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ADVANCING SUSTAINABLE WATER MANAGEMENT THROUGH SMART METERING, AC PIPELINE REPLACEMENT, AND INFRASTRUCTURE CATALYSTS IN UMDM

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ABSTRACT

uMgungundlovu District Municipality (UMDM), like many water services authorities across South Africa, faces a dual crisis: high non-revenue water (NRW) levels and aging, hazardous asbestos cement (AC) infrastructure. These challenges not only threaten water security and service delivery but also strain municipal finances and erode public trust. In alignment with the IMESA 2025 theme of Sustainable Engineering Solutions, UMDM has embarked on a multi-faceted, technology-driven initiative that integrates smart metering, targeted AC pipeline replacement, and catalytic wastewater infrastructure development to address these urgent issues. This project centres on three strategic pillars: (1) the phased replacement of AC pipelines across six local municipalities within UMDM to reduce physical water losses and mitigate health risks; (2) the deployment of ultrasonic smart meters, both domestic and bulk, to digitize water management, enable real-time monitoring, and enhance billing accuracy; and (3) the design and implementation of a new 2ML Wastewater Treatment Works (WWTW) in Mkhambathini Local Municipality (Camperdown), which will serve as a growth enabler and revenue catalyst for the region.

At the forefront of this initiative is a pilot project currently underway in Howick, focused on smart meter deployment and AC pipeline replacement. This pilot is testing key technologies and implementation methodologies to inform a district-wide roll-out strategy. It provides valuable insights into field deployment logistics, meter accuracy, remote data acquisition, and integration with existing utility systems. Smart meters are not merely a metering upgrade; they are the cornerstone of a digital utility transformation. By enabling remote readings, early leak detection, and usage profiling, these devices address both apparent and real losses in NRW. AC pipeline replacements complement this by tackling systemic physical losses caused by deteriorating infrastructure. Together, these interventions are supported by robust meter data management systems (MDMS), customer portals, and analytics engines that turn raw data into actionable intelligence. The inclusion of the WWTW in Camperdown, a strategic growth node, ensures long-term sustainability through wastewater recycling potential and tariff recovery for sanitation services. The combined initiative fosters operational efficiency, financial resilience, and environmental responsibility.

This integrated approach serves as a blueprint for other municipalities seeking to transition from reactive service provision to data-driven water governance. It demonstrates that engineering solutions, when strategically aligned, can enable a municipality not only to reduce NRW but to transform it into a driver of sustainability, service excellence, and revenue growth.

FIGURE 1: *UMDM Footprint*

INTRODUCTION

The uMgungundlovu District Municipality (UMDM), located in KwaZulu-Natal, South Africa, is currently experiencing significant water management challenges that include ageing infrastructure, high non-revenue water (NRW) rates, and inadequate wastewater treatment facilities. The cumulative effect of these challenges severely compromises water service delivery, public health, economic growth, and environmental sustainability. In response, UMDM have embarked on the ONE PLAN Losses-2-Revenue programme initiative to sustainably enhance water service delivery and management through advanced technological applications, strategic infrastructure upgrades, and strengthened institutional capacity.

UMDM's water distribution infrastructure primarily consists of aged asbestos cement (AC) pipelines installed several decades ago. These pipes are now beyond their expected service life and are prone to frequent failures and bursts, leading to extensive water loss, disrupted supply, and heightened operational costs.

Beyond the mechanical failures of ageing AC pipes, asbestos fibres in potable water can pose serious health risks, particularly with long-term ingestion. In South Africa, this issue is especially relevant due to the historic use of asbestos-cement pipes in water distribution systems. The risks associated with ingestion (via drinking water), relative to inhalation, are less well established but remain a concern; studies by the U.S. EPA (United States Environmental Protection Agency) and the WHO (World Health Organization) note a possible association between ingested asbestos and cancers of the oesophagus, stomach, and intestines. With prolonged exposure at high fibre concentrations, the risk may increase.

Taken together, the mechanical unreliability of old AC mains and the associated risk considerations make a strong case for an accelerated replacement and risk-mitigation programme, supported by active leakage control, pressure management, and metering accuracy improvements. These interventions directly curb avoidable losses and create the conditions for sustained reductions in system inefficiencies.

In parallel, high NRW levels exacerbate the economic pressures on the municipality, with significant volumes of water lost through leaks, inaccurate metering, theft, and illegal connections. Currently, NRW stands at approximately 67%, resulting in substantial revenue losses, hindering UMDM's ability to sustainably manage water resources and infrastructure effectively.

