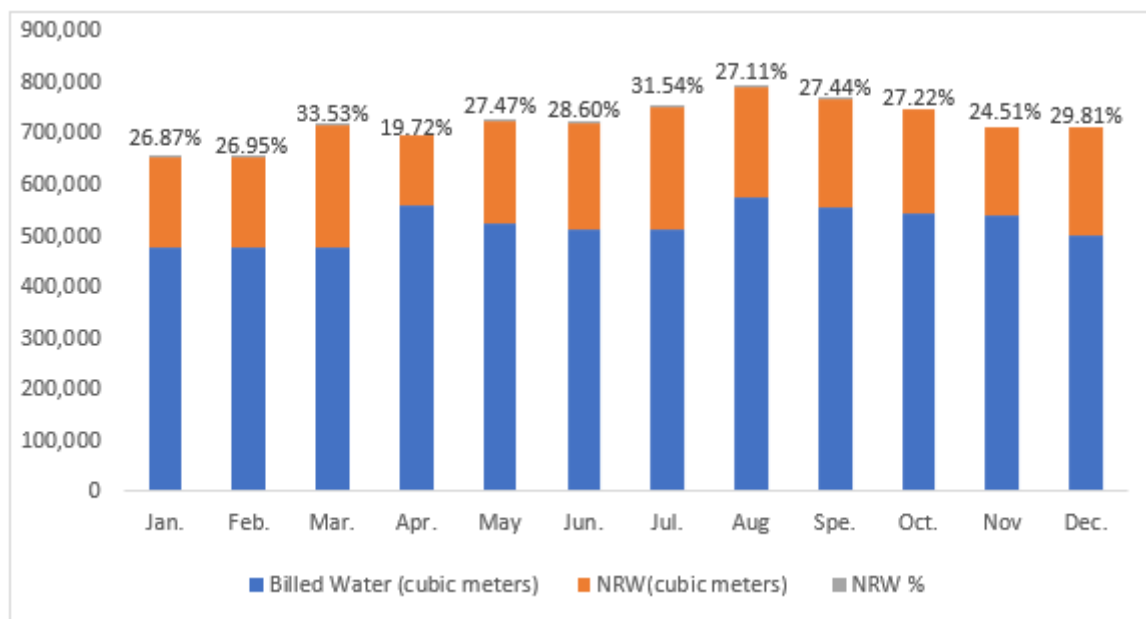


Figure 3. Khan Younis consumed and NRW per month, 2017

Financial consequences of water losses in Khan Younis Municipality are significant, as their value reaches 1.2 million USD per year. Given the financial resources available, it is possible to build a water tank with capacity of 5,000 m<sup>3</sup>, drill eight new water wells, or create new water networks of 4" and 6" diameter, reaching lengths of 124 km and 82 km, respectively. These network lengths can satisfy the needs of the remaining 15 % of the city area, which does not have any water networks installed. Moreover, it is possible to replace current networks of 4" and 6" diameter with new ones, having lengths equal to 83 km and 62 km, respectively. In fact, such information becomes crucial when it comes to the city's iron pipelines to be replaced, which are 150 km long and have various diameters.

NRW components were determined using the water balance method. This is dependent on the calculation of a number of water-related statistics which include but are not limited to: measurements, production, importations, exportations, consumptions, and wastages. The main goal is to make sure that all these figures are well balanced out. In this regard, calculations of the water balance provide a basis for assessing the amount of water loss which can be attributed to real losses, commercial losses, or administrative losses. With the help of the International Water Association (IWA) that has come up with a method based on best practices in other countries, water loss and the performance indicator can be determined. The primary objective here is to allow comparison of performance of various water service providers (Alegre et al., 2016; Lambert et al., 1999).

Based on the water balance table of Khan Younis Municipality during 2017, it is evident from Table 4 that NRW is estimated at around 2.328 million m<sup>3</sup>. Such amount makes up 27.06 percent of the overall volume of water production for 2017, which stood at 8.61 million m<sup>3</sup>. The water balance table shows different loss percentages, although it must be emphasized that such percentages are mere estimations until specialized studies are conducted for determining the quantities of losses associated with each one of them.

Table 4. Water balance for Khan Younis municipality in 2017

|                                                             |                                                                                 |                                                                        |                                                                                                                                                          |                                                                             |
|-------------------------------------------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| System Input<br>Volume (SIV)<br>8,607,651.00 m <sup>3</sup> | Authorized<br>Consumption<br>(AC)<br>=<br>6,537,071.53 m <sup>3</sup><br>75.94% | Billed Author. Cons.<br>(BAC)<br>6,278,842.00 m <sup>3</sup><br>72.94% | Billed Metered (BMC)=<br>6,278,842.00 m <sup>3</sup><br>72.94%                                                                                           | Revenue Water (RW)<br>6,278,842.00 m <sup>3</sup> /a<br>72.94%              |
|                                                             |                                                                                 |                                                                        | Billed Unmetered (BUC)=<br>0 m <sup>3</sup> /a 0.00%                                                                                                     |                                                                             |
|                                                             | Total Losses (WL)<br>=<br>2,070,579.47 m <sup>3</sup><br>24.06%                 | Unbilled Author. Cons.<br>(UAC)<br>258,229.53 m <sup>3</sup><br>3.00%  | Unbilled Metered (UMC)=<br>172,153.02 m <sup>3</sup> 2.00%                                                                                               | Non-Revenue Water<br>(NRW)<br>=<br>2,328,809.00 m <sup>3</sup> /a<br>27.06% |
|                                                             |                                                                                 |                                                                        | Unbilled Unmetered (UUC)=<br>86,076.51 m <sup>3</sup> 1.00%                                                                                              |                                                                             |
|                                                             |                                                                                 | Apparent Losses (AL)<br>1,209,814.37 m <sup>3</sup><br>14.06%          | Unauthorized Consumption<br>(UC)=<br>779,431.82 m <sup>3</sup> 9.06%                                                                                     |                                                                             |
|                                                             |                                                                                 |                                                                        | Metering Inaccuracies (MI)=<br>430,382.55 m <sup>3</sup> 5.00%                                                                                           |                                                                             |
|                                                             |                                                                                 | Real Losses (RL)<br>860,765.10 m <sup>3</sup><br>10.00%                | Leakage and Overflows at<br>Utility's Storage Tanks =<br>0 m <sup>3</sup> 0.00%                                                                          |                                                                             |
|                                                             |                                                                                 |                                                                        | Leakage on Transmission<br>Mains/Distribution Pipes and<br>Service Connections up to<br>point of Customer metering =<br>860,765.10 m <sup>3</sup> 10.00% |                                                                             |

### 3.2 Methodology

#### 3.2.1 Methodology and data sources

A case study approach was adopted in this study, integrating the analysis of operational data, field surveys, bill record analysis, and monitoring of implemented interventions was used to determine the effectiveness of the commercial-loss reduction measures by the Khan Younis Municipality in the year 2017. The data used in this analysis were categorized under 4 headings to enhance transparency.

The study was based on multiple complementary data sources to ensure a comprehensive assessment of commercial water losses and the effectiveness of the implemented intervention program. The primary dataset consisted of measured operational data obtained from the municipal water distribution system. These data included water production volumes recorded at municipal well meters and booster station meters, customer water consumption measured through service-line water meters, meter readings collected during the intervention program, and monthly water balance records. As these measurements were obtained directly from calibrated metering devices and routine operational monitoring, they formed the principal basis for evaluating water consumption patterns and quantifying changes in non-revenue water.

To support the operational measurements, data were extracted from the municipal billing system. These records included the customer subscriber database, historical billing information, recorded

water consumption, and water service account details. The billing database was used to verify customer registration status, identify discrepancies between measured consumption and billed volumes, and evaluate changes in billing performance following the implementation of corrective measures. Integrating billing records with measured water consumption provided a reliable basis for assessing apparent losses associated with administrative and commercial factors.

Field investigations constituted another important source of information. Comprehensive site surveys and physical inspections were conducted to verify the characteristics and operational status of public facilities, government-owned buildings, and residential developments. During these inspections, information was collected on the physical characteristics of water connections, facility dimensions, operational conditions, and occupancy status, particularly within newly developed residential projects. These field observations were essential for validating database records, identifying unregistered consumers, and confirming actual water demand under operating conditions.

Where direct measurements were unavailable, carefully developed engineering estimates were employed to quantify water consumption. These estimates were applied to facilities without installed water meters, previously unreported consumption, nonregistered users, and selected components of commercial water losses prior to the intervention program. The estimation procedures were based on facility characteristics, observed operating conditions, historical consumption patterns, and comparable metered facilities to ensure that the adopted values reflected realistic water use.

To enhance the transparency and reliability of the analysis, measured and estimated datasets were maintained as separate information sources throughout the study. Directly measured values were used whenever available, whereas estimated values were incorporated only where measurements could not be obtained. This distinction enabled a clear evaluation of the uncertainty associated with estimated data and prevented estimated values from influencing the interpretation of measured system performance.

### *3.2.2 Water balance analysis*

The international water association water balance methodology was adopted to quantify NRW and classify losses into authorized consumption, apparent losses, and real losses (Alegre et al., 2016; Lambert et al., 1999). System Input Volume (SIV) figures are based on production data we have measured at the municipal wells and supply meters. As for the authorized billed consumption, that was obtained directly from the billing database. The difference between supplied and billed volumes was used to estimate NRW and identify categories requiring intervention. The water balance served as the principal diagnostic instrument for selecting intervention priorities and monitoring improvements after implementation.

