Non-Revenue Water Reduction: Lessons from Rwanda

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Contents

Executive summary

Non-Revenue Water (NRW) is the difference between the volume of water put into a water distribution system and the volume of water that is billed to customers. It encompasses:

- **Physical losses** – leaks in pipes, joints, and reservoirs.
- **Commercial losses** – unbilled consumption due to theft, meter inaccuracies, or poor data management.
- **Unbilled authorized consumption** – such as free water for vulnerable populations.

NRW is a critical challenge for Rwanda's rural water supply systems (WSS). Before the Isoko y'Ubuzima[1] project, a U.S. government-funded intervention from 2021 to 2026, only 19% of the pilot systems had functioning bulk meters, and most private operators lacked the knowledge and tools to manage NRW.

To address this, the Isoko y'Ubuzima project implemented a package of targeted interventions, including the establishment of district metered areas (DMAs) in 10 pilot districts, Geographic Information System (GIS)-based mapping of water connections, and the development of five-year NRW reduction strategic plans for each private operator.

Private operators and district staff received intensive training, complemented by public engagement activities of awareness campaigns and Umuganda[2] sessions. Technical interventions included leak repairs and replacement of customer meters. Results varied across districts. In Rwamagana District (Fumbwe – Gahengeri), NRW levels dropped significantly from 65% to 15%, while in Ruhango (Nyamyishywa-Mbuye-Buhanda) and Nyabihu (Cyamabuye-Kagohe), NRW levels dropped slightly. Nonetheless, vandalism cases decreased, billing efficiency improved, and the use of GIS and Excel tools enhanced data collection and reporting.

The pilot demonstrated that combining technical solutions, institutional capacity building, and community involvement can yield substantial reductions in NRW with a rapid return on investment. To sustain and scale progress, Rwanda will need continued investment in local capacity, cross-sector collaboration, and digital data management.

[1] *Isoko y'Ubuzima* (Kinyarwanda for "Source of Life")
[2] Umuganda means "coming together in common purpose" in Kinyarwanda. It is a mandatory community service that takes place on the last Saturday of every month, where citizens engage in collective activities like cleaning and restoration projects to improve their neighbourhoods. It promotes social cohesion and civic responsibility.

Background / Context

The Isoko y'Ubuzima ("Source of Life" in English) project (2021-2026), funded by the U.S. Government, has implemented WASH activities aiming to improve sustainable water, sanitation, and hygiene in 10 rural districts in Rwanda, namely Rwamagana, Kayonza, Ngoma, Kirehe, Nyagatare, Ruhango, Nyanza, Nyamagabe, Nyabihu, and Ngororero. One of the objectives was to build the capacity of private operators to identify, reduce, and manage water losses, ensuring the financial viability of private operators and improving water services to their customers.

The selected districts relied on decentralized water supply systems, often gravity-fed or small piped systems managed by private water operators under public-private partnerships. Weak infrastructure, limited technical expertise, and poor data management have already compounded high levels of water losses.

Besides private operators responsible for daily management, other stakeholders included District governments overseeing coordination, Water and Sanitation Corporation (WASAC) providing technical support, and communities engaged through Umuganda and awareness campaigns. Central to the technical method was the creation of DMAs, which allowed for the monitoring of inflows and outflows zone by zone. This was supplemented by GIS-based mapping of customer connections, which enhanced billing accuracy and water balance calculations.

Problem Statement

Before the Isoko y'Ubuzima intervention, NRW levels in Rwanda's rural water supply systems were unknown. The project's baseline assessment revealed that the rates were alarmingly high, with some districts recording losses exceeding 90%.

Several interconnected issues drove these extreme levels of water loss. Most water systems operated without adequate monitoring, primarily due to the absence of bulk water meters at the sources and key points in the distribution network. Even where meters existed, they were often non-functional or neglected, with no routine index readings being taken. Additionally, data handling practices among private operators were inadequate, resulting in discrepancies between the water produced and the water billed. Unauthorized water connections and consumption further exacerbated the problem, and most private operators lacked the necessary technical capacity and awareness to address these challenges effectively.

Key drivers included:

- Absence of bulk meters at sources and distribution points.
- Neglected or non-functional meters with no routine readings.
- Poor data management and weak billing practices.
- Unauthorized connections and theft.
- Limited operator capacity.