Additionally, inadequate wastewater treatment infrastructure restricts new developments, particularly along strategic economic corridor SIP2, further limiting regional economic growth and urban expansion within the Mkhambathini Local Municipality, Camperdown area.

INFRASTRUCTURE AND TECHNOLOGY INTEGRATION

To address these challenges, the ONE PLAN Losses-2-Revenue programme consists of three primary components, that together address the losses and promote economic growth:

AC Pipeline Replacement

The AC Pipeline Replacement initiative stands as a critical and one of the primary components of UMDM's comprehensive infrastructure strategy, designed to proactively address ageing water distribution infrastructure. The program involves a carefully structured phased approach to upgrading and replacing approximately 1,230km of deteriorating asbestos cement (AC) pipelines spread across various Local Municipalities (LMs) within the district. Given, the significant age and vulnerability of these AC pipelines, this replacement is essential to ensure reliable water supply, improve public health outcomes by mitigating asbestos-related risks, and significantly reduce operational costs stemming from frequent pipeline bursts and leaks.

The materials selected for pipeline replacement offer superior durability, enhance water quality, and ensure substantial reductions in future maintenance and replacement costs. This strategic selection aligns with sustainability objectives and long-term financial prudence, significantly extending asset lifespan and minimizing environmental impacts.

Moreover, to ensure the initiative's success in significantly reducing Non-Revenue Water (NRW), comprehensive Water Conservation and Water Demand Management (WCWDM) practices will be concurrently implemented. The strategy includes the creation of District Metered Areas (DMAs) that facilitate precise measurement and management of water distribution, enabling targeted interventions in zones with the highest water losses. The integration of Pressure Reducing Valves (PRVs) will further address issues related to water leakage, pipe bursts, and overall distribution system inefficiencies by managing pressure in high-pressure zones effectively.

State-of-the-art technologies such as digital twin technology and Building Information Modelling (BIM) software will play an integral role in optimizing the project's planning, design, and execution. Digital twins provide real-time virtual models of the physical pipeline assets, enhancing predictive maintenance capabilities, risk mitigation, and operational optimization. Concurrently, BIM software facilitates accurate and collaborative project execution, ensuring seamless integration between various project phases from conception through to implementation and maintenance.

By systematically combining pipeline replacement with advanced water management practices and cutting-edge technological applications, UMDM ensures not only immediate enhancements in infrastructure reliability but also sustainable reductions in NRW. These initiatives align closely with the stringent NRW reduction targets set by the Department of Water and Sanitation (DWS), enabling UMDM to lift current growth restrictions and foster robust economic and infrastructural development across the district.

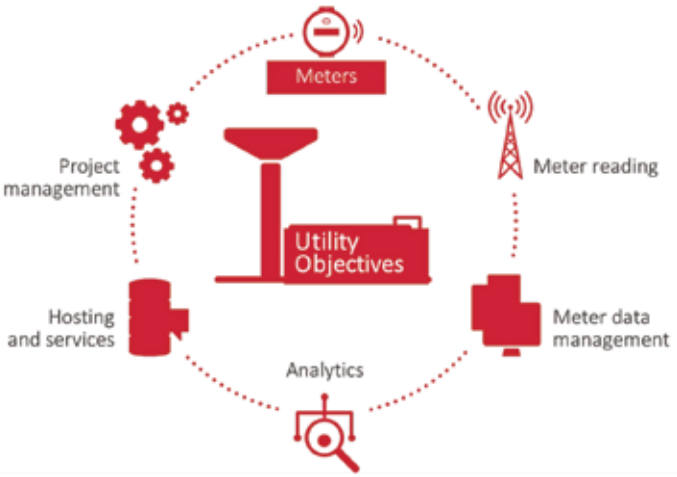

FIGURE 2: *Smart Meter Solution*

Smart Metering Infrastructure Deployment

Smart metering represents a sophisticated approach to water resource management by leveraging advanced ultrasonic technology and real-time remote communication capabilities. These intelligent meters provide precise data collection and accurate measurement of water consumption, surpassing traditional mechanical meters in reliability, accuracy, and operational efficiency. Smart meters, devoid of moving parts, maintain consistent accuracy throughout their operational lifespan, significantly reducing maintenance requirements and operational costs.