### *3.2.3 Identifying and selecting facilities*

A systematic screening process was conducted using billing records, operational database, and field inspections. Facilities would be selected if any of the following conditions were identified:

1. Unregistered water use.
2. Absence of a functioning water meter on site.
3. An authorized facility is being supplied with water yet is not included in the billing records.
4. Significant discrepancies between expected and recorded consumption.
5. Housing projects supplied through shared distribution systems without effective monitoring

As defined in the IWA water balance classification, a categorization of facilities was developed:

- Unbilled metered consumption.
- Authorized unmetered unbilled consumption.
- Apparent losses associated with administrative and commercial deficiencies.

### *3.2.4 Unmetered consumption estimates*

The estimation of consumption at sites that did not have water meters was performed using engineering judgment based upon visual observation and functional usage data. The estimation was based upon the following factors:

- Size of water supply connection diameter.
- Type and purpose of facility (e.g. Restaurant, hotel, industrial facility).
- Size of the building and its lot characteristics (e.g. Land use factors).
- Number of people serviced (number of residents, number of customers).
- Inclusion of irrigated/landscaped areas.
- Frequency and water supply duration on the facility operation.
- Reference to similarly metered facilities where available.

As an example, community forums that had 2-inch pipeline connections were allocated a greater consumption value estimate than those connected via 1-inch lines. Wastewater pumping stations were assessed based on operational, cleaning, administrative and water truck filling needs. Facility consumption, in cases where no historical consumption records were available, was determined by calculating the average monthly consumption and multiplying it by the calculated length of time the facility had been operating unregistered. After conducting an onsite investigation, and implementing new subscriptions or meters, this value was re-evaluated and modified.

### *3.2.5 Intervention implementation*

The intervention strategy focused on converting previously unrecorded consumption into monitored and billable consumption. For each targeted facility, the following actions were implemented:

1. Customer accounts created in the municipal billing system.
2. Water meters installed where technically feasible.
3. Administrative subscriptions were established for service facilities and housing projects.
4. New registered monthly reading was recorded.
5. Follow-up using the billing and performance control software of the municipality.

The types of interventions were housing projects, governmental facilities, municipal facilities, pumping stations, community forums, cemeteries and administrative service connection.

### *3.2.6 Validation of results*

In order to ensure the reliability and accuracy of the intervention results, a multi-stage verification procedure was implemented throughout the study. Field verification was the primary validation approach, which was carried out by field visits to confirm the physical conditions of the sites investigated, verify the characteristics of the water connections and assess the operational status of the identified facilities. These inspections also enabled the verification of client ownership records and occupancy status, thereby reducing potential errors associated with outdated administrative information. The estimated water consumption assigned to unmetered facilities during the intervention period was then validated by comparing with the actual water consumption recorded after installation of water meters. Every time after-intervention meter readings were made available; the estimated values were evaluated against the measured consumption and any discrepancies were corrected to improve the accuracy of the data set. This process also provided the opportunity to assess the reliability of the estimate procedures adopted for consumers who had not been measured before.

Additional validation was achieved through cross-checking of information obtained from the municipal payment system and observations collected during field surveys. The details of the customer registration, invoices and recorded water consumption were systematically compared with site observations to identify inconsistencies, verify customer information and confirm the effectiveness of the corrective measures implemented. In addition, monthly reports prepared by the

Non-Return Water (NRW) Management Team were reviewed to monitor the progress of the intervention program and verify the consistency of the results recorded over time. The combination of field verifications measured post-intervention consumption, administrative database reconciliation, and ongoing operational monitoring provided a strong validation framework that enhanced the credibility of the results and minimized uncertainty associated with the estimation process. Figure 4 summarizes the overall methodological framework adopted in this study.

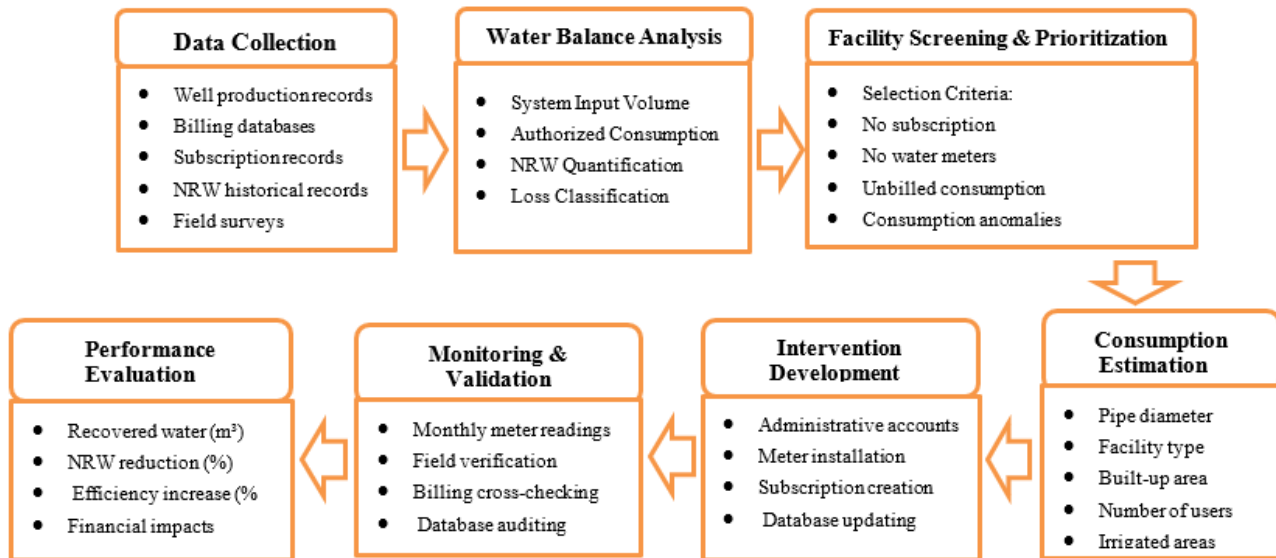


Figure 4. Methodology process diagram

### 3.2.7 Uncertainty and limitations

There is a degree of uncertainty related to the components of the estimate of commercial loss. Uncertainty may be relevant for:

- Buildings lacking historical water-consumption records.
- Illegal and unaccounted use of water.
- Historical accumulation of consumption estimates.
- Buildings without water meters.
- Estimation of Authorization but unbilled consumption.

Multiple information sources were used to estimate consumption where a direct reading was unavailable (including field surveys, pipe characteristics, facility use, operational data and comparisons with similar metered facilities). However, the estimated values must be considered to be approximations rather than accurate measurements.

The uncertainty associated with estimated consumption is expected to be higher than that associated with direct meter readings and billing-system records. Consumption that was estimated was expected to carry a higher uncertainty than consumption based on metered data and billing systems. However, because the intervention program subsequently established subscriptions and monitoring procedures, the long-term performance evaluation relied increasingly on measured consumption data rather than estimated values. Consequently, the overall conclusions regarding NRW reduction and efficiency improvement remain robust despite the inherent uncertainty associated with some estimated consumption categories.

## 4. RESULTS

The reduction and control of NRW is a more complex process than is commonly assumed. Consequently, the issue must be viewed from a comprehensive, multidimensional perspective, relying on a thorough analysis of the current situation and establishing a baseline for comparison to

measure improvements. The study documented the continuous efforts to implement the intervention plan for reducing water losses, following the framework of the 2015 and 2016 plans, through which network efficiency was increased by 4.6% by addressing issues related to housing projects and some governmental and public facilities (AbuEltayef, 2017).

#### ***4.1 Intervention design***

The action plan is structured around four key components, designed to systematically reduce NRW and improve overall water utility performance. These components are: Firstly, The preparation plan establishes the foundation by collating data, identifying key issues, and establishing objectives; Secondly, the implementation (intervention) plan delineates the specific actions and strategies that have been identified as necessary to address the aforementioned problems; Thirdly, the monitoring plan ensures continuous tracking of progress and performance; and Fourthly the monitoring and evaluation plan that assesses the effectiveness and impact of the interventions, guiding future improvements. Collectively, these elements constitute a comprehensive framework for the efficient and sustainable management of NRW.

#### ***4.2 Preparation and setup***

To support the assessment, field surveys were conducted to verify facility characteristics, document water supply connections, determine pipeline diameters, identify water supply sources and collect information on facility operation and occupancy. For facilities lacking reliable consumption records, preliminary consumption estimates were developed based on field observations and operational characteristics. The resulting dataset was then used to assess the existing conditions, identify losses. Based on these findings, intervention priorities were established and incorporated into the implementation plan. Table 5 presents the main and sub-categories of water balance classes that have been targeted in this study.

*Table 5. Target facilities classifications according to IWA*

| Water Balance Classification  | Main Categories                       | Sub- categories                            |
|-------------------------------|---------------------------------------|--------------------------------------------|
| Authorized Unmetered Unbilled | Municipal Facilities                  | Parks and recreational area                |
|                               |                                       | Sewage pump stations                       |
|                               |                                       | Community facilities                       |
|                               | Governmental facilities               | Security Facilities                        |
|                               | Administrative facilities             | Hamad Housing phases 1, 2                  |
|                               |                                       | Tohoku Housing                             |
|                               |                                       | Khan Younis family's Cemeteries            |
|                               | Khan Younis Camps family's cemeteries |                                            |
| Unauthorized metered Unbilled | Housing Projects                      | Completion of the Japanese Housing Project |
|                               |                                       | Completion of the Dutch Housing Project    |
|                               |                                       |                                            |
| Apparent Losses               | Metering-inaccuracy losses            | Meters maintenance                         |
|                               | Illegal connections                   | Consumption estimation                     |
|                               |                                       | Water tank supply                          |

#### ***4.3 Implementation (intervention) plan***

The subsequent general procedures were part of the intervention strategy and were implemented in all governmental and local facilities: 1) setting up a billing system account; 2) if one is available, installing a water meter; 3) when a meter is unavailable, entering the expected monthly use; 4) using the invoicing system to record the facility's monthly usage readings; and 5) an annual comparison of estimated and actual consumption should be carried out. Based on the IWA definition of water balance, the implementation plan was now divided into three sections. The methods used for each category are described in depth in the sections that follow.

