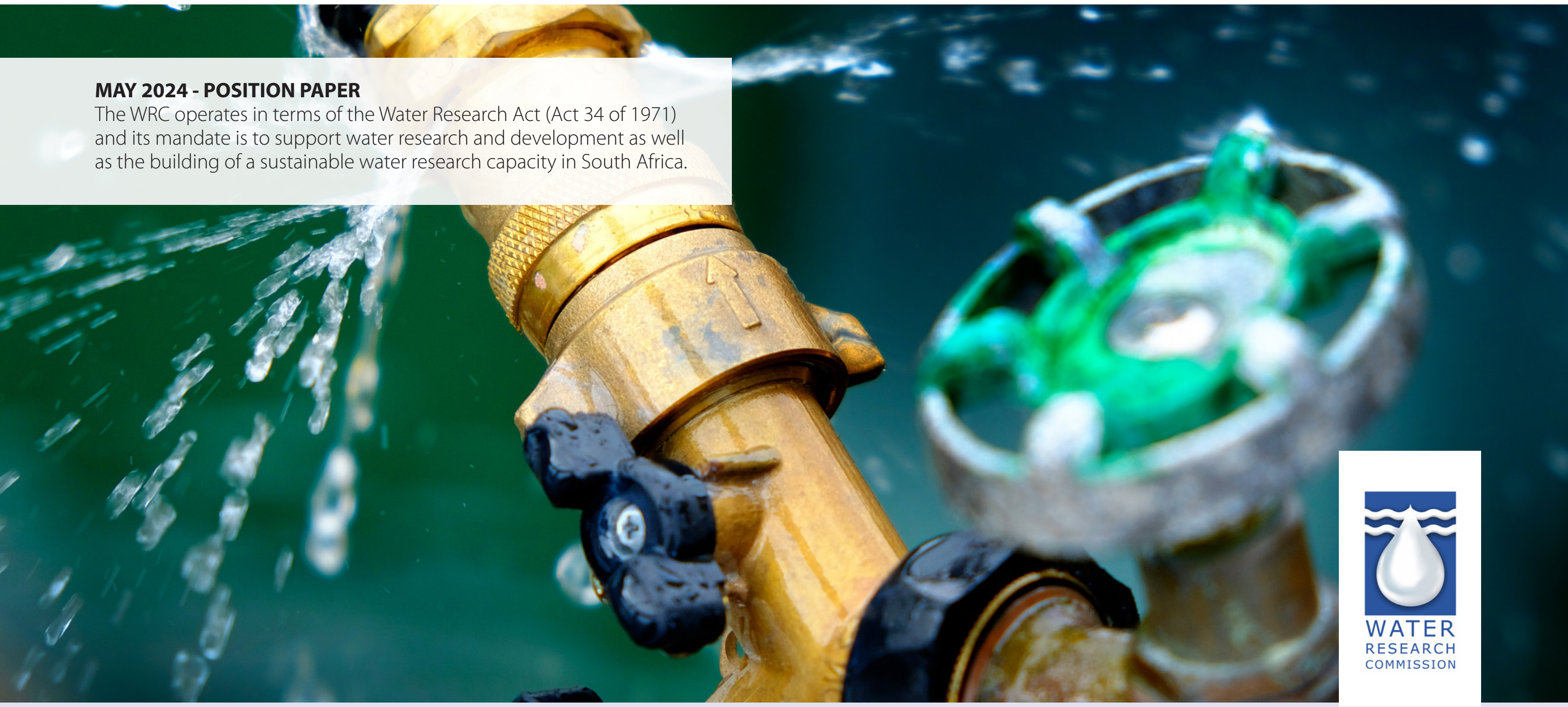

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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

NEXT GENERATION WATER LOSS TRACKING, COMPLIANCE, MANAGEMENT, AND PERFORMANCE SOLUTIONS

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The National Development Plan – 2030 (National Planning Commission, 2012) states that reducing growth in water demand is just as important as increasing its supply. The National Development Plan assumes it to be possible to achieve an average reduction in water demand of 15% below baseline levels (i.e., business-as usual levels in 2012) in urban areas by 2030. Detailed targets have been set for different areas through the Reconciliation Strategies and the All-Town Studies. Achieving demand reductions on this scale will require active programmes to reduce water leakage in distribution networks. South African bulk and domestic water service providers and authorities are under increasing pressure to address the growing concern of water losses from drinking water distribution networks. The annual water loss is breaching 50% of total water supply which directly affects the availability of water for domestic and industrial use, and indirectly lowers the amount of water available for agriculture.

