ANNEX A: SPACE FOR INFRASTRUCTURE - WATER MANGEMENT

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Reference	Space for Infrastructure/Water/Annexes
Issue/Revision	1 . 1
Date of Issue	10/04/2024
Status	Approved

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1. INTRODUCTION

This document lists the use cases to be used as part of the "Space for Infrastructure – Water Management" thematic area within the umbrella of the "Space for Infrastructure" thematic call for proposals.

The use cases presented result from the cooperation between the European Space Agency (ESA) and key stakeholders of the water infrastructure sector. It aims at developing sustainable services leveraging space assets to address the needs for modern day water infrastructure.

2. ANNEX A: SPACE FOR INFRASTRUCTURE - WATER MANAGEMENT USE CASES

2.1. Dubai Electricity and Water Authority (DEWA)

Dubai Electricity and Water Authority PJSC (DEWA) was created in 1992 and is the exclusive electricity and water utility provider in Dubai, the United Arab Emirates (UAE).

DEWA is ranked as one of the best utilities in the world, providing services to the highest standards of efficiency, reliability, availability, and sustainability to over one million customers in Dubai. DEWA aims to achieve the Dubai Net Zero Carbon Emissions Strategy 2050 to provide 100% of Dubai's total power capacity from clean energy sources by 2050. Among DEWA's key clean energy projects is the Mohammed bin Rashid Al Maktoum Solar Park, the largest single-site solar park in the world using the Independent Power Producer (IPP) model, with a planned production capacity of 5,000MW by 2030.

2.1.1. Use Case 1: Estimation of Water Usage

Problem statement

Over the next few decades, current water solutions will become ever more strained for multiple reasons. Namely:

- Strain caused by current population usage (near-term)
- Future population growth within the region, both organic and through immigration (long-term)

By predicting the future needs of the populace, water authorities such as DEWA can plan their future water infrastructure needs effectively.

Role of Space

Space based data/service can be used for a wide range of uses. Use of satellite communications (SatCom) can enable real-time monitoring of water usage, alerting agencies to spike in demand. This in turn can lead to applications in integrating digital technologies to support grid balancing in the event of strain being placed on the water grid.

Earth observation (EO) imagery can be used for the tracking of the growth of settlements and the state of the building of water infrastructure such as pipelines. In addition to this, EO can be used to monitor the impact of settlements growth on the surrounding natural environment through pollution monitoring of the water supply. Finally, EO can be used to monitor the level of static water supplies i.e. Reservoirs (when appropriate).

Global navigation satellite services (GNSS) can be used for locating and geo-referencing measurement sites for systems monitoring water infrastructure, adding a level of traceability not available before. GNSS can also be important for service deploying a large-scale internet of things (IoT) system, providing reference sensor information into the monitoring service.

Other technologies can also be supported by the use satellite-based data/services. These examples include (and are not limited to):

- AI/Machine Learning - Supported by IoT devices, sensor networks and big data, AI can be used to predict water usage levels to ensure a stable and efficient grid. AI based applications can be used in combination with SatEO to provide better water level forecasting (e.g. sea-level for desalination plants) techniques that affect the availability of water reserves.
- Hybrid networks, 5G and massive IoT - The formation of hybrid networks where satellite and terrestrial networks can merge, can contribute to the roll out of the massive IoT.
- Digital twins - The ability to digitalise the monitoring and overall performance of infrastructure while introducing IoT, AI, ML and hybrid networks, are elements empowering the concept of digital twins.

2.1.2. Use Case 2: Improving the Efficiency of Agricultural, Residential and Industrial Water Usage

Problem Statement

By having a more efficient water management system, stress on water infrastructure can be reduced to acceptable levels. With growing population levels in the middle east region, this issue is becoming ever more important.

Increasing population levels also lead to an increase in industrial and agricultural activity, both of which are key drivers of water consumption.

Role of Space

Use of space-based services/data can have a large impact on providing disruption to monitoring efficient water usage. For example, SatCom can provide ubiquitous connectivity over a large area allowing for alerts on water usage to be both sent to the water supplier and consumer. In rural areas, SatCom can enable the use of smart meters in regions where terrestrial or cellular connectivity is not necessarily present. GNSS can be used in tandem with SatCom to offer accurate time-stamping and geo-referencing of any sensor data generated.

EO can be used for monitoring of large (nation-wide scale) areas in which it can offer the following benefits:

- Improving agriculture by providing efficient watering regimes.
- Pollution monitoring.
- Flood and drought prevention.

By utilising space-based technology/data, the use of disruptive technologies can be used in synergy to bring added value to this use case. These areas of disruptive technology are:

- Hybrid networks and 5g - The formation of hybrid networks where satellite and terrestrial networks can merge, can contribute to the roll out of the massive IoT.
- Massive IoT – Massive IoT presents the opportunities in the areas of water usage on the micro level (e.g. per individual device), ensuring that limited water supplies are used in the best way possible.
- Blockchain - Can be used to trace the water usage from water grid users e.g., households or small businesses and reward these positive practices with financial schemes or other economic benefits.

2.1.3. Use Case 3: Efficiencies in Wastewater Treatment

Problem Statement

The treatment of wastewater is inherent to a modern water grid and therefore modern society. By securing public health through a reliably clean water supply, this prevents many waterborne diseases from spreading or taking hold within a region. In addition, the safe disposal of wastewater is becoming ever important due to many high-profile cases of too much wastewater entering the clean water system (i.e. rivers and oceans). An efficient and reliable wastewater system stops these problems in their tracks.