## 4.4 Results

The interventions carried out to reduce the commercial aspects of NRW within the Khan Younis Municipality are covered in this section. The interventions to be evaluated have been designed according to a Water Balance analysis and were targeted towards; authorized yet unbilled total consumption; apparent losses; and other types of unregistered consumption, each of which falls under its own intervention category. Each individual category will be covered under the categories of implementation approach; estimated or actual total consumption; and impact on billed total consumption and overall NRW reduction. The interventions were subsequently monitored via the municipality's billing and monitoring systems for their effectiveness on NRW reduction and their contribution to the greater NRW reduction program.

### 4.4.1 Plan for managing authorized metered unbilled

The focal point of this component was the completion and finalization of the 2015–2016 intervention plan for a group of housing developments. The primary objective of the project was to establish new subscriptions, digitize the billing process, and record cumulative consumption data. A particular focus was placed on an analysis of the Japanese and Emirati housing projects located in proximity to the Al-Amal neighborhood. Furthermore, the Hamad Housing Project has been equipped with administrative (service) meters, with the objective of monitoring and controlling water losses.

### 4.4.2 Completion of housing projects

Following the completion of the subscription registration process and the integration of the designated housing units into the municipal billing system, routine meter reading and consumption monitoring became fully operational. As a result, the long-standing issue associated with the UNRWA housing projects, including the Japanese, Dutch, and Emirati housing developments, was largely resolved. This achievement represents the culmination of a systematic intervention process that extended over a three-year period. Nevertheless, approximately 22 housing units remained unresolved during the 2015–2016 intervention programs due to difficulties in verifying occupancy status and identifying the current residents. These units are summarized in Table 6.

However, municipal teams successfully identified the residents and implemented the intervention measures outlined above. The results of the intervention plan are presented Table 7.

### 4.4.3 Administrative subscriptions for monitoring service consumption

International organizations and donor agencies helped develop many housing projects located in Khan Younis. Projects carried out by UNRWA, which included housing funded by the Emirates, Dutch and Japanese governments, as well as other housing projects funded by the Austrian and Japanese governments, are examples of these projects. Many of the residential units were allocated to recipients before they could be integrated into the municipal water billing system. Because of this delay, water was supplied to the units through internal distribution systems; thus, at times, a portion of the consumption for common/community facilities/services remained unmonitored and/or unaccounted for.

Unlike conventional District Metered Areas (DMAs), where an isolated geographic area has a limited number of points through which the area receives flow (as a result of the flow being metered), the water supply for the housing projects was developed as a connected (looped) distribution system. This configuration makes it difficult to identify the boundaries of a hydraulic reserve; therefore, it is not possible to compare inflows to the municipality and consumption by the users of the housing units to establish any hydraulic balance). As a result, conventional monitoring approaches based using only DMAs could not be fully implemented at the housing projects.

Table 6. Remained housing project intervention plan

| Housing Project  | Problem Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Intervention Plan                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Japanese Housing | There were 17 occupied residential buildings identified within the Japanese Housing Program. While the apartments were occupied, the original beneficiaries had no longer resided in them and the current occupants had also not completed the formal procedures required to establish a subscription for municipal water in their names. Therefore, although the water was supplied through the existing distribution network, it was not metered in the municipal billing system and no water invoices were issued to the current occupants. Thus, water was defined as authorized but unbilled consumption rather than as an illegal use. As part of the intervention program, the municipality verified occupancy records, created official customer accounts, registered new water subscriptions and incorporated the facilities into the billing system. Historical consumption was estimated from available operational records and from assessments made in the field but these estimates primarily served to demonstrate the extent of previously unrecorded consumption. The main goal of the intervention was to ensure that in the future, all consumption is accurately metered, recorded and billed via the municipal billing system. | <ul style="list-style-type: none"> <li>▪ All users who use the system to have been provided with an account for them to use with the system, and we have official water subscriptions that have been registered through the use of the system.</li> <li>▪ A letter was sent to customers in order to provide them with written proof of what the subscription fee is so that the subscription fee can be placed into the billing system.</li> <li>▪ The billing system has incorporated the subscription fee as part of the billing process.</li> <li>▪ The historical records of water usage by our customers had been entered into the system with the associated charges being charged to customer accounts and included in the bills sent to them.</li> </ul> |
| Dutch Housing    | It is evident that there are five occupied buildings on the premises that lack formal water subscriptions. It is evident that these units have been consuming water on a monthly basis for a considerable number of years.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

Table 7. Unbilled metered intervention plan results

| Consumption type | Targeted consumption | Average monthly water volume (m <sup>3</sup> /month) | Total annual water volume (m <sup>3</sup> /year) | Cumulative total over years (m <sup>3</sup> ) | Annual percentage |
|------------------|----------------------|------------------------------------------------------|--------------------------------------------------|-----------------------------------------------|-------------------|
| Unbilled Metered | Japanese Housing     | 340                                                  | 4,080                                            | 4,080                                         | 0.05%             |
|                  | Dutch Housing        | 60                                                   | 720                                              | 720                                           | 0.01%             |
|                  | Total                | 400                                                  | 4,800                                            | 4,800                                         | 0.06%             |

To address this challenge, the municipality introduced what they call an administrative service subscription. This is a special monitoring account created for water used in shared spaces at a building or project level. For example, it covers water for cleaning common areas, watering public spaces, fire hoses, mosques, shared facilities, commercial shops without their own meters, and other services used by everyone. This system is similar to how electricity companies manage service accounts for stairway lighting, elevators, and other common building services.

This administrative subscription is different from regular building-level metering. Its primary purpose is not customer billing, but to keep track of, measure, and manage shared water use that would otherwise go unrecorded. It's also not like a DMA because it works at the level of a single building or housing project, not a wider network zone. By comparing the water volume recorded by the administrative meter with the total consumption from all individual apartment meters, the municipality could pinpoint water that wasn't being accounted for. This allowed them to estimate how much water was lost through shared services and unauthorized use.

Hamad Housing was chosen as the first place to try this system because it had several features that made it easier to monitor and analyze. First, each residential building received water through a main connection that had a large meter. Second, individual apartments already had their own water meters. Third, the water supply came from a specific source (Hamad wells), which made it possible to accurately measure the total amount of water supplied to the entire area. These conditions allowed the municipality to compare the total water coming in with the total water used by all apartments and find any differences caused by shared consumption and water losses.

Table 8 demonstrates the pragmatic and economical mechanism for monitoring previously unrecorded consumption for administrative subscriptions offered. Also, this intervention program enhances accountability and mitigates commercial losses in housing developments where conventional DMA methodologies proved challenging.

*Table 8. Administrative implemented intervention plan*

| Housing Project                                                     | Problem Description                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Intervention Plan                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Administrative Subscription – Hamad Housing Project, Phases 1 and 2 | Each building contains twenty apartments, supplied with water from an overhead tank. The tank in question distributes water to the twenty apartments via individual meters. Furthermore, on each story of the building, there is a fire hose that is frequently utilized for unauthorized purposes, such as the cleaning of staircases, corridors, and, on occasion, even apartments. This usage is not measured or recorded, resulting in unaccounted water consumption. | <ul style="list-style-type: none"> <li>▪ A unique system identification number was assigned to each registered name.</li> <li>▪ An administrative (services) subscription number was created and activated.</li> <li>▪ The new subscription number was recorded and monitored on a monthly basis, and its consumption was compared with the aggregate apartment consumption within the same building.</li> <li>▪ Apartment water consumption was allocated proportionally among users based on the total recorded consumption.</li> </ul>                                |
| Administrative Subscription – Tohoku Housing Project                | The Ministry of Public Works and Housing allocated the apartments to beneficiaries without coordination with the municipality. Consequently, unregistered water consumption has been observed, attributable to the absence of identification of the legitimate apartment owners.                                                                                                                                                                                          | <ul style="list-style-type: none"> <li>▪ A unique system identification number was assigned to the users.</li> <li>▪ An administrative (service) subscription number was created and activated.</li> <li>▪ The new subscription reading was recorded on a monthly basis, and a comparison was conducted between this reading and the consumption readings of the residential apartments within the same building.</li> <li>▪ The overall water consumption was distributed proportionally among the apartments based on their respective consumption records.</li> </ul> |
| Administrative Subscription – Khan Younis Families Cemetery         | A 4-inch pipeline supplies a group of cemeteries belonging to Khan Younis families with water. The water is utilized for two primary purposes: first, in the construction of graves, and secondly, in the irrigation of trees and vegetation within the cemetery. However, there are instances of unregistered water consumption that necessitate resolution.                                                                                                             | <ul style="list-style-type: none"> <li>▪ A unique system identification number was assigned to the registered names.</li> <li>▪ An administrative (services) subscription number was created and activated.</li> </ul>                                                                                                                                                                                                                                                                                                                                                   |

Within the Hamad Housing development, a total of 113 administrative subscriptions were established, comprising 55 in Hamad Housing "Phase I" and 58 in Hamad Housing "Phase II". These subscriptions were implemented to monitor shared water consumption at the building level that had not been previously recorded. Water volumes obtained via these administrative subscriptions were subsequently compared against the aggregate consumption data from the municipal billing system. This comparison facilitated the identification and quantification of unaccounted-for water consumption pertinent to common services and shared facilities. Furthermore, administrative subscriptions were also established for several cemeteries. These cemeteries are supplied via dedicated 4-inch pipelines, with water primarily utilized for landscape irrigation and construction activities. The Tohoku Housing Project was excluded from this monitoring program. This exclusion was necessitated by inconsistencies observed between occupancy records, customer information, and billing-system data, which precluded a reliable assessment of water consumption. The outcomes of this administrative subscription intervention are presented in Table 9.