Introduction

Many water utilities have either developed or are developing strategies to reduce losses. Reducing water losses save the energy required to abstract, transport, treat, and distribute water. Additionally, less water losses reduces the expenses for water supply systems and contributes to sustainable water management.

Water losses can be either real (physical) or apparent (commercial) losses. Real losses are mainly due to leakage from joints in water pipes, service connections, pipe bursts, pipe cracks and overflows from storage tanks. Apparent losses are mainly due to illegal water consumption and inaccurate customer metering. Reducing and controlling water losses is becoming more crucial as demand increases in many parts of the country.

Real-time data from existing water network assets and monitoring technologies can be acquired, and inform conventional human-driven, trial-and-error process adaptation and optimisation approaches. However, even well-trained operators and engineers with access to 'big data' require time to process, analyse, normalise, trend out and predict what operational changes need to be made at any given time. Such delays in response time can lead to increased water losses. The amount of real time, as a consequence or more real time sensors and cheap and robust data transfer through 'Internet of Things' (IoT) connections, is likely to continue to grow.

As information and communication technology (ICT) platforms and tools improve several smart and modern solutions are being developed which offer better integration of water loss management together with daily operations and maintenance (O&M) management. There is a move toward next generation cloud-based water loss tracking platforms that will help water agencies and its customers to track water use effectively by lowering the non-revenue water and be compliant with legislations. It also offers several additional value in managing pressure, flows and asset management. It enables smarter management processes by attaching artificial intelligence which relates to significant savings in water, chemical use and energy savings.

With examples of successful implementation of emerging digital cloud-based solutions for reduction of water losses piling up worldwide and squeezed utility budgets highlighting the need for cost-effective water savings in the wake of COVID-19, the case for digital water loss tracking and minimisation technologies has never been stronger. Water loss tracking and management consists of four fundamental pillars: pressure management, active leak detection, asset condition monitoring and smart analytics. Pressure management, active leak detection and condition monitoring are complementary, with smart asset management platforms sitting on top of all the digital infrastructure, aggregating and visualising the data. Each technology performs a vital role in helping control leakage, whether its actively finding leaks or managing pressure to reduce the risks of leaks and bursts in the first instance. Integrating all these technologies together can reduce non-revenue water (NRW) to below 10%, though few utilities have done this so far.

Current status of NRW Management globally

In order to explore new technological advancements to manage NRW, it is important to understand the current status of NRW management, including why it is so crucial to utilities to reduce NRW and the wider environmental effects as well as what approaches are most commonly being taken to reduce leakage from a technology point of view.

Motivation

- **Financial sustainability**: Reducing NRW can lead to significant cost savings for water utilities. By reducing leaks, optimising distribution networks, and improving efficiency, utilities can lower their operational costs associated with pumping, treatment, and energy consumption on 'wasted resources'.
- **Customer expectations and satisfaction**: As with other consumer-facing services in developed countries, expectations are higher than ever before, and utilities are working hard to ensure stable and high-quality services. High levels of NRW can result in water supply disruptions, low pressure, and unreliable service, leading to customer dissatisfaction. By reducing NRW, utilities can ensure consistent water supply, improve service reliability, and enhance customer satisfaction. Reducing NRW demonstrates a water utility's commitment to serving its community and being socially responsible. It shows a dedication to efficient resource management, water conservation, and sustainable development.
- **Environmental sustainability and increased water scarcity**: Addressing NRW contributes to environmental sustainability by reducing unnecessary water abstraction. It helps conserve valuable water resources, promotes sustainable water management practices, and aligns with the broader goal of environmental stewardship.
- **Regulatory compliance**: Many regulatory frameworks require water utilities to meet specific targets for NRW reduction. Utilities that fail to meet these targets may face penalties, reputational damage, or limitations on their operations. Therefore, complying with regulatory requirements is a strong motivation for utilities to actively reduce NRW.
- **Public perception**: Even if a utility is not bound by strict penalties for not achieving leakage targets, it is very much in their interest to prioritise reduction of NRW due to the public having higher expectations from their utility from a constitutional, social and environmental perspective. Utilities may have their own targets to reduce their Infrastructure Leakage Index (ILI).
- **Water resource planning**: Managing NRW allows utilities to accurately assess water availability and plan for future water demand. By understanding their water losses, utilities can make informed decisions about water infrastructure investments, resource allocation, and long-term water supply planning