Integral to UMDM's strategic initiative, the deployment of smart metering infrastructure aims to modernize water management, optimize operational processes, and enhance financial sustainability. The adoption of ultrasonic smart meters and Low Power Wide Area Network (LPWAN) communication technology forms the foundation of a robust infrastructure, facilitating secure, reliable data transmission and enabling proactive management through real-time analytics.

To ensure strategic alignment and stakeholder coherence, the smart metering program in UMDM is meticulously scoped, with clearly defined objectives designed specifically for the region's infrastructure challenges and operational context. By transitioning to remote data collection, UMDM addresses common inefficiencies associated with manual meter readings, such as inaccuracies and labour-intensive processes, significantly enhancing the quality and immediacy of data.

A comprehensive Meter Data Management System (MDMS) underpins the smart metering framework, aggregating vast data streams from the meters to offer valuable insights into consumption patterns, system leakages, and demand forecasting. This analytical capability enables utility managers to adopt proactive and targeted maintenance strategies, ultimately enhancing infrastructure reliability and optimizing resource allocation.

Customer engagement is notably enhanced through integrated, user-friendly portals providing real-time visibility of water usage. Such transparency fosters greater awareness among consumers, encouraging water conservation behaviours and resulting in improved billing accuracy, fairness, and customer satisfaction.

Key Benefits of Smart Metering within the UMDM ONE Plan include:

- **Cost savings:** By detecting leaks and providing more accurate billing, smart meters can help reduce water waste and lower costs for both Utilities and consumers. Automation and visibility in the meter to cash process, allows for increased operational efficiency.

- **Increased transparency and fairness:** Smart meters can help ensure that water billing is based on actual usage, rather than estimated usage, leading to a more fair and transparent billing process.
- **Improved customer experience:** With access to real-time usage data and the ability to monitor their water consumption, customers can make informed decisions about their water usage and reduce their costs.
- **Revenue enhancement:** With the above benefits and innovative credit control policy mechanisms from the meter to cash process, revenue streams are significantly enhanced.
- **Improved water management:** Real-time data on water usage enables users to monitor and manage water resources more efficiently.
- **Sustainability:** By reducing water waste and promoting conservation, smart water meters can help conserve water resources and contribute to a more sustainable future.

The smart metering initiative brings clear financial and operational improvements. It contributes to long-term financial stability by increasing revenue recovery, controlling costs more effectively, and improving overall profitability. On the operational side, the programme supports ongoing innovation, drives efficiency, and reduces waste.

UMDM's implementation prioritizes three key areas:

- **Accurate Billing**: Strengthening the reliability of metering and billing systems to prevent losses due to incorrect or missed charges.
- **Loss Prevention**: Reducing risks such as meter tampering and unauthorized use through built-in monitoring and alert features.
- **Income Optimization**: Boosting revenue by identifying unmetered consumption and improving follow-up on outstanding payments.

Qualitative advantages encompass improved customer satisfaction by providing customers real-time updates on water consumption, quality, and supply disruptions, thereby significantly enhancing responsiveness and trust in the utility. The program is also closely aligned with broader economic, social, and environmental imperatives, aiming to achieve sustainable water management practices. This holistic approach emphasizes responsible resource utilization, equitable social outcomes, and long-term environmental sustainability.

Smart metering within UMDM specifically addresses several types of water losses:

- **Inaccurate Mechanical Meters**: Mechanical meters are often less accurate than ultrasonic meters, especially over time. They start measuring only after a higher flow of water, leading to unrecorded water usage. Ultrasonic meters, which don't have moving parts, remain accurate throughout their life, helping reduce unbilled water usage.
- **Manual Meter Reading Problems**: Reading meters by hand takes a lot of time and is prone to errors, which can lower the quality of your data. This makes managing Non-Revenue Water more challenging.
- **Switching to Remote Readings**: Using remote readings can prevent mistakes and save time. It allows you to update your water usage data more frequently, from yearly to monthly or even daily. This helps you quickly spot and address problems.
- **Theft Detection**: Smart meters can send alerts if there's any tampering or theft attempts, letting you respond quickly.
- **Identifying Unmetered Water Use**: Smart meters help distinguish between real water losses (like leaks) and apparent losses (due to meter inaccuracies or usage not being recorded). This is crucial for managing water loss in different areas, such as construction sites.
- **Leak Detection Efficiency**: New technology in smart meters provides a clear view of your water distribution, making it easier and more efficient to locate leaks. This allows you to prioritize leak detection efforts more effectively.