Table 9. Unbilled metered housing projects interventions results

| Consumption type | Targeted consumption                                             | Average monthly water volume (m <sup>3</sup> /month) | Total monthly consumption (m <sup>3</sup> /month) | Total annual water volume (m <sup>3</sup> /year) | Total yearly consumption (m <sup>3</sup> /year) | Annual percentage |
|------------------|------------------------------------------------------------------|------------------------------------------------------|---------------------------------------------------|--------------------------------------------------|-------------------------------------------------|-------------------|
| Unbilled Metered | Hamad Housing project 1,2                                        | 6,559                                                |                                                   | 78,705                                           |                                                 |                   |
|                  | Administrative Subscription – Tohoku Housing Project             | 800                                                  |                                                   | 9,600                                            |                                                 |                   |
|                  | Administrative Subscription – Khan Younis Families Cemetery      | 100                                                  | 8,259                                             | 1,200                                            | 99,105                                          | 1.15%             |
|                  | Administrative Subscription – Khan Younis Camp Families Cemetery | 800                                                  |                                                   | 9,600                                            |                                                 |                   |
|                  |                                                                  |                                                      |                                                   |                                                  |                                                 |                   |

#### 4.4.3.1 Plan for managing authorized unmetered unbilled consumption

A significant number of municipal and government facilities consume considerable amounts of water; however, these facilities are typically not measured or included in recorded consumption figures. In the absence of a comprehensive and accurate database, it is challenging for municipal officials to provide precise information regarding water consumption. The absence of metering infrastructure, subscription-based monitoring systems, and the lack of a centralized database hinder the ability to accurately track and report usage. In the 2015–2016 intervention plan, a number of such facilities were targeted, and this study highlights the additional facilities that have been targeted for this year, as follows:

#### 4.4.3.2 Community forums

As demonstrated in Table 10, a number of community forums have been supplied with water for extended periods without the requisite registration of subscriptions or estimation of their consumption. This particular instance of water usage is thus classified as authorized unbilled consumption. Table 10 illustrates the described problem situation and targeted intervention plan.

Table 10. Community forums intervention plan

| Community Forums Name                                                                                                        | Problem Description                                                                                                                                                                                                                                                                                   | Intervention Plan                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Al-Qadisiyyah Forum<br>Al-Quds Forum<br>Al-Harazin Forum<br>Al-Maghariba Forum<br>Al-Buraq Forum<br>The Slaughterhouse Forum | It is evident that six forums have been in existence for a considerable number of years without the presence of formal water subscriptions. It has been observed that a considerable quantity of water has been consumed on a monthly basis, with no recorded usage over the course of several years. | <ul style="list-style-type: none"> <li>▪ A unique system identification number was assigned to the entities, and an official subscription number was established for each account.</li> <li>▪ Water meters were installed to enable accurate measurement and monitoring of consumption.</li> <li>▪ Historical water consumption was estimated and documented as part of the study.</li> <li>▪ Historical consumption records were entered into the billing system, and the corresponding charges were applied accordingly.</li> </ul> |

A calculation of water consumption was conducted, with the estimation being derived from several parameters. These parameters included the diameter of the supply line from the municipal network, the area of the facility, the nature of its usage, and the presence of green spaces. The findings indicated that the average monthly consumption is approximately 1,150 m<sup>3</sup>. Following the conclusion of the intervention plan previously delineated, Table 11 provides a presentation of the intervention's outcomes.

Table 11. Estimated consumption community forums

| Targeted consumption | Pipe diameter | Estimated consumption (m <sup>3</sup> /month) | Consumption / month | Annual consumption (m <sup>3</sup> ) | Accumulated estimated consumption (m <sup>3</sup> /year) | Accumulated consumption over years (m <sup>3</sup> ) | Accumulated percentage |
|----------------------|---------------|-----------------------------------------------|---------------------|--------------------------------------|----------------------------------------------------------|------------------------------------------------------|------------------------|
| Al-Qadisiyah         | 2"            | 300                                           | 120                 |                                      | 36,000                                                   |                                                      |                        |
| Al-Quds              | 1"            | 150                                           | 36                  |                                      | 5,400                                                    |                                                      |                        |
| Al-Harazin           | 1"            | 150                                           | 60                  | 13,800                               | 9,000                                                    | 59,600                                               | 0.69%                  |
| Al-Maghariba         | 1"            | 150                                           | 36                  |                                      | 5,400                                                    |                                                      |                        |
| Al-Buraq             | 2"            | 300                                           | 12                  |                                      | 3,600                                                    |                                                      |                        |
| Al-Maslakh           | 4/3"          | 100                                           | 2                   |                                      | 200                                                      |                                                      |                        |

#### 4.4.3.3 Wastewater / stormwater pumping stations

A total of eight primary and secondary wastewater pumping stations (WWPS) were identified as part of the assessment of authorized unbilled consumption. Field investigations revealed that some stations consumed water without dedicated water meters, while others were equipped with meters but were not formally registered within municipal billing system. Water consumption at these facilities is associated with several operational activities, including administrative use, caretaker requirement, station cleaning operations, equipment maintenance, vehicle washing, and water-truck filling for cleaning purposes. As this consumption was not fully measured, recorded, or billed, it was classified as authorized unbilled consumption, and therefore contributed to the commercial-loss component of NRW. Consequently, an intervention plan was developed to establish the necessary subscriptions, improve monitoring, and integrate consumption records into the municipal billing system.

Once the completion of inventory and field assessment process, the wastewater pumping station supplied by the water network were identified, noting that several smaller stations were not connected to water supply network. For each connected station, the characteristics of the water supply connection, including pipeline diameter, were documented. In stations lacking water meters, which represent the majority of the facilities, water consumption was estimated based on operational requirements, facility characteristics, and field observations.

Subsequently, official water subscription was established, and water meter were installed, where technically feasible, the resulting consumption records were then integrated into the municipal billing system to enable ongoing monitoring and accounting of water consumption. The data presented in Table 12 provides preliminary consumption estimates and percentage.

Table 12. Wastewater / stormwater pumping stations interventions results

| Type of consumption | Targeted consumption | Average consumed water volume (m <sup>3</sup> /month) | Total monthly consumption (m <sup>3</sup> /month) | Total consumed water volume (m <sup>3</sup> /year) | Annual percentage | Total annual water volume (m <sup>3</sup> /year) |
|---------------------|----------------------|-------------------------------------------------------|---------------------------------------------------|----------------------------------------------------|-------------------|--------------------------------------------------|
| Authorized          | Al-Wafiyah WWPS      | 90                                                    |                                                   | 9012                                               |                   |                                                  |
| Unmetered           | Fish Market WWPS     | 90                                                    | 220                                               | 9012                                               | 18504             | 0.21%                                            |
| Unbilled            | Al-Mujadala WWPS     | 20                                                    |                                                   | 240                                                |                   |                                                  |
|                     | Al-Satar WWPS        | 20                                                    |                                                   | 240                                                |                   |                                                  |

#### 4.4.3.4 Police facilities

Governmental facilities were identified within the NRW assessment based on anomalous water consumption patterns and inconsistent billing statuses. These facilities were categorized into two groups: those possessing inactive or inadequately updated water subscriptions within the billing system, and those connected to the municipal water network with documented consumption but lacking official municipal subscriptions. In both instances, water consumption records were either

incomplete or entirely absent from the billing database, leading to authorized yet unbilled consumption and consequently contributing to commercial water losses. The subsequent intervention plan involved verifying subscription records, establishing or reactivating customer accounts, installing or validating water meters as necessary, and integrating consumption data into the municipal billing system. A summary of the intervention measures implemented for these facilities is presented in Table 13.

*Table 13. Police facilities intervention plan*

| Facilities Name   | Problem Description                                                                                                                                                                           | Intervention Plan                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Police facilities | It is evident that ten security facilities have been in operation for an extended period without any formal water subscription, consuming significant quantities of water on a monthly basis. | <ul style="list-style-type: none"> <li>▪ System identification codes were assigned, and official water subscriptions were established for the facilities.</li> <li>▪ Water meters were provided and installed to enable accurate measurement of water consumption.</li> <li>▪ Historical water consumption was estimated and incorporated into the analysis.</li> <li>▪ Previous consumption records were entered into the billing system, and the corresponding charges were applied to customer accounts.</li> </ul> |

An assessment drawing on field surveys, billing-system records, and engineering estimates determined that the targeted facilities had an estimated monthly water consumption of approximately 2,900 m<sup>3</sup>, totaling about 34,800 m<sup>3</sup> annually. Historical analysis further indicated a cumulative unrecorded consumption of approximately 282,600 m<sup>3</sup> since these facilities commenced operation. As part of the intervention program, water meters were installed where technically feasible, inactive subscriptions were reactivated, and new customer accounts were established for previously unregistered facilities. Subsequently, consumption records were incorporated into the municipal billing system, which enabled ongoing monitoring and an improved quantification of authorized but previously unbilled consumption. Table 14 presents the outcomes following the implementation of these measures.