Role of Space

Examples of the use of space assets to be used in relation to this use can are (and are not limited to):

- SatCom can be used to:
  - Enable (real-time) remote monitoring (e.g. IoT) of wastewater infrastructure conditions.
  - Enable a faster sharing of large data files containing information on waste management.
  - Provide ubiquitous connectivity when the terrestrial network is not available. (i.e. disaster situations).
- SatEO can be used to:
  - Collect information on geographical and environmental parameters such as status of waste infrastructure.
  - Monitor pollution levels and associated risks to relevant communities.
  - Provide imagery enabling services such as mapping, risk detection, and situational awareness.
- SatNav can be used to:
  - Enable georeferencing for high precision positioning, navigation and tracking people, vehicles,
  - Provide ubiquitous high accuracy PNT technologies to support accurate and seamless positioning provided by GNSS, 5G and other technologies.

These space assets in turn can be used to create services related to the following areas: Monitoring of wastewater infrastructure, wastewater vehicle fleet management, risk management related to wastewater and supplying insights/metrics into the operation of wastewater infrastructure.

2.1.4. Use Case 4: Preventative Infrastructure Maintenance

Problem Statement

Globally, 126 billion cubic meters of water (which equates to a global loss of $187.2B) is lost before it reaches the consumer. Typically, through leaks or poor maintenance of the infrastructure. This loss, in turn deters future investment into water infrastructure assets.

Additionally, as water systems become ever more strained, good maintenance can increase the grid capacity and allow for a more efficient system.

Role of Space

Preventative infrastructure maintenance can see benefits from space-based data/services in the following ways.

SatCom can provide benefits to IoT systems, providing high bandwidth, low latency, ubiquitous connectivity in remote regions. GNNS can be used in tandem with SatCom to provide timestamping and geo-referencing of data, thus providing a higher level of data verification.

EO (not just optical wavelengths) can be used for monitoring of large areas, with a large focus on showing small ground movements, thus highlighting future potential maintenance issues. In addition, large ground movements (landslips) can be detected, showing where targeted infrastructure repair is needed. These lead to the overall use case of monitoring for leaks within the water infrastructure.

GNSS can be used with EO data to provide extra precision in these measurements by geo-locating surface-based reference stations.

2.1.5. Use Case 5: Water Policy Creation & Enforcement

Problem Statement

By creating robust water policy on a national and international stage, the strain on at-risk water grids can be somewhat relieved. However, the strength of water policy is only as good as the enforcement behind it.

By using space technologies, both water policy creation and enforcement can be better informed so that more informed policy decisions can be made.

Role of Space

Part of water policy is that of communication to the relevant stakeholders. SatCom can provide connectivity where terrestrial communications cannot. Therefore, notifying stakeholders of relevant policy review decisions and enforcement notices in areas where connectivity is poor is a possibility. This extends to enabling real-time collaboration between policy makers and enforcement agencies.

Large areas can be monitored using EO, providing relevant ecological and environmental data to ensure water policies are being adhered to. In addition to this, EO provides mapping data to help provide insights into areas such as water risk management and situational awareness for policy makers/enforcers.

GNSS can enable applications in areas such as geo-fencing water assets or provide geo-referencing or timestamping data which is required in water policy enforcement.

2.1.6. Use Case 6: Water Grid Security and Threats to Infrastructure

Problem Statement

With populations increasing and impacts on the environment due to climate change, water resources are becoming ever more strained. Therefore, water authorities are becoming ever more protective over their limited water resources and infrastructure to ensure future water security of their respective populations.

Role of Space

Water security extends to both the tactical (short-term) and strategic (long-term) realms of operation.

For short-term security, SatCom enables secure and reliable communications channels between security personnel during times when the terrestrial network is not available or overloaded (i.e. crisis situations). It also enables the use of UAVs/Drones, in tandem with GNSS, in security applications to help protect water assets. In addition, EO can be used to monitor for large-scale security breaches in remote areas, such as a damaged pipeline. GNSS unlocks applications in which water infrastructure assets can be geo-fenced or enable traceability of the asset. GNSS also enable advanced GIS for spatial information management, including the addition of EO data to monitor risk.

With respect to long term water security, EO data can be used to protect water supplies in two ways: the monitor of natural and environmental parameters to protect clean water sources; and secondly, monitoring the risk of pollution to the clean water supply (i.e. shutting down de-salination plants if algae blooms are present).

2.2. Ofwat: Water Services Regulation Authority

Ofwat is the governmental body responsible for the economic regulation of the privatised water and sewage industry in England and Wales (UK) and in recent years has put an increasing emphasis on the need for innovation to address the urgent challenges the sector faces around climate change, the environment, population growth and water scarcity. The Ofwat Innovation Fund has been established to support the innovation effort in water by:

- Accelerating the creation and roll-out of innovative products, services and concepts.
- Growing the capacity and capability of the water sector innovate; and
- Embedding a culture that values, encourages and supports innovation.

ESA and Ofwat are working together to invite innovators to apply with feasibility studies against a series of use cases to help tackle these key challenge areas for the water sector.

2.2.1. Use Case 7: Water Asset Resilience and Performance

Asset resilience in the UK water sector refers to the capacity of water and wastewater infrastructure, including pipes, treatment plants, pumping stations, and reservoirs, to withstand, adapt to, and recover from a number of key challenges such as climate change impacts, ageing infrastructure, population growth (transient swells and sustained increases), changing societal water consumption behaviours and other factors such as emerging pollutants (microplastics, pharmaceuticals, antimicrobial resistant bacteria, pathogens etc...). This concept encompasses not only the physical durability and operational flexibility of these assets but also their ability to ensure uninterrupted water and wastewater supply and treatment services under a range of conditions from short-term shocks to longer-term systemic stresses.