The high levels of NRW have serious implications. Water service providers struggle to generate sufficient revenue to sustain operations, repair their infrastructure, or expand services. Technically, the system inefficiencies translate into poor service quality, including unreliable supply and low pressure, which erode user confidence and limit willingness to pay. Environmentally, the loss of treated water represented a significant waste of scarce water resources. More broadly, persistent NRW hinders Rwanda's progress toward Sustainable Development Goal (SDG) 6, which calls for universal and equitable access to safe and affordable drinking water. Without addressing NRW, efforts to improve rural water service delivery risk being undermined by systemic inefficiencies and operational gaps.

Key baseline indicators highlighted the severity of the situation. Of the 297 WSS assessed by the Isoko y'Ubuzima project, only 57 had functioning bulk meters. In several districts, NRW levels routinely exceeded 70%, with some as high as 98%. Additionally, private operators lacked structured monitoring systems or tools to track water losses, making it nearly impossible to implement effective corrective actions. These baseline conditions provided a compelling rationale for the comprehensive NRW reduction initiative undertaken by the Isoko y'Ubuzima project.

Objectives of the NRW Reduction Strategy

Main Objective

To demonstrate that a combined package of technical, institutional, and community-based interventions could significantly reduce NRW in selected rural districts, improve WSS efficiency and financial viability, and provide evidence for national scale-up.

Specific Objectives

- **Improve Data Collection and Monitoring Capabilities:** Establish and operationalize DMAs in pilot water systems and apply GIS-based mapping tools to enhance the accuracy of water flow measurement, customer registration, and water balance analysis.
- **Strengthen Institutional and Technical Capacity:** Provide targeted training and technical assistance to private operators and district water staff to build their competencies in NRW monitoring, leak detection, data handling, billing efficiency, and network management.
- **Promote Community Participation and Behavior Change:** Implement community awareness and engagement campaigns to encourage public involvement in reporting leakages, discouraging unauthorized connections, and reducing vandalism through local platforms like Umuganda and community dialogues.
- **Standardize and Institutionalize NRW Management Practices:** Support the development and adoption of five-year NRW reduction strategic plans for all participating private operators to ensure systematic, long-term planning and accountability in water loss management.

- **Support National Policy and Development Goals:** Align local interventions with Rwanda's national water sector policies and development priorities, reinforcing the country's commitment to universal access to clean and affordable water services outlined in SDG 6.

Approach

The NRW reduction initiative used a targeted approach combining network segmentation, data improvements, and operator capacity strengthening. Ten pilot WSS were selected based on high losses, lack of monitoring infrastructure, and readiness of local partners. Each system was subdivided into DMAs to enable flow tracking and isolate loss points.

Teams then mapped all networks and customer connections in GIS, allowing visualization of the system, identification of unregistered users, and calculation of water balances for each DMA. These balances quantified losses and directed follow-up actions.

Capacity-building sessions for private operators, district staff, and WASAC covered NRW concepts, DMA management, leak detection, meter reading, data recording, and analysis using Excel and GIS. Community education through Umuganda and public dialogues reinforced reporting of leaks, discouraged vandalism, and encouraged responsible consumption.

Data Sources

- Quantitative inputs included bulk and customer meter readings, billing records, and GIS outputs on network infrastructure and customer locations, forming the basis for NRW and billing-efficiency calculations.

- Qualitative insights came from interviews, site observations, and community feedback. Input from operators, district officers, and water users helped interpret anomalies in the data, identify operational barriers, and refine the intervention.

Timeline

- February 2022: Baseline assessment to document existing NRW, metering gaps, and system conditions.

- November 2022–June 2023: DMA installation, GIS mapping, training, and community engagement. Activities were adapted to each district's operational context.

- August 2023–March 2026: Post-intervention analysis of NRW trends, billing efficiency, and system performance, culminating in consolidated reporting for scale-up planning.

Steps Taken

- **Baseline Assessment:** Established initial NRW levels, identified operational weaknesses, and guided the design of district-specific interventions.
- **Metering Infrastructure:** Installation of bulk meters at critical points enabled accurate comparison of production and billed consumption, forming the basis for loss analysis.
- **DMA Creation:** Networks were segmented into DMAs supported by RWF 69,414,626 ($47,827). Each DMA had its own monitoring system to localize leaks and track improvements.
- **GIS Mapping:** Geo-referencing of all connections strengthened billing accuracy, exposed illegal or unregistered users, and supported DMA water balance calculations.
- **Capacity Building:** Operators and district/WASAC staff received hands-on training in NRW management, data analysis, and routine operational monitoring.
- **Community Engagement:** Awareness campaigns encouraged reporting of leaks and illegal connections and promoted collective responsibility for system protection.
- **Leak Detection and Meter Replacement:** Routine surveys and targeted replacement of faulty or oversized meters, especially for large consumers, reduced both physical and commercial losses.