#### 4.4.3.5 Parks and public gardens

Within Khan Younis, several housing developments feature public parks and landscaped green areas, which receive water directly from the municipal supply network. A challenge in these areas was the absence of dedicated water meters, which impeded the accurate quantification of irrigation water consumption and its subsequent contribution to non-revenue water. To address this quantification challenge, an intervention program was initiated in selected parks situated within Hamad Housing. Specifically, three water meters were installed in representative green areas. Water consumption was subsequently monitored on a monthly basis over an eight-month period, encompassing the peak summer season characterized by maximal irrigation demand. From the recorded meter readings, the average monthly water consumption per dunum (1,000 m<sup>2</sup>) of landscaped area was calculated. This derived consumption rate was then extrapolated to other parks and green areas exhibiting similar characteristics, thereby enabling the estimation of their irrigation water requirements. This methodological approach offered a practical strategy for estimating water consumption in locations where direct meter installation was deemed technically or economically unfeasible. Such infeasibility was primarily attributed to factors including network complexity, challenging site conditions, or the extensive infrastructure modifications that would have been necessitated. Table 15 presents a summary of the implemented intervention measures and the corresponding estimated irrigation water consumption values.

The results of this intervention are shown in Table 16 following the completion of the subscriptions, consumption estimation, and partial meter installation.

Table 14. Estimated consumption police facilities results

| Targeted Consumption                        | Pipe diameter | Installation year | Out of service year | Estimate monthly consumption (m <sup>3</sup> /month) | Monthly consumption (m <sup>3</sup> /month) | Accumulated number of months of consumption | Annual consumption (m <sup>3</sup> /year) | Total consumed water (m <sup>3</sup> ) | Accumulated annually consumption (m <sup>3</sup> /year) | Accumulated consumption percentage |
|---------------------------------------------|---------------|-------------------|---------------------|------------------------------------------------------|---------------------------------------------|---------------------------------------------|-------------------------------------------|----------------------------------------|---------------------------------------------------------|------------------------------------|
| Al-Balad Police Station                     | 2"            | 2007              | 2017                | 250                                                  |                                             | 120                                         |                                           | 30000                                  |                                                         |                                    |
| Internal Security office                    | 1"            | 2007              | 2017                | 100                                                  |                                             | 120                                         |                                           | 12000                                  |                                                         |                                    |
| West Police Station office                  | 2"            | 2012              | 2017                | 250                                                  |                                             | 60                                          |                                           | 15000                                  |                                                         |                                    |
| Special Force office                        | 2"            | 2007              | 2017                | 200                                                  |                                             | 120                                         |                                           | 24000                                  |                                                         |                                    |
| Military College                            | 1"            | 2012              | 2017                | 100                                                  |                                             | z60                                         |                                           | 6000                                   |                                                         |                                    |
| Military College Center                     | 1"            | 2007              | 2017                | 150                                                  |                                             | 120                                         |                                           | 18000                                  |                                                         |                                    |
| Internal Security office                    | 1"            | 2012              | 2017                | 150                                                  |                                             | 60                                          |                                           | 9000                                   |                                                         |                                    |
| Marine Police office                        | 1"            | 2007              | 2017                | 100                                                  |                                             | 120                                         |                                           | 12000                                  |                                                         |                                    |
| Police Security office                      | 1"            | 2007              | 2017                | 150                                                  |                                             | 120                                         |                                           | 18000                                  |                                                         |                                    |
| Traffic Police office                       | 1"            | 2001              | 2017                | 100                                                  |                                             | 192                                         |                                           | 19200                                  |                                                         |                                    |
| Civil Defense Directorate                   | 2"            | 2007              | 2017                | 300                                                  | 2,900                                       | 120                                         | 34,800                                    | 36000                                  | 282,600                                                 | 1.02%                              |
| Branch Office of the Interior               | 1"            | 2007              | 2017                | 100                                                  |                                             | 120                                         |                                           | 12000                                  |                                                         |                                    |
| Academy for Security Sciences               | 1"            | 2007              | 2017                | 200                                                  |                                             | 120                                         |                                           | 24000                                  |                                                         |                                    |
| Supply and Equipment, Interior office       | 1"            | 2012              | 2017                | 100                                                  |                                             | 60                                          |                                           | 6000                                   |                                                         |                                    |
| Security Service office                     | 2"            | 2007              | 2017                | 150                                                  |                                             | 120                                         |                                           | 18000                                  |                                                         |                                    |
| Rapid Intervention office                   | 2"            | 2007              | 2017                | 150                                                  |                                             | 120                                         |                                           | 18000                                  |                                                         |                                    |
| Drug Control office                         | 3/4"          | 2012              | 2017                | 50                                                   |                                             | 60                                          |                                           | 3000                                   |                                                         |                                    |
| General Directorate of Supply and Equipment | 1"            | 2015              | 2017                | 100                                                  |                                             | 24                                          |                                           | 2400                                   |                                                         |                                    |
| Ma'an Police Station                        | 1"            | 2007              | 2017                | 100                                                  |                                             | 120                                         |                                           | 12000                                  |                                                         |                                    |

Table 15. Parks and public intervention plan

| Facilities Name          | Problem Description                                                                                                                                                                                                                          | Intervention Plan                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Parks and Public Gardens | Considerable areas of land cultivated with grass or trees consume considerable quantities of water, which are not documented as part of the municipality's facility consumption and are therefore categorized as non-revenue water (losses). | <ul style="list-style-type: none"> <li>A comprehensive review of the available blueprints was conducted, and field surveys were carried out for all parks, gardens, and tree-lined streets.</li> <li>Irrigated areas, water supply sources, and the diameters of the supplying pipelines were identified and documented.</li> <li>The water consumption of the facilities was estimated for a one-month period.</li> <li>Water meters were installed at the supply points to improve the accuracy of consumption measurements.</li> <li>A monthly monitoring program was established to track and evaluate water consumption.</li> </ul> |

#### 4.4.4 Plan for managing apparent losses

A number of actions were targeted for apparent losses, including the maintenance of meters and the estimation of consumption for cases identified by the theft committee. Furthermore, residents residing in peripheral districts and unplanned urban extensions were supplied with water via a contracted entity, with the objective of regulating illegal connections and violations of the water network.

Table 16. Parks and public gardens estimate results

| Type of Consumption           | Facility Name                             | Facility Area (m <sup>2</sup> ) | Average consumption (Dunum/month) | Calculated Monthly Consumption (m <sup>3</sup> ) | Number (months/year) | Actual consumption (m <sup>3</sup> /month) | Monthly consumption (m <sup>3</sup> ) | Accumulated consumption (m <sup>3</sup> /year) | Annual consumption (m <sup>3</sup> ) | Consumption Percentage |
|-------------------------------|-------------------------------------------|---------------------------------|-----------------------------------|--------------------------------------------------|----------------------|--------------------------------------------|---------------------------------------|------------------------------------------------|--------------------------------------|------------------------|
| Authorized Unmetered Unbilled | Hamad Town 1 Parks                        | 13,001                          | 85-171                            | 128                                              | 9                    | 2,432                                      |                                       | 21,889                                         |                                      |                        |
|                               | Hamad Town 2 Parks                        | 1,031                           | 85-171                            | 128                                              | 9                    | 1,412                                      |                                       | 12,708                                         |                                      |                        |
|                               | Hamad Town 3 Parks                        | -                               | 0                                 | 0                                                |                      | -                                          |                                       | -                                              |                                      |                        |
|                               | Administrative Area Park (Sea Roundabout) | 4,000                           | 100                               | 100                                              | 9                    | 1,400                                      |                                       | 12,600                                         |                                      |                        |
|                               | Municipality Nursery - Sea Roundabout     | 3,000                           | 400-300                           | 350                                              | 9                    | 1,050                                      |                                       | 9,450                                          |                                      |                        |
|                               | Tohoku Gardens                            | 984                             | 150-100                           | 125                                              | 9                    | 123                                        | 7,833                                 | 1,107                                          | 70,818                               | %0.82                  |
|                               | Dutch Parks                               | 2,823                           | 50-30                             | 40                                               | 9                    | 113                                        |                                       | 1,016                                          |                                      |                        |
|                               | Emirati                                   | 8,344                           | 50-30                             | 40                                               | 9                    | 334                                        |                                       | 3,004                                          |                                      |                        |
|                               | Japanese                                  | 6,613                           | 50-30                             | 40                                               | 9                    | 265                                        |                                       | 2,381                                          |                                      |                        |
|                               | Austrian Garden                           | 6,140                           | 40-60                             | 50                                               | 9                    | 154                                        |                                       | 2,763                                          |                                      |                        |
|                               | Al-Bayara Garden                          | 1,000                           | 140-170                           | 50                                               | 6                    | 150                                        |                                       | 300                                            |                                      |                        |
|                               | Hamad Town 1 public Parks                 | 6,000                           | 60-70                             | 66                                               | 9                    | 400                                        |                                       | 3,600                                          |                                      |                        |

#### 4.4.4.1 Metering inaccuracies

This study evaluated the impact of meter maintenance on recorded water consumption. All customer water meters that underwent maintenance during 2016 were identified from municipal maintenance and billing databases. A total of 538 meters were included in the analysis, representing the complete set of meters repaired that year, rather than a randomly selected sample. For each meter, billed consumption was examined across three periods. The pre-maintenance period (2015) involved meters classified as defective, where consumption was billed using the municipality's standard estimated value of 30 m<sup>3</sup> per month per subscription. The maintenance period during 2016 was excluded from comparative analysis due to ongoing meter replacement and repair activities. The post-maintenance period (2017) provided a full year of actual meter readings subsequent to repair.