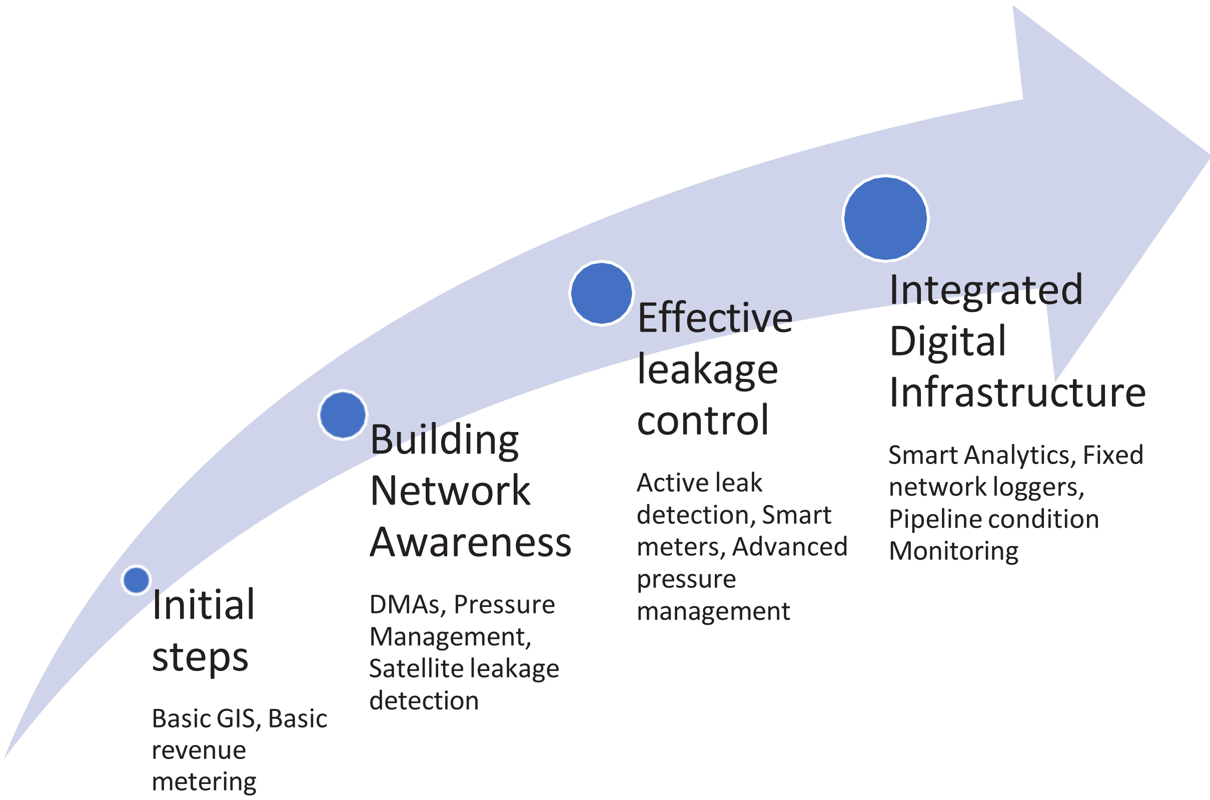
Water-energy nexus

Commonly when a utility is putting forward a business case to reduce NRW, the predominant motivator is to save money through reducing water wastage and preserving our natural resources. However, in recent times, the role of the water-energy nexus and how energy and water are highly interlinked is becoming an increasing priority for water utilities worldwide.

The presence of NRW directly impacts a utility's energy consumption. According to the latest GWI energy efficiency research, water distribution networks are the second largest consumer of energy in the conventional utility water cycle (after wastewater treatment and excluding desalination and sludge). For utilities with net zero commitments and those in locations with high electricity costs, pumping optimisation across the distribution network and treatment plants is fast becoming a priority. For example, optimal pump scheduling has saved the City of Toronto $1 million (R14.3M) in energy costs annually while Evides NV has reduced energy use at pumping stations by 33% through implementing a hydraulic digital twin of its supply network.