Stakeholder Roles

- **Isoko y'Ubuzima** coordinated design, planning, technical support, capacity building, and major procurements.
- **Private Operators** implemented day-to-day tasks: meter installation, leak detection, repairs, database updates, meter replacement, and routine monitoring.
- **District Governments** provided oversight, community mobilization, and integration of activities into district plans, reinforcing operator accountability.
- **WASAC** offered specialized technical input on DMA design, hydraulic analysis, and alignment with national standards.

Together, these partners created a coordinated system capable of reducing losses and improving rural service reliability.

Tools and Resources

GIS and Excel were cornerstone tools for data analysis and monitoring. GIS software enabled the mapping of water supply networks and the precise location of customer connections. This spatial visualization allowed operators to track service coverage, identify unauthorized connections, and isolate areas with high leakage rates. Meanwhile, Excel spreadsheets were used for managing large volumes of operational data, including meter readings and billing records. Excel was also instrumental in generating water balance calculations and building dashboards to visualize trends in NRW performance across different DMAs.

Bulk and customer meters were essential for the quantitative measurement of water input and consumption. Bulk meters were installed at key inflow points to monitor the total volume of water entering each system, while customer meters captured consumption at the household or institutional level. This two-tier metering approach enabled operators to identify discrepancies between water supplied and billed, revealing areas of both physical and commercial losses. Reliable metering was also foundational to the water balance calculations that informed all further interventions.

Custom reporting templates were developed to standardize how private operators and district teams documented and reported their activities. These templates helped track leakage incidents, meter installations, billing anomalies, and maintenance interventions. By introducing consistent formats, the project improved data quality and facilitated more accurate comparisons and aggregated analysis across districts. The templates also served as training tools, reinforcing best practices in record-keeping and internal accountability.

Leak detection and repair kits were provided to help private operators respond quickly and effectively to reported or observed leaks in the distribution network. These kits typically included basic plumbing tools, spare parts, and safety gear necessary for on-site repairs. In addition to reducing physical water losses, these tools enabled operators to demonstrate responsiveness to customer concerns, thereby improving service reliability and public trust.

Results

Coordinated interventions under the Isoko y'Ubuzima project led to notable NRW reductions in pilot districts, demonstrating the effectiveness of DMAs, improved metering, leak repairs, and data monitoring, setting a strong foundation for nationwide scale-up. However, some areas require efforts to mark progress in the reduction of NRW.

Table 1. Non-revenue water reduction between 2023 and 2025. Nyamyishywa-Mbuye-Buhanda, Ruhashya-Ntyazo, and Mutengeri -Nyarwungo-Musaraba supply systems did not collect metering or billing data throughout quarters; those cells were left blank in this table.

Name of WSS	Baseline NRW % FY2022-2023	Q4 FY 2023-2024	Q1 FY2024-2025	Q2 FY2024-2025	Q3 FY2024-2025	Q4 FY2024-2025
Fumbwe-Gahengeri	65%	34%	21%	18%	17%	15%
Kahene	51%	5%	22%		32%	32%
Nyamyishywa-Mbuye-Buhanda	98%		75%		74%	78%
Ruhashya-Ntyazo	90%		88%	82%	70%	42%
Ngabwe-Ryarubondo	35%	57%	35%	49%	23%	32%
Mutengeri -Nyarwungo -Musaraba	90%		46%		48%	43%
Cyamabuye-Kagohe	59%	25%	41%	61%	55%	49%