The objective was to assess whether the standard estimated consumption assigned to defective meters accurately reflected actual customer consumption. A comparison of pre-maintenance estimated consumption with post-maintenance metered consumption revealed a substantial increase in recorded water use after meter repair. This finding suggests that the fixed billing value of 30 m<sup>3</sup> per month may underestimate actual consumption for a significant proportion of customers with defective meters, underscoring the importance of meter maintenance in reducing apparent losses associated with metering inaccuracies. Results indicated that the total billed consumption for the targeted subscriptions increased from 15,369 m<sup>3</sup> in 2015 to 28,837 m<sup>3</sup> in 2017 following meter repair and restoration of accurate measurement. Table 17 summarizes the consumption volumes and annual percentage changes associated with this intervention.

Table 17. Apparent losses intervention results

| Type of consumption | Targeted consumption                            | Average consumed water volume (m <sup>3</sup> /month) | Total consumed water volume (m <sup>3</sup> /year) | Accumulated consumed water volume (m <sup>3</sup> /years) | Consumption percentage |
|---------------------|-------------------------------------------------|-------------------------------------------------------|----------------------------------------------------|-----------------------------------------------------------|------------------------|
| Apparent Losses     | Metering Inaccuracies (538 broken water meters) | 991                                                   | 11,891                                             | 11,891                                                    | 0.14%                  |

#### 4.4.4.2 Illegal connections estimations

Unauthorized Connections refer to water being taken from service connections that are not registered in the municipal billing system. The Water Regulations of the Khan Younis Municipality – adopted in 2013 – state that properties with unauthorized connections will be subjected to a number of administrative procedures such as an attempt to regularize their service status, the application of the appropriate penalties, and the adjudication of the consumption that will not have been recorded prior to this day.

For purposes of estimating the previous consumption of water that has occurred as a result of unauthorized connections, the municipality uses an assessment method based on available information from the field and administrative file of the subject property. The estimation of the amount of previous water usage will include three components, which include: (1) the number of people that benefit from the water at each property; (2) the number of residential units at that property; and (3) the estimated period of time that each property received water without a registered subscription. In accordance with municipal regulations, the amount of previous water usage will be established at a minimum monthly rate of 20 m<sup>3</sup> for each apartment, and the maximum period that the subject property will be considered for consumption will be the prior seven (7) years.

Once verified, the estimated consumption will be recorded in the municipal billing system as "previously unbilled consumption" and the property owner is required to obtain a formal water subscription. The estimated consumption will then be incorporated into the billing records as per the municipality regulations. The estimates presented are subject to inherent uncertainty, as historical consumption cannot be directly quantified. Therefore, the calculated volumes should be regarded as administrative estimates derived from the best available information, rather than precise measurements. Table 18 details the outcomes of this intervention.

*Table 18. Unauthorized consumption intervention results*

| Type of consumption      | Targeted consumption            | Average consumed water volume (m <sup>3</sup> /month) | Total consumed water volume (m <sup>3</sup> /year) | Accumulated consumed water volume (m <sup>3</sup> /years) | Consumption percentage |
|--------------------------|---------------------------------|-------------------------------------------------------|----------------------------------------------------|-----------------------------------------------------------|------------------------|
| Unauthorized Consumption | Illegal connections Estimations | 486                                                   | 5,830                                              | 5,830                                                     | 0.07%                  |

#### 4.4.4.3 Central water dispensing units consumption for 2017

In some slum areas with high density population and low services provided by the municipality of Khan Younis, some residents did not have access to direct household water-supply connections at household level which contributed to unauthorized connections and unaccountable water usage. To mitigate this issue, the municipality decided to have public water dispensing unit supplied by main municipal water network via metered 2-inch pipe.

Each dispensing unit, as shown in Figure 5 was integrated into the municipal billing system and fitted with a municipal water meter that measured the total volume of water supplied to the respective facility. The operational management of these units was delegated to local contractors, who were responsible for distributing water to individual consumers within their service areas. While the internal distribution system and customer-level meters fell under contractor management and were not part of the municipal metering infrastructure, the municipality retained responsibility for monitoring the master meter installed at each dispensing unit. Regular meter readings were collected and subsequently compared with billing records to verify supplied volumes and ensure accountability.

This intervention aimed to establish a regulated and monitored water supply mechanism for areas not readily accessible via conventional household subscriptions. The establishment of officially registered supply points enabled the municipality to transition previously unrecorded water consumption into quantifiable and billable volumes. Thus, the recorded volumes from these dispensing units indicate water consumption that was previously unbilled or challenging to quantify

through the existing distribution infrastructure. Furthermore, the intervention mitigated incentives for unauthorized connections by offering an accessible and regulated source of municipal water. Table 19 presents a summary of the intervention's outcomes, detailing established subscriptions, estimated consumption, and monitored water volumes.



Figure 5. One of the installed central water dispensing units

Table 19. Central water dispensing units' consumption per months, 2017

| Contractor number | Jan | Feb | Mar | Apr | May   | Jun   | Jul | Aug   | Sep   | Oct   | Nov   | Dec   | Total  | Accumulated consumed water volume (m <sup>3</sup> /years) | Consumption percentage |
|-------------------|-----|-----|-----|-----|-------|-------|-----|-------|-------|-------|-------|-------|--------|-----------------------------------------------------------|------------------------|
| 1                 | 800 | 800 | 700 | 800 | -     | -     | -   | 1,500 | 1,500 | 4,500 | 1,000 | 1,100 | 12,700 | 56,348                                                    | 0.65%                  |
| 2                 | 600 | 600 | 635 | 495 | -     | -     | -   | 1,000 | 1,000 | 2,970 | 1,000 | 800   | 9,100  |                                                           |                        |
| 3                 | 400 | 450 | 703 | 600 | -     | 20    | -   | 2,120 | 1,093 | 828   | 816   | 682   | 7,712  |                                                           |                        |
| 4                 | 249 | 260 | 280 | 280 | -     | -     | -   | 1,228 | 300   | 330   | 248   | 377   | 3,552  |                                                           |                        |
| 5                 | 391 | 559 | 563 | 633 | 1,151 | -     | -   | 2,093 | 999   | 549   | 530   | 663   | 8,131  |                                                           |                        |
| 6                 | 375 | 358 | 400 | 514 | 1,344 | 1,795 | -   | 3,925 | 2,028 | 1,664 | 1,499 | 1,251 | 15,153 |                                                           |                        |

#### 4.4.5 Follow-up plan

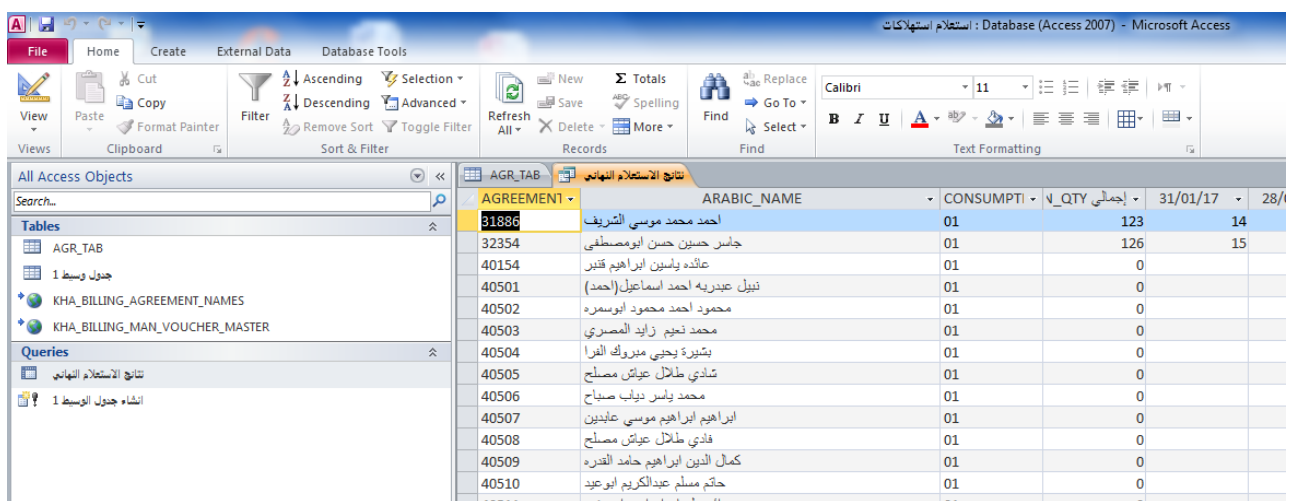
The follow-up plan is intended to guarantee the effective implementation of the process and to verify that all activities and procedures have been executed in the following manner. The following four stages must be completed in order to complete the subscription process: 1) creation of the subscription and signing of the Geographic Information System (GIS); 2) installation of the meter; 3) recording of accumulated consumption; and 4) taking of the monthly regular reading.

#### 4.4.6 Monitoring and evaluation plan

The monitoring plan aimed to evaluate the implementation of interventions and quantify their effect on mitigating commercial losses. In support of this objective, Khan Younis Municipality developed a monitoring application, which was integrated with the existing municipal billing system. The system's primary function was to track water consumption for specific subscription groups and intervention categories, analyzing data monthly and annually. This enabled the NRW reduction team to identify shifts in consumption patterns and evaluate the efficacy of implemented measures.