Current approaches

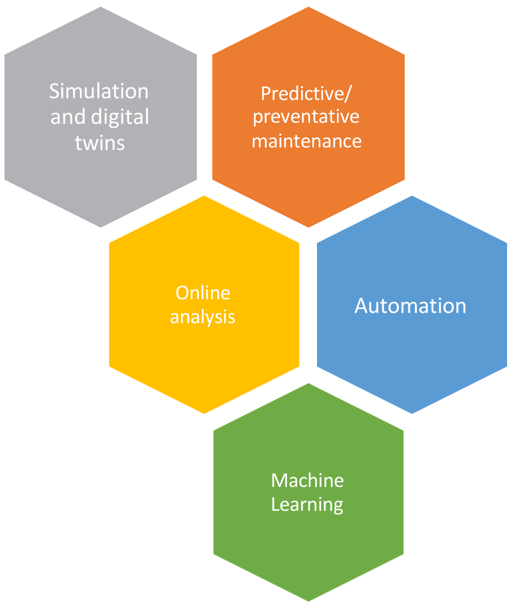
The schematic below shows the stages of digital leak management maturity in utilities (GWI Water 2021), with the most common approaches being establishing basic network awareness, involving SCADA systems to enable remote control and monitoring of sites across the network and a basic geographic information system (GIS) to plot data on maps and some input metering for measuring water entering the network. Pressure management is also commonly used by many utilities with Cape Town as an example utility that relied heavily on a technology from i2O to manage pressure and reduce leakage during its 2017/18 'Day Zero' water crisis.



Trends and developments in the technology market

The below schematic shows the general direction of the water sector in terms of technology development. There is a huge digital focus, with many utilities turning to smart analytic platforms with cloud-based capabilities. The market for smart analytics is characterised mainly by large companies with extensive experience either producing or implementing a range of smart technologies, such as Xylem and Royal HaskoningDHV. Smaller companies such as FIDO are also entering the smart analytics field, indicating that future competition may come increasingly from startups with data software expertise.

A Technology Scan was undertaken primarily focused on these kinds of solutions due to the need to overcome data siloes, centralise data, and explore cloud-based solutions. As a result of the scan, 35 technologies were identified that matched the criteria for the technology search. 33 of the technologies listed in the matrix are cloud-based solutions or have mentioned cloud-based capabilities.



Schematic showing the key areas and opportunities in digital leak management, GWI

Utility implementation of next generation solutions

The following table highlights some of the utility case studies.

Utility	Technology	Brief overview
De Watergroep	LeakRedux	LeakRedux is an online, cloud based, real-time leakage detection and decision support system for water distribution networks. implementation of LeakRedux helped De Watergroep improve their prioritisation and they are now working on a business case for NRW, not per DMA but per region which will include which regions to focus on with projects and technologies. De Watergroep is also looking at making DMAs smaller where NRW is an issue to get better insights.
Sydney Water	TakaDu	TaKaDu's algorithmic engine detects, classifies, alerts and provides real-time insight on leaks, bursts, DMA breaches, meter faults and other network inefficiencies. Overall, TaKaDu has enabled Sydney Water to avoid or minimise water interruptions to over 140,000 properties that would have otherwise been affected. There was one specific leak that was losing 1.3 million litres per day.
Thames Water	FIDO	FIDO (Free Intelligent Domain Observers) AI is a software-as-a- service (SaaS) end-to-end leak detection cloud AI solution which identifies leak/no leak and the size of leaks to reduce the run time of each leak and remove false positives and human error in analysis. FIDO AI analysed over 35,000 historic sound files in 2.5 hours and returned a report which Thames Water retrospectively followed up with its own leakage repair records and dig data. FIDO then carried out analysis of Thames Water's entire logger estate, an additional 6,810 new acoustic files. From daily reports, Thames identified 33 POIs for on-site verification by its leakage detection service providers and FIDO staff. Of these, 11 led to the discovery of misaligned loggers, and 20 were correctly confirmed as leaks or not leaks (including four customer side leaks), an accuracy of over 92%.
Mekorot	Fiber Optics	Focusing on fiber optics, the water company developed a way to probe fiber optic lines throughout the country using Israel's existing pipeline infrastructure. As well as reducing NRW, using fiber optics in existing pipelines can open up new opportunities to link other utility sectors. As Mekorot has pipes all across the country – even in the remote sections – essentially by using the pipes, communications companies can connect to these remote areas quickly, instead of waiting three to four years to do it.
Global Omnium	GoAigua	GoAigua is a platform that enables the integration of all data types and analysis under a single login portal, including water quality. The technology has reduced NRW by more than 80% in 400 municipalities that Global Omnium manages, saving water and energy. In the past, a utility in Valencia improved their NRW by 35% over the course of 20 years, but now they are close to 88% reduction in NRW due to digital transformation.