The UK water sector is increasingly focusing on enhancing asset resilience through investments in network and asset upgrades, adoption of innovative technologies, and implementation of digital, AI-led smart (proactive) maintenance and management strategies. These efforts are crucial for safeguarding water quality, protecting public health, and ensuring sustainable water management in the face of evolving environmental, societal and economic pressures.

Implementation and Operational Context

In the UK water sector, Asset Resilience and Performance technologies are being applied within a context characterised by the urgent need to modernise ageing infrastructure, enhance system efficiency, and address the challenges posed by climate change and other factors that either cause short-term shocks to the system, or more insidious longer-term stresses. The current technological landscape includes advanced monitoring and diagnostic tools, such as AIoT (Artificial Intelligence of Things) systems and sensors and AI-driven analytics, which provide real-time insights into system performance and network and asset health to improve real-time monitoring and predictive maintenance capabilities, enabling proactive identification and resolution of potential issues before they escalate into critical failures.

State-of-the-art solutions enable predictive maintenance, reducing the likelihood of system failures, ensuring continuous service delivery and minimised supply interruptions. The sector benefits from a strong supply chain, comprising technology providers, engineering firms, and academic institutions collaborating to innovate and deliver solutions in these areas of the sector, but pace of adoption and/or change is relatively slow. The integration of digital twins and smart water networks exemplifies how the sector is leveraging technology to simulate and optimise operations, enhancing asset performance and resilience, aiming to extend the lifespan of existing infrastructure, reduce the frequency and impact of service interruptions, and optimise operational performance to meet the growing and changing demands of the population and the environment.

Challenges and Considerations

Any new technology solution that supports asset resilience and performance in the UK water sector will need to understand the current operational asset base and wider infrastructure to identify potential compatibility issues and integration points. Customisation is often necessary to tailor a solution to specific operational needs and differing infrastructure configurations, requiring significant planning, technical expertise and close cooperation from both the asset owner and the innovator. Current challenges include the difficulty of integrating advanced technologies with legacy systems (hardware, operational technologies, IT, software and data), which may lack the necessary interfaces or capacity for new data streams or hardware integration as well as computational and data science skills gaps in AI and smart water applications which can lead to barriers to integrate and onboard novel solutions. High initial costs associated with the adoption of cutting-edge technologies poses a considerable barrier to some water utilities, especially those smaller Water Only Companies (WOCs), where investment in new infrastructure, training, and maintenance can strain the financial resources of water utilities, already grappling with the need to maintain affordable water services. Water companies are given performance incentives or penalties (ODIs) and performance commitments in a number of areas relating to asset resilience - supply interruptions, leakage, supply outage, mains bursts, sewer collapse etc. - and these carry significant fines if targets are not met, therefore innovations in this area can contribute to significant savings and even outperformance rewards for water companies.

Use of Space Assets

Solutions can take advantage of the use of space assets in the following ways:

- SatCom can be used to provide ubiquitous and secure connectivity for deployed sensors which can be used to detect defects or be used for infrastructure monitoring.
- SatEO applications can vary from monitoring large bodies of water (i.e. reservoirs) to ensure the provision of continuous water supply, to monitoring water infrastructure plants on a regional level, and supplying updates on a regular basis.
- SatNav can be used for geo-fencing key water assets, geo-referencing monitors and providing timestamping of monitoring data to ensure data traceability.

These space assets can be used as data sources for AI-ML enabled solutions which provide insightful analytics into the state of the water grid and usage predictions, such that the service is un-interrupted.

Conclusion

The UK water sector presents a significant opportunity for innovations in asset resilience and performance, driven by the imperative to modernise infrastructure, improve efficiency, and respond to the challenges posed by climate change. As the sector grapples with ageing assets, increasing regulatory pressures, and the need for sustainable water management practices, innovative solutions offer the potential to transform how water services are delivered.

Technologies such as advanced monitoring systems, predictive analytics, and smart infrastructure can enhance the resilience of water assets, allowing for more effective asset management and maintenance, reduced costs and ultimately reduced environmental impact. Moreover, by embedding resilience and performance at the core of asset management strategies, the water sector can ensure long-term sustainability and adaptability to future challenges.

Successful technologies should achieve a robust enhancement of infrastructure durability and operational reliability, enabling the system to withstand, adapt to, and quickly recover from disruptions such as extreme weather events, effects of ageing infrastructure, and fluctuating/increased demand pressures. They should ensure the continuous delivery of high-quality water and wastewater services, minimise environmental impact, and contribute to the sector's sustainability goals. Additionally, such technologies will need to integrate seamlessly with existing systems, offering scalability and ease of implementation across diverse operational settings.

By improving predictive maintenance capabilities, it would also reduce downtime and operational costs, while extending the lifespan of critical assets. Ultimately, a successful asset resilience technology is predicated on a proactive rather than reactive approach to asset management, supporting the sector's adaptation to future challenges and ensuring the resilience of water services against the backdrop of a changing climate, growing populations, changing customer behaviours and an evolving regulatory landscape.

2.2.2. Use Case 8: Water Catchment Management

Water catchment management refers to the holistic approach to managing both water quality and quantity within a given drainage basin or catchment area. This encompasses a range of activities and interventions aimed at protecting and enhancing the natural environment from which water is sourced and abstracted, whilst also ensuring the sustainable use of water resources through optimal land use practices. It involves collaboration among water companies, regulators, landowners, farmers, and local communities to implement measures that reduce pollution, mitigate flooding, and restore natural habitats. Practices such as the creation of buffer zones, the restoration of wetlands, and the adoption of sustainable agricultural techniques are common within catchment management programmes.

Implementation and Operational Context

In the UK water sector, catchment management innovations are applied within a context that increasingly recognises the importance of integrated, ecosystem and nature-based approaches to water management.