The system facilitated the monitoring of both individual subscriptions and aggregates of subscriptions linked to particular interventions. Consumption records were directly linked to billing data, thereby permitting continuous comparison between projected and actual consumption. To enhance data quality, the application integrated validation procedures designed to flag abnormal readings. These readings necessitated field verification prior to their integration into the billing system. Furthermore, the application supported georeferenced meter reading, systematic field documentation, and comprehensive audit procedures. These functionalities contributed to minimizing data-entry errors and improving the overall reliability of consumption records.

Figure 6 demonstrates how integration of the monitoring system with the municipal billing database enables automatic synchronization and analysis of consumption data collected in the field. This functionality allowed the NRW team to monitor intervention performance, identify deviations from expected consumption patterns, verify field observations, and assess the contribution of individual interventions to NRW reduction. Consequently, the monitoring system functioned as a pivotal management tool, enhancing data quality, reinforcing field verification procedures, and supporting evidence-based decision-making throughout the implementation process.



| ID    | ARABIC_NAME                     | CONSUMPTI | QTY | 31/01/17 | 28/01/17 |
|-------|---------------------------------|-----------|-----|----------|----------|
| 31886 | احمد محمد موسى الشريف           | 01        | 123 | 14       |          |
| 32354 | جاسر حسين حسن ابومصطفى          | 01        | 126 | 15       |          |
| 40154 | عائده ياسين ابراهيم قنبر        | 01        | 0   |          |          |
| 40501 | نبيل عديريه احمد اسماعيل (احمد) | 01        | 0   |          |          |
| 40502 | محمود احمد محمود ابوسمره        | 01        | 0   |          |          |
| 40503 | محمد نعيم زايد المصري           | 01        | 0   |          |          |
| 40504 | بشيرة يحيى مبروك الفراء         | 01        | 0   |          |          |
| 40505 | شادي طلال عياش مصلح             | 01        | 0   |          |          |
| 40506 | محمد ياسر دياب صناح             | 01        | 0   |          |          |
| 40507 | ابراهيم ابراهيم موسى عابدين     | 01        | 0   |          |          |
| 40508 | فادي طلال عياش مصلح             | 01        | 0   |          |          |
| 40509 | كمال الدين ابراهيم حامد القنبره | 01        | 0   |          |          |
| 40510 | حاتم مسلم عبدالكريم ابو عيد     | 01        | 0   |          |          |

Figure 6. Monitoring operational software mechanism to track consumption

#### 4.4.7 Intervention plan results

##### 4.4.7.1 Authorized metered unbilled

The results indicate that the impact of registering subscriptions for the remaining housing units has not yet been fully reflected in the recorded consumption data. Current billing records show that only the minimum monthly consumption is being registered for these subscriptions. In addition, historical accumulated consumption has not been captured because the newly established subscriptions had not yet been integrated into the GIS database. Consequently, these subscriptions were not available within the Android-based meter reading application used by field supervisors during routine data collection. Following the M&E process, instructions were issued to the technical teams responsible to complete the GIS registration and integration procedures for the newly established subscriptions.

It is expected that the full impact of this intervention will become more apparent once the integration process is completed and regular meter readings are consistently recorded. Based on the available data, the intervention contributed an average recorded consumption of approximately 400 m<sup>3</sup> per month, equivalent to an estimated annual consumption of 4,800 m<sup>3</sup>. This resulted in an increase of approximately 0.06% in network efficiency during the study period. Table 20 provides a comprehensive overview of the intervention outcomes for each housing project.

Table 20. Summary results of authorized metered unbilled consumption

| Type of consumption according to IWA | Main group targeted consumption | Sub-main group targeted consumption                           | Average consumed water volume (m <sup>3</sup> /month) | Total monthly retroactive quantities (m <sup>3</sup> /month) | Annual retroactive quantities volume (m <sup>3</sup> /year) | Total accumulated retroactive quantities (m <sup>3</sup> ) | Consumption percentage |
|--------------------------------------|---------------------------------|---------------------------------------------------------------|-------------------------------------------------------|--------------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------|------------------------|
| Authorized Metered Unbilled          | Housing projects                | Completion of the Japanese Housing Project (17 subscriptions) | 340                                                   | 400                                                          | 4,080                                                       | 4,800                                                      | 0.06%                  |
|                                      |                                 | Completion of the Dutch Housing Project (3 subscriptions)     | 60                                                    |                                                              | 720                                                         |                                                            |                        |

#### 4.4.7.2 Authorized unmetered unbilled

The intervention plan targeting municipal, governmental, and administrative facilities has yielded significant results, recording the largest contribution to the improvement in network efficiency. This is primarily due to the fact that the majority of these facilities previously lacked water meters and official water subscriptions, despite consuming large monthly volumes of water - often over extended periods - without any formal registration or billing of such consumption.

As a result of the intervention, a total of 530,627 m<sup>3</sup> was documented on an annual basis, with an equivalent amount registered as a one-time cumulative adjustment. This contributed to a 6.15% increase in network efficiency, which is categorized as an extraordinary increase. The predominant proportion of this consumption was ascribed to police facilities, with administrative facilities accounting for a significant but comparatively smaller share, as shown in Table 21.

#### 4.4.7.3 Apparent losses

In relation to apparent losses resulting from theft, meter inaccuracies and other issues, the Theft Committee continued its efforts to estimate consumption for detected illegal connections. In addition to the penalties stipulated in the 2013 water regulation, which is enforced by the Khan Younis Municipality, consumption during the period of unauthorized connection was estimated based on several established criteria. The estimated annual consumption from these cases was 5,830 m<sup>3</sup>. It was obligatory for offenders to establish a formal water subscription, in the absence of which they were required to do so. The estimated amounts were recorded on their bills, and the relevant financial settlements were arranged. In addition, the utilization of central water dispensing units persisted, accompanied by an observed escalation in water volumes. This increase is attributed to the acceptance of this solution by residents of informal settlements, who have come to depend on water delivery services managed by contracted providers.

Regarding the water meter repair workshop, it was previously assumed that implementing a flat consumption estimate of 30 m<sup>3</sup> per apartment, as stipulated by the water regulations, would be adequate until the replacement of the faulty meters. However, subsequent analysis of data from the years 2015, 2016, and 2017 demonstrated that this assumption was incorrect. The study indicated a surplus of over 12,000 m<sup>3</sup> in 2017 compared to 2016, suggesting a significant underestimation of actual consumption. As illustrated in Table 22, the implementation of this year's intervention strategy has yielded a total outcome of 74,069 m<sup>3</sup> of water registered, signifying a 0.86% enhancement in network efficiency, which can be attributed to a reduction in commercial losses.

Table 21. Summary results of authorized unmetered unbilled consumption

| Type of consumption according to IWA | Main group targeted consumption | Sub-main group targeted consumption  | Average consumed water volume (m <sup>3</sup> /month) | Total monthly consumption (m <sup>3</sup> /month) | Annual consumed water volume (m <sup>3</sup> /year) | Total annual consumption (m <sup>3</sup> /year) | Annual retroactive quantities volume (m <sup>3</sup> /years) | Total accumulated retroactive quantities (m <sup>3</sup> ) | Consumption percentage |
|--------------------------------------|---------------------------------|--------------------------------------|-------------------------------------------------------|---------------------------------------------------|-----------------------------------------------------|-------------------------------------------------|--------------------------------------------------------------|------------------------------------------------------------|------------------------|
| Authorized Unmetered Unbilled        | Municipal Facilities            | Parks and Public Gardens             | 7,833                                                 |                                                   | 70,818                                              |                                                 | 70,818                                                       |                                                            |                        |
|                                      |                                 | WWPS                                 | 220                                                   |                                                   | 18,504                                              |                                                 | 18,504                                                       |                                                            |                        |
|                                      |                                 | Community Facilities                 | 1,150                                                 |                                                   | 13,800                                              |                                                 | 59,600                                                       |                                                            |                        |
|                                      | Governmental Facilities         | Police Facilities                    | 2,900                                                 |                                                   | 34,800                                              |                                                 | 282,600                                                      |                                                            |                        |
|                                      |                                 | Hammad Housing Project 1,2           |                                                       | 20,362                                            |                                                     | 237,027                                         |                                                              | 530,627                                                    | 6.15%                  |
|                                      | Administrative facilities       | Tuhoku Housing Project               |                                                       |                                                   |                                                     |                                                 |                                                              |                                                            |                        |
|                                      |                                 | Khan Younis Families Cemeteries      | 8,259                                                 |                                                   | 99,105                                              |                                                 | 99,105                                                       |                                                            |                        |
|                                      |                                 | Khan Younis camp families cemeteries |                                                       |                                                   |                                                     |                                                 |                                                              |                                                            |                        |

Table 22. Summary result of apparent losses intervention plan

| Type of consumption according to IWA | Main group targeted consumption | Sub-main group targeted consumption | Average consumed water volume (m <sup>3</sup> /month) | Total monthly consumption (m <sup>3</sup> /month) | Total consumed water volume (m <sup>3</sup> /year) | Annual retroactive quantities volume (m <sup>3</sup> /year) | Total accumulated retroactive quantities (m <sup>3</sup> ) | Consumption percentage |
|--------------------------------------|---------------------------------|-------------------------------------|-------------------------------------------------------|---------------------------------------------------|----------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------|------------------------|
| Apparent Losses                      | Illegal Connections             | detected illegal connections        | 486                                                   | 6,173                                             | 5,830                                              | 5,830                                                       |                                                            |                        |
|                                      |                                 | central water dispensing units      | 4,696                                                 |                                                   | 56,348                                             | 56,348                                                      | 74,069                                                     | 0.86%                  |
|                                      | Inaccurate readings             | water meter repair workshop         | 991                                                   |                                                   | 11,891                                             | 11,891                                                      |                                                            |                        |

#### 4.4.7.4 Summary of the 2017 water loss reduction plan results

Following the presentation of the comprehensive plan and the subsequent discussion of each category of water loss, as delineated in the accompanying table, it can be concluded that the 2017 water loss reduction initiative yielded favorable outcomes. The subsequent summary outlines the key benefits and the main takeaways. The intervention plan successfully identified and quantified various forms of non-revenue water based on IWA classifications.