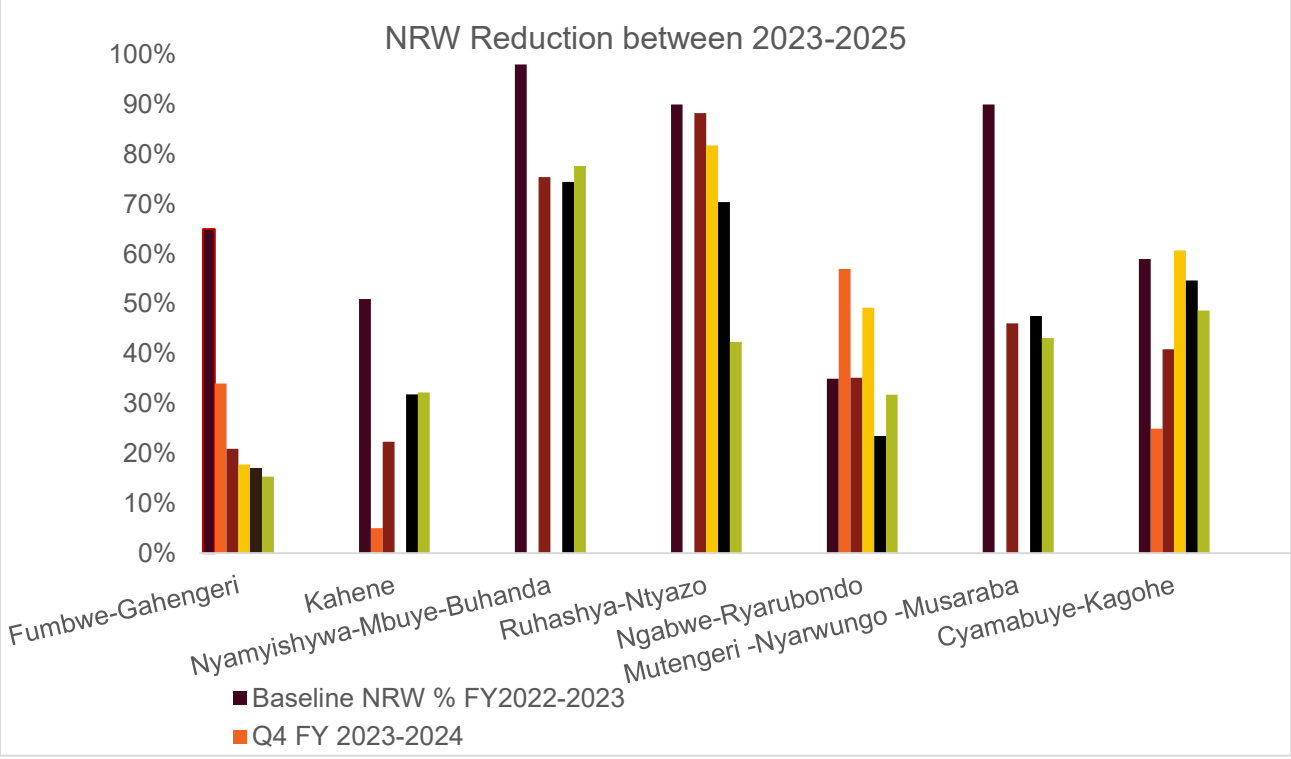

Figure 1: NRW Reduction over Quarters 2023-2025

The data from the table and chart show that NRW levels in supply systems and water schemes vary widely, with a general trend of improvement over time. Baseline NRW was highest in Nyamagabe's Nyamyishywa-Mbuye-Buhanda scheme at 98%, while some areas like Ngabwe-Ryarubondo had lower levels at 35%. During FY24-25, NRW percentages decreased in many schemes, indicating progress in reducing water losses. Overall, NRW decreased from an average of 69% at baseline to approximately 38% as of November 30, 2025, with variations among WSS, reflecting ongoing efforts to improve water management and cut losses across the districts.

Other Outcomes

Reduction in vandalism cases: Through community awareness campaigns, especially those conducted during Umuganda and local dialogues, residents were educated on the negative impacts of vandalism on water service delivery. As a result, the community became more proactive in safeguarding water infrastructure, reporting suspicious activities, and discouraging unauthorized tampering with meters and pipelines. This shift in community behavior helped minimize infrastructure damage and service interruptions.

Replacement of faulty water meters: In several districts, private operators managed to replace over non-functional meters each month. These replacements improved the accuracy of consumption data, reduced billing errors, and helped recover previously unbilled water. Prioritizing the replacement of meters for large users had an outsized impact on revenue recovery and fairness in billing.

Leakage reporting system: This enabled private operators to document and respond to detect leaks systematically. This tool standardized the recording and tracking of leak incidents, making it easier to identify recurring problem areas and prioritize repairs. Although still in its early stages, the system laid the groundwork for more responsive and data-driven maintenance practices.

Improved billing accuracy: This was achieved through the registration of previously unbilled customers. During GIS mapping and customer surveys, many users who had been consuming water but were not captured in billing systems were identified and formally added to the customer database. This not only increased billing efficiency but also contributed to equitable service delivery and enhanced financial sustainability for private operators.