The current technological landscape features advanced monitoring and analytical tools, including remote sensing (water quality, soil, temperature, flow rates etc.), as well as GIS technologies, and data analytics platforms, which enable precise mapping, assessment, and management of catchment areas as well as support for natural water retention measures, pollution control, and habitat restoration. This facilitates a deeper understanding of hydrological processes, pollution sources, and the impacts of land use changes, allowing for more targeted and effective management strategies and interventions. The goals of implementing such technology include improving water quality, reducing the incidence of flooding and drought, and mitigating the effects of pollution from agricultural runoff and other sources. Catchment management innovations, such as advanced monitoring systems, predictive analytics, and nature-based solutions could significantly improve the sector's ability to manage water resources more effectively and efficiently. These technologies offer the potential to better understand and predict hydrological changes, optimise water use, and support the restoration of natural habitats within catchment areas.

The sector is seeing a rise in collaborative partnerships that bring together water companies, environmental agencies and Non-Governmental Organisations, landowners, and community groups (citizen science) to co-develop and implement catchment management solutions. This collaborative approach is supported by a strong policy foundation, emphasising the need for sustainable water management practices that protect resources and biodiversity (Environment Act 2021, Water Industry National Environment Programme (WINEP), Environmental Land Management (ELM) and Farming Rules for Water are among a range of important policy drivers).

The convergence of advanced technology, increased investment, collaborative stakeholder engagement, and supportive policy creates fertile grounds for the adoption of catchment management innovations, aiming to enhance water quality, ensure sustainable water supply, and contribute to the resilience of water ecosystems in the face of climate change and urbanisation pressures.

Challenges and Considerations

The deployment and onboarding of new catchment management innovations in the UK water sector involves a great deal of stakeholder engagement, ensuring that landowners, farmers, local communities, and regulatory bodies are involved in the planning and decision-making processes. This collaborative approach fosters shared responsibility and commitment to sustainable water management practices. Education and training programmes are also essential for building understanding and capacity among stakeholders to adopt and maintain new practices, especially among farming communities and citizen-led initiatives.

The deployment of catchment management innovations demands not only technological solutions but also adaptive management practices and strong collaborative networks. The geographical scope and complexity of catchment areas can pose significant technical challenges, from data collection across vast and varied terrains to the analysis of complex environmental interactions.

Use of Space Assets

Space assets can be used to tackle this challenge in some of the example (but not limited to) ways:

- SatEO can be used for the monitoring of run-off in a certain water catchment, allowing for easy, region-scale monitoring, looking at several different environmental factors such as water quality, soil, flow rates, etc… In addition, SatEO can be useful for policy creation and enforcement, providing a top-down view of a regional area, providing key environmental metrics to policy decision makers.
- SatNav can be used for geo-location, underpinning GIS technologies, feeding into more accurate models of the water catchment area.

Conclusion

The opportunity for catchment management innovations in the UK water sector is considerable, with water companies demonstrating their priority with a marked increase in investment in the AMP8 regulatory period (2025-30). Innovations in this area present a chance to revolutionise water management practices, moving beyond traditional infrastructure-focused approaches to embrace holistic, ecosystem-based strategies that consider the entire water cycle and its interconnections with land use, climate change, and human activity. By leveraging advanced technologies such as remote sensing, data analytics, and nature-based solutions, the sector can enhance water quality, increase resource efficiency, and improve resilience to extreme weather events. Furthermore, these innovations offer a platform for unprecedented collaboration among stakeholders, including water utilities, regulatory bodies, environmental organisations, landowners, and communities, fostering a more integrated and cooperative approach to water management.

Successful catchment management innovations in the UK water sector should achieve comprehensive, sustainable management of water resources across entire catchment areas, addressing both quality and quantity of water. They should facilitate the integration of environmental, social, and economic considerations, enabling the sector to meet current needs without compromising the ability of future generations to meet theirs. By fostering collaborative partnerships among stakeholders, including government agencies, water companies, landowners, farmers, and communities, these innovations should create a shared sense of responsibility and collective action towards water stewardship. Moreover, they should offer scalable and adaptable solutions that can be customised to the unique characteristics of each catchment, while also being cost-effective and compliant with regulatory standards.

2.2.3. Use Case 9: Drinking Water Quality

Drinking water quality in the UK is regulated by stringent guidelines and monitored by dedicated agencies such as the Drinking Water Inspectorate (DWI) in England and Wales, Scottish Water in Scotland, and the Drinking Water Inspectorate for Northern Ireland. Drinking water quality directly impacts public health, as ensuring the water is free from contaminants and pathogens is essential to prevent waterborne diseases and safeguard the wellbeing of the population. High-quality drinking water supports the overall health of communities, reducing the burden on healthcare systems by preventing illness.

Maintaining stringent water quality standards fosters public trust and confidence in the water supply, which is vital for the social and economic wellbeing of the country. Thirdly, it aligns with environmental sustainability goals, as protecting water quality necessitates preserving natural water sources and ecosystems from pollution and degradation. Despite the high quality of drinking water, challenges such as ageing infrastructure, pollution, and climate change-induced variability in water availability pose ongoing risks that the sector must manage to sustain these standards. The commitment to maintaining high-quality drinking water reflects the sector's broader dedication to public health, environmental protection, and customer satisfaction.

Implementation and Operational Context

In the UK water sector, drinking water quality is shaped by stringent regulatory standards, growing environmental concerns, and an increasing emphasis on sustainability and customer satisfaction. The regulatory frameworks which drive these standards are in alignment with EU directives (now adapted into UK law post-Brexit) and WHO guidelines, ensuring that water supplied to consumers is safe, clean, and free from contaminants.