Conclusions

Key trends and developments

An increasing number of utilities around the world are looking to employ digital technologies in order to meet a range of challenges across the water life cycle, including NRW reduction. This project undertook a market analysis of where the trends and developments are in leakage management technology. Smart analytics platforms, with a focus on cloud-based capabilities, is an area which is rapidly evolving, with more competition between large and small technology providers to provide service.

The rise of cloud computing has transformed the GIS market. Cloud-based systems enable multiple users to access a GIS system at one time, whilst further enabling operators to download and publish maps to the internet. Furthermore, operators can now leverage cloud-based AI and analytics to analyse spatial data without having to install additional on-premise software or hardware.

AI is expected to be at the core of the asset management market in the future. In asset performance management (APM), AI will play an increasing role in facilitating predictive maintenance, with complex performance data automatically analysed in order to identify early warning signs of device failure. In asset investment planning (AIP), financial decisions will continue to be justified through the use of advanced algorithms, which can search datasets of potential investment decisions to identify optimal financial strategies. These solutions address a number of utility challenges but bring with it their own risks, opportunities and barriers to adoption.

A number of utilities globally were engaged on this project, and it was noted that while cloud-based water loss platforms are definitely the way forward, attention and innovation should also be prioritised in all aspects of the PALM (Prevent, Aware, Locate, Mend) model, and Infrastructure Management, and through doing this NRW can be successfully managed and reduced.

Opportunities

Utilising cloud-based water loss platforms and AI technologies offer a range of opportunities to better manage utility networks for the long term. The key opportunities are highlighted below.

- **Real-time Monitoring and Predictive Maintenance:** Cloud-based platforms and AI technologies enable real-time monitoring of water infrastructure, such as pipelines, pumps, or reservoirs. Predictive analytics can identify potential failures or maintenance needs, enabling proactive actions to prevent system disruptions and optimise maintenance schedules.
- **Data integration**: Siloed data existing within separate utility departments is a key digital challenge within the sector and can place severe restraints on the level of insight an operator can gain from monitoring operations. Being able to integrate data sets in to one platform offers opportunities to better manage the whole water network long-term. Utilities who have undertaken successful digitisation projects have underlined the importance of creating a universal platform capable of integrating data from previously separate streams. Cloud based platforms can ensure organisations are both transparent and efficient when it comes to operational decision making through data sharing and integration among different stakeholders in the water sector, such as water utilities, regulators, researchers, and customers.
- Public **perception**: While the word 'cloud' and 'AI' causes scepticism amongst some customers, cloud-based platforms can actually increase customer satisfaction. More frequent readings mean it is easier to pick up leaks, and although it is not economical to find the smallest leaks, public image matters and utilities are trying their best to maintain good public perception from a social and environmental perspective. Cloud based platforms offer transparency by being able to integrate with customer communication systems and notify when leak repairs will be carried out for instance. Utilities have quoted up to 60% reduction in customer complaints due to customer transparency.
- **Efficient customer service** is also another advantage, with cloud-based platforms and AI-powered chatbots or virtual assistants. These technologies can handle customer inquiries, provide real-time information, or offer personalised suggestions, enhancing customer satisfaction and reducing the load on customer support teams.
- **Using data for multiple purposes:** Faced with mounting regulatory pressures regarding water quality, utilities have stressed a desire for digital technology to report on water quality more frequently. It is possible to pull information such as water quality from sensors and this information can be redirected and used. APIs can be used to send data to different systems from the cloud, rather than data being sent solely to a utility's leakage server for example. There are also opportunities to integrate customer billing systems. Customer meter information can be sent to billing systems and this data can be redirected to relevant places, so for example data which has previously only been used for billing can also be used for leakage targeting. AI algorithms can analyse vast amounts of data, including historical patterns, weather forecasts, or sensor data, to optimise water management strategies. This can help with demand forecasting, leakage detection, water quality monitoring, and resource allocation, leading to more efficient water distribution and conservation. Data can be used to feed directly into communication systems as well. For example, if a leaky pipe ultimately needs to be replaced, then the operator can create a network

order on the platform to inform the maintenance team and warehouse to repair leak. This information can also be shared with customers so that they can be notified when a leak will be repaired and between what times their water supply may be shut off to repair.