FIGURE 3: *Proposed Mkhambathini WWTW*

- **Household Leaks**: Leaks inside a house may not affect revenue directly, but they can cause high bills for consumers. Smart meters can detect these leaks early, allowing you to alert the customer and reduce water loss.
- **Service Connection Leaks**: Smart meters with acoustic leak detection act like a network of noise-loggers, constantly monitoring for leaks. This lets you focus on specific areas for leak checks, saving time and resources compared to manual methods or separate devices

In summary, UMDM's comprehensive smart metering deployment represents a strategic, technology-driven transformation towards sustainable municipal water management. By systematically addressing operational inefficiencies, enhancing financial and resource sustainability, and delivering superior customer engagement, the program sets a robust framework for resilient, future-proofed water resource management.

Catalytic Wastewater Treatment Plant

The new Wastewater Treatment Works (WWTW) in Mkhambathini Local Municipality is an essential infrastructure catalyst aimed at overcoming current development restrictions linked to insufficient sanitation services. The facility will serve as a cornerstone for unlocking significant developmental potential, particularly in fostering the growth and establishment of Camperdown as a dynamic business and industrial hub along the prominent N3 economic corridor. Employing cutting-edge digital twin technology and Building Information Modelling (BIM) software, the design, construction, and operation phases of the WWTW will be meticulously optimized. Digital twin technology will offer real-time digital replicas of physical assets, enabling precise predictive analytics, enhanced efficiency, and proactive maintenance management. Simultaneously, BIM software will facilitate seamless integration, collaboration, and accuracy throughout the project lifecycle, ensuring compliance with rigorous environmental regulations and standards.

This WWTW will be crucial in enabling and accelerating major commercial and industrial developments within the Camperdown area, significantly enhancing regional economic prosperity. Among these anticipated developments are a landmark R7 Billion Heineken Brewery Plant, a R40 Billion Aviation Fuel Facility, a R1 Billion Chemical Factory, a R50 Million Spar Centre Upgrade, and a R150 Million Solar Installation. Collectively, these developments underscore the transformative economic impact that this infrastructure investment will facilitate.

The recent strategic emphasis placed on the N3 Corridor and the District Development Model (DDM), alongside ambitious plans for establishing Camperdown as a green smart city, further reinforces the imperative for

a reliable, efficient, and environmentally sustainable WWTW. Without this essential facility, the significant economic opportunities, investments, and sustainable development envisioned for the Camperdown Smart City cannot materialize.

The integration of smart metering technology for both water and electricity within the WWTW will further enhance resource management, operational efficiency, and sustainability. Additionally, linking the WWTW to the smart city infrastructure will significantly bolster the green credentials of the Camperdown development, promoting water and energy conservation, effective waste recycling, and overall environmental stewardship.

The catalytic Wastewater Treatment Plant in Mkhambathini not only addresses immediate sanitation constraints but also strategically positions the region for substantial economic growth, technological advancement, and sustainable urban development, ultimately serving as a model for modern infrastructure development in South Africa.

The completion of the WWTW in conjunction with the AC Replacement and Smart Metering initiatives, will also facilitate the removal of the 0% growth restriction imposed by the Department of Water and Sanitation (DWS), contingent upon measurable reductions in NRW, thereby unlocking new water connections and fostering sustainable infrastructure growth.

Financial Strategy and Institutional Capacity

UMDM has strategically aligned the infrastructure upgrade program with national funding frameworks, Private and Public collaborations and the District Development Model (DDM), ensuring financial sustainability and operational accountability. This approach projects a substantial return on investment, significantly improving revenue generation through enhanced billing accuracy and substantial NRW reductions.

Institutionally, the municipality has established a dedicated Programme Management Unit (PMU), which collaborates closely with specialized consultants, strategic partners, and performance-based contractors. Capacity-building initiatives, including targeted training and skills development programs, are embedded within the project framework to ensure sustainable operational excellence.

Socio-economic and Environmental Benefits

The initiative is expected to generate significant socio-economic benefits, creating approximately 12,800 job-years and promoting regional economic stability. By providing reliable water services, the program directly contributes to poverty alleviation and improved public health outcomes.

From an environmental perspective, the replacement of hazardous AC pipelines and establishment of advanced wastewater treatment infrastructure significantly mitigates health and environmental risks, aligning with both national and international regulatory standards. These interventions support broader climate resilience goals and ensure the sustainable management of vital water resources.