The UK water sector employs advanced treatment processes, including filtration, disinfection, and chemical adjustment, to remove pathogens, chemical pollutants, and manage water hardness, thereby maintaining the purity and taste of drinking water. Continuous monitoring and rigorous testing are conducted at various stages of supply, to assure compliance with health and safety standards. The current technological status quo encompasses advanced treatment processes such as membrane filtration, ultraviolet (UV) disinfection, and granular activated carbon (GAC) filtration, which represent the state of the art in removing contaminants, pathogens, and ensuring the safety and palatability (taste and odour) of drinking water. The sector is increasingly looking at its abstraction and raw water management processes, leveraging catchment management and nature-based solutions to increase the quality of the water upstream of its treatment assets, to minimise treatment costs and energy, whilst improving the natural environment.

Continuous Water Quality Monitoring, largely driven by recent legislation mandating water companies continuously monitor water quality upstream and downstream of CSOs (Combined Sewer Overflows), is an emerging technology opportunity for sensing hardware as well as soft sensing and broader AI applications, relaying river quality and health data in real-time, 15-minute and hourly rates.

Challenges and Considerations

Introducing drinking water quality innovations into the UK water sector can be challenging with several prominent regulatory hurdles, especially if locating a technology solution in an “in-pipe scenario”, with complex and stringent standards and approvals from bodies such as the Drinking Water Inspectorate (DWI), also ensuring compliance with both national and wider EU regulations. With public health at risk, the UK's regulatory framework for water quality is among the most rigorous in the world, requiring any new technology to undergo extensive testing and approval processes to prove its efficacy and safety. This can result in lengthy delays in adoption and significant upfront costs for innovation developers.

The UK's drinking water infrastructure is vast and often ageing, making the integration of new technologies logistically challenging and costly. Innovations need to consider compatibility and integration with existing systems - especially when dealing with network assets and data. Reliability, replicability, repeatability, and scalability are crucial to consider when designing a solution in this field. To overcome these challenges and scale successfully, innovations must offer compelling evidence of their benefits, align with regulatory requirements and industry standards, and provide flexible implementation options that can adapt to the diverse needs of water utilities across the UK.

Public perception and trust are increasingly a consideration of any new approach to innovation in drinking water quality - treatment, detection, monitoring etc.- given the prominence of this topic in the media and political spheres. Water customers and users are increasingly sensitive to issues of water quality. Overcoming these challenges requires a multi-faceted approach, including robust pilot studies, strategic partnerships, and comprehensive stakeholder engagement strategies to demonstrate the efficacy, safety, and economic viability of any innovation.

Use of Space Assets

Space assets can potentially be applied to this use case in the following (but not limited to) ways:

- SatCom can be used for providing IoT monitoring devices and a constantly available communication channel to send data back to a central location. In addition, the main benefit of SatCom is that it provides ubiquitous connectivity. I.e. SatCom can provide coverage where terrestrial cell networks cannot. Edge-computing devices take particular advantage of SatCom as they are able to pre-process data before it is sent back to a central server.
- SatEO provides advantages in the areas of regular, regional scale monitoring, providing an overview of the situation to key decision makers. It can be used to monitor environmental parameters such as water pollution, soil quality, infrastructure plant monitoring, etc…
- SatNav can be applied to this use case by providing timing and geo-location services to IoT devices. The IoT devices can be both geo-located and geo-fenced to a specific location. Timing data can be used to synchronise a network of IoT devices, ensuring that the data produced is traceable.

Conclusion

The UK water sector presents a significant opportunity for drinking water quality innovations, driven by the imperative to ensure safe and wholesome water with sustainable and efficient supply mechanisms, in the face of evolving environmental challenges and increasing regulatory scrutiny. With the growing concerns over pollutants, such as microplastics, pharmaceutical residues, and new chemical contaminants, there is a pressing need for new technologies that either disrupt or enhance current practice. These innovations are vital not only for safeguarding public health but also for enhancing the resilience of water systems against climate change impacts, including increased rainfall variability and the risk of droughts.

Furthermore, as the population grows and urbanises, the demand for clean drinking water continues to rise among households and businesses, underscoring the importance of scalable and sustainable solutions. Innovations in this field can lead to more effective resource management, reduce the environmental footprint of water treatment processes, and contribute to the broader goals of sustainability and carbon neutrality.

2.2.4. Use Case 10: Reducing Leakage Lost from Potable Water Distribution Systems

Water companies in the UK are responsible for ensuring customers have access to wholesome drinking water at their properties. This involves managing a vast network of potable water distribution mains, many of which are well over 50 years old, some over 100 years old. Currently it is estimated that over a fifth of water that enters these systems is lost through leakage, and whilst companies have gone a long way to drive this figure down, there is still work to be done in order to meet future demands. Leakage measurement involves calculating the difference between water supplied and water delivered, with adjustments for unmetered properties and other uses like firefighting. Water companies face annual leakage targets, with financial implications for non-compliance. Regulatory targets set by Ofwat outlined an average 16% reduction in leakage being required from a 2018 baseline over the period from 2020 - 2025, with the latest business plan submissions proposing taking this to an average 31.2% reduction against the same baseline by 2030.

Innovations can help address leakage across all stages of the PALM (Prevent, Aware, Locate, Mend). From innovative solutions for preventing the formation of leaks, to smart devices and data solutions that can raise awareness of leaks and their locations or solutions targeted at helping mend leaks quickly and efficiently without the need for large excavations.

Implementation and Operational Context

Innovation can be used to help address leakage across a wide range of areas including prevention, raising awareness, locating losses, and repairing infrastructure. Depending on whether the solution is invasive or non-invasive, digital, or physical will impact the deployment context.