- **Enhanced decision making:** AI technologies can provide valuable insights and predictive models that support data-driven decision-making. This can help water utilities optimise energy usage, prioritise infrastructure investments, or plan for emergencies, leading to better resource allocation and cost savings.
- **Feedback:** Feedback is critical and any information of leak incidents must be recorded on the system. Once a leak is detected, localised and fixed, the system can automatically update GIS. This means utilities can make better decisions when deciding to repair leaks or replace pipes in the future, in case a leaky pipe has several leaks in the near future.
- **Digital maturity and 4IR workforce:** AI technologies lend to the digital maturity of utilities and allow for new capabilities and upskilling of utility workforce. These opportunities guide strategic and operational areas of the business.

Barriers to adopting cloud-based water loss platforms

It is important to acknowledge and address the risks while leveraging the opportunities offered by cloud-based platforms and AI technologies in the water sector. Proper planning, robust security measures, and ethical considerations are crucial to maximising the benefits and minimising potential drawback. Some of the main barriers highlighted by utilities are summarised below.

General conservatism

Water utilities are generally conservative when it comes to investing in new software, often preferring the stability of legacy solutions rather than embracing new digital platforms. Though GIS software is relatively common within key regional markets (e.g. North America), uptake in less developed markets could be impeded by this conservative culture.

The rapid rise of cloud-based technologies has triggered mixed reactions within the utility sector. Some operators welcome the scalability, ease-of-use and lower integration costs associated with cloud-based systems. On the other hand, utilities preferring capex models often remain resistant to the monthly OpEx fees associated with cloud-based systems. Though cloud-based technologies have often triggered cybersecurity concerns amongst operators, a broad consensus is beginning to form in the sector that cloud offerings can be just as secure as on-premise alternatives.

Resistance to change by utility staff

Resistance to change was another key point echoed by more than one utility. The attitude of field technicians and staff working in the control room tends to be reactive rather than proactive. It was found that it was difficult to engage Supervisory Control And Data Acquisition (SCADA) monitoring experts unless there was an alert or alarm set off. More than one utility mentioned that staff needs to be more data minded and that a change in mindset was required to get them to realise the benefit of using a predictive approach and pick up events before it gets to alarm stage, potentially preventing bigger incidents like a main break. A lot of the discussion suggested that however ground-breaking or cutting-edge a technology is, it's full potential can absolutely not be realised without behavioural change and the correct attitudes to use the system and achieve the most effective results.

Despite hurdles related to mindset and behaviour, the utilities expressed that the challenges were worth it. Going forward, the cloud based technological installations have cleared the way for other similar data export services that the utilities use, helping to break down barriers and change mindsets so that other projects were easier to get off the ground. Furthermore, improved data quality improved understanding of the network and other issues for the future which will save the utility money long-term.

Cybersecurity

During utility interviews it was found that most commonly, there was scepticism over data security and fear over the word 'cloud' was a recording theme. Data security concerns around pushing data to the cloud and going offshore was a concern of many staff. Driven by a string of recent attacks, and developing national legislation regarding the protection of critical infrastructure, cybersecurity is becoming a heightening concern for utility operators. Cybersecurity initiatives vary significantly, though intrusion detection, extensive staff training and end-user security are all key focus areas within the sector. Some larger utilities have gone one step further, simulating attacks using 'polite hackers' who are tasked with exposing flaws in digital systems. These efforts are expected to increase as legislation mandates the establishment of cybersecurity protocols in the future.

Lack of clear ROI

Uptake of GIS software may be limited by a lack of clear ROI (return-on-investment) associated with the software. Whereas uptake of other solutions (e.g. asset investment planning) provides visibility regarding investment returns, the cost saving potential of GIS is more ambiguous; often linked to associated improvements in network and field service management. This restraint is especially present in less developed markets, where utility budgets are already strained.