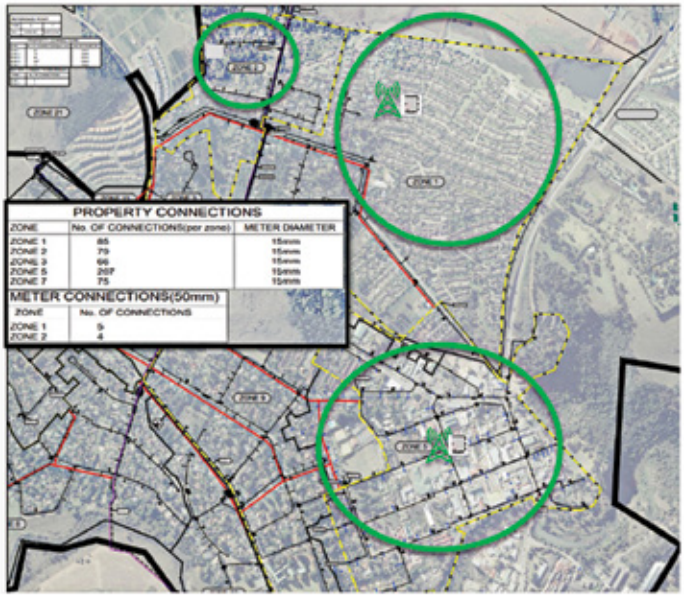

FIGURE 4: *Howick area*

CASE STUDY - HOWICK AC REPLACEMENT AND SMART METERING PILOT PROJECT

The Howick Pilot Project is a foundational component of UMDM's integrated ONE Plan initiative, serving as a practical demonstration of the broader strategy to modernize water management, reduce non-revenue water (NRW), and enhance revenue collection. Launched in July 2024 under the ONE Plan framework, the Howick pilot aligns directly with the initiative's three pillars: AC pipeline replacement, smart metering deployment, and infrastructure-driven revenue catalysts.

By situating Howick within the ONE Plan, the pilot exemplifies how targeted, phased interventions contribute to district-wide objectives. The AC pipeline replacement efforts in Howick are coordinated with smart metering roll-out, ensuring that physical loss reduction and accurate usage measurement occur in tandem. This integrated approach mirrors the overarching goal of synchronizing supply-side improvements (pipeline upgrades) with demand-side innovations (smart meters) to achieve measurable NRW reductions.

Objectives and Scope

- **Physical Loss Reduction**: Replace ageing AC pipelines in the Howick area as part of the phased district-wide AC renewal, utilizing durable materials and digital twin/BIM tools for precise planning, risk mitigation, and lifecycle management.
- **Digital Transformation**: Deploy ultrasonic smart meters with Low Power Wide Area Network (LPWAN) connectivity across selected customer clusters, integrated into the MDMS platform, to enable real-time monitoring, proactive leak detection, and seamless data-driven decision-making.
- **Revenue Enhancement**: Automate billing processes tied to the smart meters, reducing operational inefficiencies and revenue leakage. Howick's pilot billing automation is piloted within the ONE Plan's revenue-enhancement framework, informing district-wide billing strategies.
- **Stakeholder Engagement and Capacity Building**: Conduct targeted stakeholder consultations, training sessions, and communication campaigns in Howick to ensure community buy-in and operational readiness, reflecting the ONE Plan's emphasis on institutional strengthening.

Technological and Operational Integration

- **Digital Twin/BIM in Howick**: Digital twin models/BIM software are employed in Howick to create precise virtual representations of the existing pipeline network, facilitating scenario analysis for replacement works, predicting system pressures, and optimizing project timelines. These tools align with the ONE Plan's commitment to leveraging advanced technology for efficient implementation and long-term asset management.
- **Smart Meter and MDMS Integration Testing**: As part of the

construction-phase activities, planned smart meters in Howick will interface with the central MDMS platform once commissioned, enabling future analytics to identify leak patterns, consumption anomalies, and demand trends. This anticipated integration exemplifies the ONE Plan's data-centric methodology: field-collected data will feed analytic engines to support proactive interventions and, after system commissioning, provide evidence toward validating NRW reduction efforts.