Physical sensors are most likely to be deployed in contact with the existing infrastructure, either buried next to pipelines, or in contact with water at specific access points such as hydrants, customer metres or inspection chambers. The sector has increased its deployment of smart water technology over the last decade with many companies now using large volumes of acoustic, pressure and flow sensors throughout their distribution systems to help them better understand how they are operated and where issues might arise. New solutions are needed to be less reliant on ground investigations to accurately locate leaks to less than 1m as well as solutions for quickly and efficiently conducting targeted repairs without impacting customers' water supply.

Challenges and Considerations

Integrating leakage innovations into existing water sector infrastructure can be a challenge, particularly due to the diverse and often outdated nature of current systems and supporting data. Some of the following considerations need to be made when developing solutions for the market:

- **Diverse, patchwork of infrastructure** - the water distribution network has been updated and repaired incrementally across its lifecycle and as a result is now built from a wide range of materials, sizes and ages.
- **Inaccurate or outdated datasets** - As a result of its incremental upgrading, data about buried assets such as pipelines may not be accurate and is often outdated.
- **Repair speed** - leak repairs need to be made with minimal impact to customer supplies in order to not impact other performance commitments. As such, repairs need to be made quickly or whilst the system remains pressurised.
- **Impact on water quality** - intrusive solutions that are intended to be used in contact with the water must be made from approved materials (DWI Regulation 31) and must

not introduce additional water quality risk by dislodging sediment that has built up in pipes.

- **Detection accuracy -** To repair leaks as efficiently as possible, water companies need to be able to pinpoint its location to an accuracy of roughly 1m. Ground investigations can be used to narrow down on locations prior to digging but this makes activities more resource intensive.
- **Data transmission -** physical sensors are likely to be deployed underground and often under heavy metal covers that impact data transmission.

Use of Space Assets

Space-based data sources/services can provide the following (but not limited to) benefits:

- SatEO can be used to detect leaks over a regional-size area. It can also be used as a data source to predict where water leaks may occur. I.e. Through the monitoring of land slippage.
- SatNav can be used for navigation of technologies such as robotics or drones which can be used to monitor the network for leaks or to pinpoint leak sources, in turn increasing the repair speed.
- SatCom can be used to communicate remotely with infrastructure monitoring devices such as remote drones or IoT devices in remote locations where terrestrial cellular network coverage is poor. SatCom can provide real-time data from devices installed to monitor the water grid to ensure that leaks could be detected and diagnosed with the shortest delay possible.

Conclusion

Despite significant efforts by water companies to reduce leakage, over a fifth of water entering distribution systems is still lost, underscoring the urgency to enhance efficiency to meet the challenges posed by climate change, sustainability goals, and regulatory pressures. Ofwat's regulatory targets, demanding a 16% reduction from a 2018 baseline by 2025, and aspirations to achieve a 31.2% reduction by 2030, highlight the critical need for innovation.

Advancements in smart water technology, including acoustic sensors, satellite imagery, AI analytics, and non-invasive repair techniques, present promising avenues to detect, locate, and repair leaks more efficiently. These technologies aim to complement and enhance traditional methods, focusing on prevention, awareness, leak location and minimally disruptive repairs. There is significant opportunity to leverage technology developed for space, to help solve the challenges posed by terrestrial leakage. Solutions that enable accurate location of leaks, as well as fast and non-intrusive repair will help the sector to secure long-term water supply for the country.

2.2.5. Use Case 11: Operational Carbon Reduction

Operational carbon reduction in the UK water sector refers to the strategies and practices implemented to decrease carbon dioxide and other greenhouse gas (GHG) emissions produced during the day-to-day operations of water and wastewater treatment facilities and networks. This encompasses a wide range of activities, from the energy-intensive processes of pumping, treating, and distributing water, to the management of wastewater and sewage. Given the sector's significant energy usage, efforts to reduce operational carbon focus on increasing energy efficiency, adopting renewable energy sources, implementing advanced, less energy-intensive treatment technologies, and optimising system operations to minimise energy consumption.

Implementation and Operational Context

In the water sector, operational carbon reduction technologies are being applied across the entire operational cycle from raw water collection to effluent disposal against a backdrop of regulatory, customer and financial pressure as well as the sector-wide recognition of the need to mitigate climate change impacts. The current technological status quo includes (but is not limited to) advanced treatment processes that are energy-intensive, such as reverse osmosis and activated sludge systems for wastewater treatment, aeration, and disinfection of drinking water, as well as other processes that include pumping, heating and/or gaseous exchanges. While these technologies represent the state of the art in ensuring water quality and availability, they also contribute significantly to the sector's carbon footprint. The urgent demand for carbon reduction calls for innovative solutions that can:

- Optimise energy use.
- Incorporate renewable energy sources.
- Employ novel, less energy-intensive treatment technologies.
- Sense (remotely) and measure fugitive emissions from both water and wastewater treatment processes at sufficient resolution (spatial and temporal).

The goal of implementing operational carbon reduction technology in the water sector is to meet the sector-wide target of Water Companies achieving “Net Zero” by 2030, for Scope 1 & 2 emissions[1], as well as reducing operational TOTEX spend, whilst maintaining the service expected by its customers, society, and the environment.

Challenges and Considerations

The deployment and onboarding of new carbon reduction technologies in the UK water sector can be challenging, given the complexities of navigating key regulatory frameworks, as well as integrating with existing water and wastewater treatment, processing, and management systems. A further challenge that is likely to be encountered is ensuring compatibility between new technologies and legacy infrastructure, to achieve seamless integration. This process could require substantial resources and capital investment for technology adoption and modification of existing facilities.