These additional outcomes underscore the broader impact of the NRW reduction initiative, demonstrating how technical and community-level interventions can bring about systemic improvements in rural water management.

Challenges

Several challenges emerged during implementation, highlighting key operational, technical, and institutional barriers that need to be addressed for long-term success and scalability. These challenges include:

Lack of consistent bulk meter readings: While bulk meters were installed to measure the volume of water entering DMAs, many operators failed to take regular and accurate readings. In some cases, readings were taken at inconsistent intervals or not recorded at all, undermining the accuracy of water balance calculations and the ability to detect and respond to losses promptly.

Incomplete billing due to unregistered customers: During customer mapping, it was discovered that many water users were not formally registered in the billing systems of private operators. These users were either billed manually or not at all, resulting in significant commercial losses and inaccurate billing data. This also made it difficult to track actual consumption and hindered efforts to reduce apparent NRW.

Removal of bulk meters: Some operators claimed that the meters caused a drop in water pressure within the distribution network. This resistance reflected both a misunderstanding of the metering's purpose and value, as well as a lack of technical capacity to manage pressure-related issues. The removal of meters reversed some of the progress made in monitoring and severely limited the ability to calculate NRW accurately.

Lack of GIS and hydraulic modeling skills: Although GIS tools and EPANET modeling were introduced as part of the technical approach, most operators lacked the necessary expertise to utilize these systems effectively. This limited their ability to perform advanced pressure management, simulate network behavior, and fully utilize the analytical capabilities of the tools provided.

Weak record-keeping systems: This posed a challenge to consistent monitoring and reporting. Many operators did not maintain structured records of leak repairs, billing anomalies, or maintenance activities. Additionally, there was a lack of standardized templates or digital systems for recording operational data, resulting in fragmented and unreliable documentation. This lack of organized data made it difficult to assess performance over time or make informed decisions.

Addressing these challenges will require ongoing training by WASAC, improved oversight, and stronger systems for accountability and data management to ensure that the gains made can be sustained and expanded.

Mitigation Strategies

To address the operational and technical challenges encountered during the implementation of the NRW reduction initiative, a series of mitigation strategies was planned and initiated. These strategies aimed at strengthening the capacity of water service providers, enhancing data accuracy, and ensuring more effective and sustainable water management practices, such as:

Training on GIS and EPANET: Recognizing the skills gap in hydraulic modeling and spatial data analysis, the project built the technical capacity of private operators and district engineers to use these tools effectively. GIS training enabled operators to manage and analyze water distribution networks spatially, while EPANET facilitated detailed simulation of hydraulic behavior, supporting better pressure management and system optimization.

Development of NRW monitoring dashboards: These dashboards, built using Excel and integrated with data from GIS and billing systems, provide operators with visual and interactive tools to track performance indicators such as water loss rates, metering efficiency, and leak reports. By simplifying complex data into clear charts and trends, the dashboards facilitate better decision-making, improve reporting, and encourage regular performance reviews.

Customer registration and system updates: Continued efforts to register all active water consumers and digitize their information not only increase revenue recovery but also enable more accurate monitoring of consumption patterns and detection of irregularities. These updates were essential for maintaining an up-to-date customer database and enhancing transparency in billing processes.

House-to-house billing surveys. These surveys serve multiple purposes: validating the accuracy of registered customer data, identifying unauthorized or illegal connections, and detecting faulty or outdated meters. By engaging directly with customers at the household level, the surveys provide valuable insights into water usage behaviors and uncover billing anomalies that might otherwise go unnoticed.

Lesson learned

The NRW reduction initiative revealed that combining technical strategies with strong stakeholder coordination and community involvement is key to success. Effective tools, such as DMA monitoring and public engagement, significantly reduced water losses, while gaps, including manual billing and poor data systems, highlighted areas needing improvement. Community participation, especially through local leadership, proved vital in promoting ownership and reducing unauthorized use. These lessons provide a clear direction for strengthening and scaling similar interventions in the future.

What Worked

Adoption of DMAs for monitoring water loss: By dividing large water supply networks into smaller, manageable zones, DMA-based monitoring allowed for precise tracking of water inflow versus outflow. This enabled operators to pinpoint specific areas with high levels of NRW and focus on their interventions accordingly—whether through leak detection, customer meter replacement, or unauthorized connection checks. The ability to generate water balances within each DMA provided actionable data, which improved decision-making and accountability at both the operational and managerial levels.