Lack of good data

Artificial intelligence and machine learning are powerful tools but are only as good as the data available to them. A solid foundation of data collection and validation is key. In markets with ageing network infrastructure, operators may not have extensive data regarding water and wastewater systems, especially if pipes are buried and inaccessible. This lack of information severely limits the uptake of GIS software platforms, which rely on the digital cataloguing of utility assets during integration periods. In markets where pre-existing records of infrastructure remain limited, integration could take a significant amount of time and money.

Skills gap

Access to cloud-based platforms and AI technologies may be limited in certain regions or organisations due to factors like infrastructure development or affordability. Additionally, there may be a skills gap within the organisation, requiring specialised expertise to implement and leverage these technologies effectively.

Uncertainty over technology costs

Technology costs have the potential to rise (as has been seen in 2021 with a global shortage of microprocessor chips), but they can also reduce if market pressures, and efficiencies are exploited. This will make a significant difference to the overall cost of this scenario. The cost of a wide roll out of Advance Metering Infrastructure (AMI) is also not fully understood. Potentially this could reduce if all utilities and other users share spare bandwidth of these solutions.

Recommendations and focus areas for improvement

- Ensuring intra-organisational/departmental alignment across the utility results in utility-wide benefits. Unlocking data from legacy systems, centralising existing datasets and adopting common data standards at the utility level, are all crucial to providing better data accessibility.

- The benefits of sharing and integrating data should not be measured only in a specific project's ROI, but also in the possibilities for further development that it can facilitate. Helping utilities foster innovation and interdepartmental collaboration is an important part of this. Running successful pilots is a good way to demonstrate this value. Utilities should look to engage with partners such as SALGA to develop, test and pilot new technologies for NRW reduction.

- Implementation of digital solutions requires clear objectives against which to measure success. Without this, valuable data and functionalities can sit unused in a utility's system. Outcome- oriented digitisation requires an organisation-wide culture shift. Helping utilities prioritise data literacy in training and recruitment and democratise access to data across the organisation, are important steps in this. Utility staff will also need to be able to better communicate across departments. Crucial to successful implementation is understanding what is realistically possible and not over-reaching.

- As utilities increasingly look to employ digital technologies in order to meet a range of challenges across the water lifecycle, and absorbing technical knowledge from other industries remains a key avenue for developing digital competencies. Collaboration between other industries can overcome practical challenges. This is especially the case when it comes to applications of AI, which have a rich history in other industries such as manufacturing and pharma. One fertile application for absorbing AI competencies lies in construction, where data-driven approaches have been harnessed in order to optimise material use, capital investment and carbon impacts.

- Addressing utility concerns over data security and cybersecurity, a central hub should be implemented which would be managed by a neutral science council such as the WRC's Research Observatory or housed by the eminent Water Infrastructure Agency.

- To overcome reluctance to take on the challenges of change management or risks of failure that come with it, a roll-out of change management and skills development programmes should be implemented alongside technology demonstrations. This will build long-term capabilities as well as short-term capabilities through technology vendor support.

- Methods of enhancing the effectiveness of the technologies was also discussed and multiple utilities highlighted the need to make zones/DMAs smaller with additional flow meters. The optimal DMA size was recommended as 500-1200 properties.

- Extending focus to transmission mains areas was another operational point highlighted. NRW has historically been in distribution mains but transmission mains should also be paid attention to, because if they fail then customers cannot receive water.

- An increasing number of utilities around the world are looking to employ digital technologies in order to meet a range of challenges across the water life cycle, including NRW reduction. This project undertook a market analysis identifying trends and developments in leakage management technology. Specifically, smart analytics platforms, with a focus on cloud-based capabilities, are rapidly evolving, with increased competition between both large and small technology providers. The key opportunities and barriers of using cloud-based solutions are summarised below and expanded on with conclusions and recommendations at the end of this document.

Key opportunities	Key barriers
Real-time monitoring and predictive maintenance	General conservatism of utilities
Data integration and overcoming siloes	Resistance to change within utility staff
Public perception	Cybersecurity threats
Using data for multiple purposes	Lack of clear ROI
Enhanced decision making	Lack of good data
Feedback on incidents for better awareness	Skills gap
Digital maturity and 4IR workforce	Uncertainty over technology costs

Related project: *Next Generation Water Loss Tracking, Compliance, Management, and Performance Solutions,* (**WRC project no. C2022/2023-00755**).
Contact Jay Bhagwan (jayb@wrc.org.za) for more information.