Successful implementation of carbon reduction innovations will often also hinge on the availability of skilled professionals to train and be trained in the latest techniques and technologies. Stakeholders involved in this use case include water utility companies, technology providers, regulatory bodies, and, dependent on the solution, water customers themselves whose support and acceptance could be critical for the adoption of new practices.

Technical limitations of new technologies - scalability and/or reliability issues - as well as how these new technologies integrate with existing processes (not negatively impacting the effectiveness of key processes, particularly biological treatment - as seen when covering tanks with hoods to capture fugitive emissions for example) can cause challenges and the cost implications of deploying advanced systems, represents additional hurdles.

Use of Space Assets

Space-based data sources/services can help in operational carbon reduction in the following example ways:

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[1] Scope 1 emissions are direct emissions from owned or controlled sources - e.g. GHG released into the atmosphere because of activities such as the combustion of fuels for heating or vehicular use within the operations of water and wastewater treatment plants, as well as any fugitive emissions from the treatment processes themselves.

Scope 2 emissions are indirect emissions from the generation of purchased energy - e.g. emissions from the electricity used to power equipment, facilities, and any other energy-consuming processes involved in the treatment, pumping, and distribution of water and the treatment of wastewater.

- SatEO – Suitable for monitoring the operational carbon emissions from water infrastructure plants and its impact on the surrounding environment. This data can then be used for highlighting key areas where improvements can be made. Example parameters to be measured include: Methane emissions, CO2 emissions and other environmental parameters.
- SatCom can be used to:
  - Enable (real-time) remote monitoring (e.g. IoT) water infrastructure emissions.
  - Enable the use of security UAVs/robots in areas which are remote or in a harsh environment to help with issues such as maintenance.
- SatNav provides benefits through its timing and geo-location service. Timestamping of data produced by IoT monitoring devices can be key in ensuring data traceability. Geo-locating and geo-fencing assets can be important when using technologies such as digital twins to help decrease the operational carbon of water infrastructure plants.

Conclusion

The UK water sector presents a significant opportunity for operational carbon reduction, driven by the imperatives of environmental sustainability, regulatory compliance, and economic efficiencies. With the sector being a notable consumer of energy, primarily due to the intensive processes involved in water and wastewater treatment and distribution, there's substantial scope for implementing energy-efficient technologies and practices.

A successful carbon reduction technology should achieve a significant decrease in GHG emissions, contributing markedly to the sector’s Net Zero ambitions, whilst ensuring economic viability and operational efficiency. It should integrate seamlessly with existing systems, offering scalability and flexibility to adapt to various operational scales and contexts. Beyond the immediate environmental benefits, the technology should also enhance energy efficiency and reduce operational costs. Importantly, it should be accessible and adaptable, allowing for widespread adoption across different operational contexts and legacy systems. Whole life carbon must be considered, to ensure not only the useful life of a technology is accounted for, from a carbon perspective, but also its onward use and disposal.

2.2.6. Use Case 12: Pollution and Sewer Flooding

Wastewater (also termed sewage) is conveyed from properties to the treatment works (WwTW) via a series of pipes called sewers. These sewers can transport sewage only (“separate sewers") or they might also transport rainwater and runoff ("combined sewers"). Storm overflows, including combined sewer overflows and storm tank discharges at wastewater treatment works (WwTW), are designed to discharge dilute but untreated sewage into the water environment. This is done during particularly heavy rains to prevent sewage backing up into properties or overwhelming WwTW. Sometimes there can be issues with the sewers that means sewage is spilled into the environment, or even backflows into customers' property. The reasons for this can be simplified into the following:

- Bursts or failings in the sewer structure which releases sewage into the surrounding environment by seeping up through the ground.
- Blockages in the sewer due to a buildup of debris, fats, wipes and other material which prevent the sewage from passing through. This can cause the sewage to back up, including into properties.
- Releases from a storm overflow when it isn't raining, due to groundwater intrusion into the sewer or a pump failure within the sewer network (for example).

Implementation and Operational Context

The topic area encompasses a wide range of potential technological solutions, and there are a range of products already available on the market. There is a particular need for solutions in the following areas:

- Condition assessment to identify sewers which may be close to failure, and to identify the condition of pumps before they fail, in particular those which are low cost, reliable and provide accurate early warnings.
- Sewer rehabilitation and repair to prevent bursts and releases, in particular solutions which are "no dig" i.e. can be used without taking out a pipe or causing disruption to the land above the sewer.
- Valves and the use of other technology to prevent backflow into customer's properties, especially solutions which require no maintenance or operation from a customer.
- Blockage detection, before it is large enough to cause an issue and in particular solutions which can be placed in a sewer to provide early warnings of issues.
- Blockage reduction and destruction and in particular, in sewer solutions which don't require manual intervention. It is worth noting there are several products on the market that claim to be able to prevent blockages through the use of enzymes, microbial dosing

and similar. Tests to show the efficacy of these have been limited and such products are often viewed as only being applicable in limited and specific sites.

- Blockage prevention, generally through education but can also be through flushing technologies or interventions before discharge to sewer.

Within the water company business plans for the next investment cycle (AMP 8) there are targets to reduce flooding and pollution events. It is a key metric for performance within the water companies, and one that very much captures the public's attention. There is therefore an urgency for water companies to act within the next five years.

Challenges and Considerations

Within the water sector, a trial is generally required before any solution will be deployed. Such trials will look at not only the performance of a technology, but also its operational requirement, maintenance needs and how easy it is to install or dismantle.

Any solution which is placed within a sewer must be able to operate in an environment where there can be hazardous gases such as methane and hydrogen sulphide. Sewage can contain rags and items which can snag on equipment or even any rough edges in a sewer. Any solution placed within a sewer needs to demonstrate that it will not cause an issue, for example by encouraging a blockage.