The total accumulated water volume associated with unbilled unauthorized consumption was 609,496 m<sup>3</sup>/year, representing 7.07% of overall consumption. The largest proportion – 6.15% – was attributed to authorized unmetered unbilled municipal and governmental facilities. Apparent losses, including illegal connections and unregistered uses, accounted for 0.86%, while unauthorized metered but unbilled housing projects contributed 0.06%. These findings underscore the necessity for enhanced metering, billing systems, and enforcement mechanisms to address institutional inefficiencies and unauthorized consumption. Table 23 demonstrates the final result of annual intervention plan in 2017.

## 5. DISCUSSION

The findings indicate that considerable reduction in NRW can be achieved through the proper management of administrative and commercial losses even where there may be a lack of adequate finances or infrastructure. This is particularly significant for utilities operating in conflict-affected or resource-limited environments, where large-scale rehabilitation programs are often technically or

financially infeasible. While conventional NRW programs prioritize physical loss reduction through the leakage control and network rehabilitation (Alegre et al., 2016; Farley et al., 2008), this case illustrates that strengthening customer registration, billing systems, and consumption monitoring can generate measurable improvements in water utility performance without major capital investment.

*Table 23. Final results of the whole intervention plan*

| Type of consumption according to IWA | Main group targeted consumption                                                           | Average consumed water volume (m <sup>3</sup> /month) | Total monthly consumption (m <sup>3</sup> /month) | Total consumed water volume (m <sup>3</sup> /year) | Total Annual consumption (m <sup>3</sup> /year) | Annual retroactive quantities volume(m <sup>3</sup> /years) | Total accumulated retroactive quantities (m <sup>3</sup> ) | Consumption percentage | Percentage accumulated |
|--------------------------------------|-------------------------------------------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------|----------------------------------------------------|-------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------|------------------------|------------------------|
| Authorized Unmetered Unbilled        | Municipal and Governmental facilities                                                     | 20,362                                                |                                                   | 237,027                                            |                                                 | 530,627                                                     |                                                            | 6.15%                  |                        |
| Apparent Losses                      | detected illegal connections, central water dispensing units, water meter repair workshop | 6,173                                                 | 26,935                                            | 74,069                                             | 315,896                                         | 74,069                                                      | 609,496                                                    | 0.86%                  | 7.07%                  |
| Unauthorized metered Unbilled        | Housing Projects                                                                          | 400                                                   |                                                   | 4,800                                              |                                                 | 4,800                                                       |                                                            | 0.06%                  |                        |

An important finding suggests that apparent losses associated with institutional and public facilities may represent a largely overlooked source of NRW in many developing countries. Consequently, utilities should view commercial-loss management not merely as a financial exercise, but as a strategic component of water resource management, particularly where public facilities account for a remarkable proportion of unbilled consumption (Kingdom et al., 2006; Wyatt, 2010). Unlike conventional DMAs which require hydraulic separation and considerable infrastructure investment (Fantozzi et al., 2014; Farley et al., 2008), the administrative subscriptions approach provides a management-based alternative for complex housing developments where technical implementation of DMAs is impractical. The experience from Khan Younis suggests that administrative monitoring can complement rather than replace engineering solutions, extending NRW management to setting where physical sectorization cannot realistically be implemented.

Beyond improving billing accuracy, systematic meter management increases confidence in water demand estimates and utility performance indicators. This strengthens long term planning and supports evidence-based decision-making regarding future infrastructure investment (Arregui et al., 2007). These findings reinforce the growing recognition that improving customer databases and billing systems may generate rapid NRW improvement with relatively low implementation costs. Compared with infrastructure rehabilitation projects, which often require considerable financial resources and long implementation periods, administrative interventions can deliver immediate operational benefits while simultaneously improving institutional accountability (Arregui et al., 2018; Kingdom et al., 2006; Mutikanga et al., 2011).

The broader implications of this study are that NRW reduction strategies should be adapted to local operational conditions rather than depending on exclusively standardized engineering approaches. In many developing regions, institutional weaknesses, incomplete customer database, and unregistered consumption may contribute as much as physical leakage. Accordingly, utilities may achieve greater short-term benefits by first strengthening administrative management before undertaking large-scale infrastructure rehabilitation. This integrated perspective aligns with recent recommendations advocating balanced investment in both physical and commercial loss reduction (Alegre et al., 2016; Arregui et al., 2007).

This also demonstrates that sustainable NRW reduction should be viewed as a continuous management process rather than a one-time engineering intervention. Reliable monitoring systems provide the feedback necessary to evaluate administrative measures, update customer records, and

identify emerging commercial losses before they become persistent sources of NRW (Alegre et al., 2016; Lambert, 2002). Nevertheless, these limitations do not diminish the practical value of the intervention. Rather, they reflect the operational realities commonly encountered by utilities working in environments with incomplete metering infrastructure and limited historical records.

Overall, this case study demonstrates that commercial-loss management should be regarded as a core pillar of NRW reduction rather than a secondary administrative activity. While infrastructure rehabilitation remains essential for reducing physical losses, the experience of Khan Younis indicates that significant improvements can be achieved through customer registration, administrative subscriptions, billing-system integration, meter management, and on-going monitoring. These interventions require substantially lower financial investment than network rehabilitation while producing measurable improvements in water accountability and utility performance. Consequently, for utilities operating under financial constraints, post-conflict conditions, or aging infrastructure, commercial-loss management offers a practical and scalable pathway for improving NRW performance and strengthening institutional capacity alongside future infrastructure investments.

### ***5.1 Study limitations***

Several limitations should be considered when interpreting the findings of this study. First, although a considerable proportion of the analysis was measured data based on consumption data, billing records, and field observations, some intervention categories required the estimation of water consumption due to the absence of water meters or historical consumption records. This was particularly relevant to governmental and municipal facilities, unauthorized connections, public green spaces, and previously unregistered consumers. Consequently, the reported consumption values for these categories should be interpreted as reasonable engineering estimates rather than exact measurements.

Second, the estimation of historical consumption associated with unauthorized connections and unbilled consumption was based on administrative procedures, field assessments, and municipal regulations. While these procedures were designed to ensure consistency and fairness, the actual historical consumption may differ from the estimated values due to uncertainties regarding occupancy level, water use duration, and user consumption behavior.

Third, the study was conducted as a municipal case study within Khan Younis Municipality. Although, many of the identified challenges are common among water utilities in developing countries, the specific institutional, operational, and regulatory conditions may limit the direct transferability of some findings to other contexts without appropriate adaptation.

Fourth, the evaluation period differed among intervention categories, while several interventions were monitored using actual consumption records after implementation, some categories were assessed over relatively short monitoring period. Longer-term monitoring would provide additional evidence regarding the sustainability of the observed reductions in NRW.

Finally, the study mainly focused on the quantification and management of commercial losses and authorized unbilled consumption. A detailed economic assessment of intervention costs. Cost-effectiveness. And long-term financial benefits were beyond the scope of this article and represent an important area for future investigations.

Despite these limitations, the integration of water balance analysis, billing-system records, field verifications, and ongoing monitoring provides a solid foundation for evaluating the effectiveness of the implemented interventions and supports the overall conclusions of the study.

## **6. CONCLUSIONS AND RECOMMENDATIONS**

The aim of this study was to assess the effectiveness of a targeted intervention program to reduce non-revenue water (NRW) in Khan Younis Municipality with special focus on commercial losses.

The findings demonstrate that improvements in water utility performance can be achieved through administrative, managerial and monitoring interventions without depending exclusively on costly infrastructure rehabilitation. The intervention program significantly improved consumption accountability, strengthened the integration of the billing system and increased the municipality's ability to monitor and manage water use by identifying and quantifying previously unrecorded or inadequately monitored water consumption including municipal and governmental facilities, housing projects, unauthorized connections, public green areas, administrative subscriptions, and metering inaccuracies.

The study further demonstrates that an integrated framework comprising water balance analysis, specific field investigations, billing system improvements and continuous monitoring is a viable and effective approach for managing commercial losses. Unlike traditional NRW reduction strategies, which are generally directed towards physical leakage control and network rehabilitation, the intervention measures implemented in this study were mainly aimed at improving administrative processes and institutional management. The results indicate that these low-cost interventions can recover significant amounts of previously unrecorded consumption, improve operational efficiency, and lead to better decision making. Commercial loss management should be regarded as a basic component of NRW reduction strategies and not as an administrative side-activity.

Based on these findings, water utilities should adopt a balanced NRW management strategy that concurrently addresses commercial and physical losses. Regular water balance assessments, improving customer registration and billing systems, increasing water metering for public and municipal facilities, creating integrated monitoring systems connected to billing databases, and putting in place methodical meter testing, maintenance, and replacement programs should all be given top priority. Administrative subscriptions could be a useful substitute for traditional District Metered Areas (DMAs) in housing developments and comparable facilities when DMAs are either technically challenging or financially unfeasible. Future research should evaluate the long-term performance assessment of administrative interventions under different operational conditions, compare their efficacy with infrastructure-based NRW reduction programs, and further improve techniques for estimating unmetered consumption.

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