Community engagement: Raising awareness among water users through campaigns, Umuganda sessions, and community dialogues helped build a sense of shared responsibility for the water infrastructure. This led to a substantial decrease in vandalism cases, as community members began to view the systems as their own and took active roles in protecting them. Involving the public not only reduced infrastructure damage but also improved trust between water service providers and users, an important factor in fostering compliance and cooperation.

Strategic planning and stakeholder coordination: The project clearly defined roles and responsibilities among the leading actors, Isoko y'Ubuzima, private operators, district governments, and WASAC, which ensured smooth implementation and effective communication. Regular planning meetings, joint monitoring efforts, and collaborative problem-solving created a cohesive working environment where challenges could be addressed quickly and collectively. This level of coordination helped align technical solutions with local needs and strengthened institutional ownership of the NRW reduction goals.

What Didn’t Work

Reliance on manual billing systems: Manual billing led to frequent inconsistencies in customer data, incomplete billing lists, and a lack of transparency in revenue tracking. In several instances, water users were billed on paper forms that were not integrated into central systems, resulting in untracked consumption and reduced billing efficiency. The manual process also made it challenging to identify discrepancies or analyze trends over time. As a result, the lack of automated digital billing systems undermined the project's ability to measure commercial water losses and recover revenue effectively and accurately.

Absence of standardized Operation and Maintenance (O&M) manuals: Without clear and up-to-date O&M documentation, many operators struggled to make informed operational decisions regarding routine maintenance, emergency repairs, and system optimization. This hindered the effective management of DMAs and delayed responses to issues such as leaks or pressure imbalances. Additionally, the lack of detailed engineering drawings and technical guidelines limited the field teams' ability to quickly and efficiently isolate problem zones, resulting in increased downtime and reduced service reliability.

Inadequate data systems: This limited the ability to report and respond to issues promptly. Many private operators lacked structured processes or digital platforms for recording operational data such as meter readings, leak repairs, customer complaints, or water use for maintenance activities. This fragmented and inconsistent data environment made it difficult to monitor performance, detect patterns, or conduct accurate water balance analyses. The absence of centralized data systems also reduced the ability of district authorities and project managers to oversee progress and make evidence-based decisions.

These shortcomings illustrate the need for continued investment in digital tools, standardized procedures, and data management systems to ensure that future NRW reduction efforts are both efficient and sustainable. Addressing these gaps will be critical for scaling successful interventions and achieving lasting impact.

Community Insights

Engaging communities proved to be a vital component of the NRW reduction initiative, yielding valuable insights into the roles of local leadership and public participation. These lessons emphasized that technical interventions alone are insufficient; community involvement must be integrated into every stage of rural water management for a sustainable impact.

Local leaders played a central role in community mobilization, acting as bridges between the project implementers and the population. Their presence in awareness campaigns, Umuganda sessions, and community dialogues helped increase attendance, reinforce key messages, and build trust. As respected figures in their communities, local leaders played a crucial role in encouraging households to report leaks, refrain from tampering with infrastructure, and support efforts to reduce water losses. Their involvement also lent legitimacy to the project’s objectives and helped mediate concerns or resistance that emerged during implementation.

Additionally, public awareness efforts significantly contributed to a sense of ownership and responsibility among water users, which in turn helped reduce unauthorized water use and vandalism. As communities learned about the consequences of NRW, such as higher tariffs, poor service quality, and delayed maintenance, they became more engaged in protecting the water infrastructure. Residents began reporting leaks more frequently, discouraging illegal connections, and even assisting operators with locating faults. This behavioral shift not only improved system performance but also fostered a culture of shared accountability that will be essential for maintaining the gains achieved.

These community insights reinforce the idea that sustainable water management is not solely a technical challenge but also a social one. Building trust, promoting education, and leveraging community leadership can lead to lasting changes in how people interact with and value their water systems.

Conclusion

The *Isoko y'Ubuzima* NRW reduction initiative demonstrated that well-integrated technical, institutional, and community approaches can transform rural WSS performance. DMAs, GIS mapping, metering, and systematic data monitoring backed by training and public engagement produced measurable reductions in NRW and strengthened financial sustainability.

However, sustaining progress requires addressing systemic gaps in digital billing, record-keeping, and technical capacity. The lessons from this pilot, particularly the importance of community ownership and cross-sector collaboration, offer a roadmap for scaling NRW reduction across Rwanda and advancing toward universal access to safe, reliable, and affordable water.

Disclaimer

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