Preliminary Observations and Expected Insights

- **Construction Progress and Early Learnings**: During the construction phase in Howick, initial installation logistics have been tested, revealing insights into coordination between contractors, field teams, and local stakeholders. These learnings inform refined scheduling, resource allocation, and risk mitigation strategies for subsequent phases.
- **Technological Integration Testing**: Early-stage integration of digital twin models, BIM workflows, and smart metering hardware is underway, allowing the project team to verify data flows, communication reliability, and system interoperability.
- **Stakeholder Engagement in Practice**: Construction-phase engagement activities, such as community briefings, technical demonstrations, and training sessions, have provided feedback on communication approaches and stakeholder expectations. This feedback shapes refined engagement strategies for wider rollout, ensuring continued community support.
- **Operational Readiness Preparations**: Preliminary training of operational staff on new technologies and maintenance procedures is still to be implemented. Early simulations and dry runs will highlight areas requiring additional capacity-building, which will be addressed before full commissioning.
- **Anticipated Benefits Tracking Framework**: Though full outcomes await post-commissioning data, the project team has established monitoring frameworks and key performance indicators aligned with ONE Plan targets. These frameworks will enable systematic tracking of NRW reductions, billing accuracy improvements, and system reliability once operational data becomes available.

By documenting construction-phase observations and preparing rigorous monitoring protocols, the Howick pilot positions UMDM to demonstrate, upon commissioning, measurable progress toward lifting DWS-imposed growth restrictions. The anticipated data-driven evidence will support the ONE Plan's objective to unlock new water connections and catalyse broader development initiatives.

The Howick Pilot Project, as part of the ONE Plan initiative, validates the integrated strategy of coupling AC pipeline renewal with smart metering and data analytics to achieve sustainable water management. Its outcomes offer actionable insights and a proven blueprint for expanding similar interventions throughout UMDM, reinforcing the ONE Plan's vision of transforming water governance into a driver of operational excellence, financial resilience, and socio-economic growth.

CONCLUSION

The uMgungundlovu District Municipality's ONE Plan initiative exemplifies a robust and forward-thinking response to significant water management challenges, including ageing infrastructure, high non-revenue water (NRW) levels, and inadequate wastewater treatment capabilities. The strategic integration of AC pipeline replacement, smart metering infrastructure deployment, and the catalytic wastewater treatment plant in Mkhambathini positions the district to overcome operational, environmental, and economic constraints sustainably. The Howick Pilot Project illustrates practical, ongoing efforts to validate this integrated approach, emphasizing real-time data management, advanced technology applications, and enhanced stakeholder engagement. Collectively, these initiatives promise substantial socio-economic benefits, environmental improvements, and a blueprint for sustainable municipal water governance, ultimately promoting operational resilience, financial sustainability, and regional economic growth.

RECOMMENDATIONS

To ensure the successful continuation and broader implementation of the ONE Plan initiative, the following recommendations are proposed:

- **Accelerate Infrastructure Implementation:**
  - Expedite the phased replacement of ageing AC pipelines, prioritizing high-risk and high-loss areas based on comprehensive asset management data.
- **Complete and Evaluate Pilot Initiatives:**
  - Ensure timely completion and thorough evaluation of the Howick Pilot Project to gather essential insights on logistical, technological, and operational integration, informing future phases of district-wide implementation.
- **Enhance Data-Driven Decision-Making:**
  - Expand and fully integrate the Meter Data Management System (MDMS) with advanced analytics capabilities district-wide to facilitate proactive maintenance, targeted NRW interventions, and accurate revenue collection.
- **Institutional Strengthening and Capacity Building:**
  - Invest in continuous professional development and targeted training programs for operational and technical staff to ensure optimal management and sustainability of new technologies and infrastructure.
- **Community Engagement and Transparency:**
  - Sustain robust stakeholder and community engagement efforts, using transparent communication strategies and interactive platforms to enhance public trust and collaborative participation in water conservation initiatives.
- **Align with Regulatory and Funding Frameworks:**
  - Continue strategic alignment with national funding mechanisms and regulatory standards to secure additional resources, ensuring compliance and enhancing the financial viability and sustainability of infrastructure projects.
- **Foster Economic Development:**
  - Capitalize on infrastructure improvements, particularly the catalytic wastewater treatment plant, to actively facilitate and attract commercial and industrial investments, thereby stimulating regional economic growth and job creation.
- **Commitment to Environmental Sustainability:**
  - Maintain rigorous adherence to environmental best practices and sustainability standards in all project phases, leveraging digital technologies such as BIM and digital twins to optimize environmental outcomes and resource utilization.

By diligently applying these recommendations, UMDM will effectively

transform its water management challenges into sustainable opportunities, providing a replicable model for other municipalities seeking similar transformations in water governance and infrastructure management.

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