Gaining access to a sewer to deploy a solution can be a challenge. There are manholes placed along a sewer and the distances between them will vary from sewer to sewer. Some manholes are within roads or streets, and some may be in remote fields. All are classified as confined spaces and require certified staff to operate within them.

Use of Space Assets

Space assets can assist in the prevention of flooding wastewater in some of the following ways:

- SatEO via non-invasive techniques could possibly detect where leaks and blockages are occurring allowing for a rapid response to fix these issues. In addition, SatEO can also monitor the impact of any wastewater flooding on the surrounding environment through monitoring environmental parameters such as water quality. Finally, SatEO can help predict when surges due to inclement weather can occur through providing weather data to digital twins of the sewer network.
- SatCom can help maintenance teams communicate back to the control room in the event of a crisis and enables the use of robotics in harsh environments (i.e. outdoor wastewater plants). In addition, SatCom can be used to enable the use of IoT devices

which can be used to measure wastewater overflow in remote locations where cellular networks are not available.

- SatNav enables the navigation of robotics or other unmanned vehicles in harsh environments (i.e. a sewer). These robots can then be used to clear blockages or perform maintenance if required. In addition, SatNav can be used for the geo-location of wastewater overflow sensors, and in tandem with SatCom, this data can then be timestamped due ensure data traceability.

Conclusion

Within the theme of pollution and sewer flooding there are opportunities for the development of technology that will enable water companies to reduce and ultimately cease any unintended discharges. To do this, there needs to be consideration over how such discharges and pollution can be prevented in the first place, how any issues can be quickly identified (and ideally before any pollution occurs) and how rapid responses can be enacted.

2.2.7. Use Case 13: Storm Overflows

Storm overflows, including combined sewer overflows and storm tank discharges at wastewater treatment works (WwTW), are designed to discharge dilute but untreated sewage into the water environment. This is done during particularly heavy rains to prevent sewage backing up into properties or overwhelming WwTW. The Environment Act was introduced at the end of 2021 placing further duties and responsibilities on English water companies, regulators, and the government in terms of reducing environmental impacts including the reduction in use of storm overflows. The Act also includes the requirement to monitor all storm overflows in England. As of the end of 2023, all storm overflows had been fitted with Event Duration Monitors (EDMs), EDMs show when an overflow is discharging and how long for.

EDMs do not provide any data on the impact of the discharge on the environment, or what the discharge contains. Under Section 82 of the Environment Act, sewerage undertakers (i.e. water companies which convey and treat sewage) must continuously monitor the quarter quality upstream and downstream of a storm overflow, for: levels of dissolved oxygen, temperature and pH values, turbidity, levels of ammonia and anything else as specified in regulations made by the Secretary of the State.

Implementation and Operational Context

EDMs and any other monitoring equipment is placed within or near to storm overflow discharge points. With around 15,000 overflows in England, this is a substantial number of monitors. Many of these sites are remote, and only accessible on foot. There is rarely any power available on site, and Wi-Fi connectivity can be low. Therefore, monitors need to be self-sufficient in terms of power and any data communication. The intermittent nature of storm overflows means that the monitors may sometimes be dry and other times submersed in water. This water can sometimes contain debris such as twigs, grit and rags. Being able to continue to operate in these conditions is crucial.

Whilst there are many EDM available on the market, there is still a need for low-cost monitors which includes solutions which have an extended life span, reduced maintenance requirements, and which require no external power source. Providing a reliable and accurate reading is imperative, and something which can be improved upon compared to conventional EDMs which can go offline or provide false alarms.

With a need for the monitoring of water quality upstream and downstream of a storm overflow coming into play under the Environment Act, technologies which provide an integrated solution to EDMs and water quality could be of interest to the sector.

Challenges and Considerations

With any monitor or sensor that is placed within the environment, the key challenges are:

- Self-sufficient operation .
- Battery life.
- Connectivity to relay signals and data back to a central location.
- Low maintenance requirements.
- Vandalism proof, and robust enough to operate in flows which may contain debris and rags.
- Able to operate in dry and wet conditions.

Any monitor will need to be able to communicate with the existing systems within a water company, providing the raw data in the correct format. The required format may vary from one water company to another. Business models where the raw data is not owned by the water company tend not to be popular.

Use of Space Assets

The main benefit of SatCom is that of ubiquitous connectivity, when used in tandem with edge computing, **SatCom** can be used efficiently to save on both power and data sent via Satellite.

In addition, SatCom is also available during high-stress situations (i.e. a storm) so data can be always relayed back to a central station and in real-time.

SatNav can be used to geo-locate and geo-fence devices for two reasons. Geo-location devices can be used to ensure they are installed in the right place. Geo-fencing can then ensure that these devices are not being tampered with and being moved. Time referencing of the data produced can also lead to a high degree of data traceability.

EO could possibly be used for the prediction of events in which wastewater is discharged (i.e. a storm).

Conclusion

There is a growing need for robust and accurate monitors for storm overflows. Although there is currently a high level of coverage across England, there will be a requirement for the next generation of monitors - those which provide higher levels of accuracy, and which can potentially provide additional data beyond the duration of a spill event. Given the number of monitors that are deployed, cost is an important factor, alongside good and quick availability of supply of the monitors themselves and any component parts should replacements be required.

2.3. Servicio Meteorológico Nacional (SMN) & Comisión Nacional del Agua (CONAQUA), Mexico

2.3.1. Use Case 14 – Monitoring of Agricultural Areas to Determine Irrigation Requirements

To predict future water needs, the planning of water use within areas of high-water usage is required. One key area for this are those regions that have been identified to be agricultural areas. More specifically, irrigation districts where constant irrigation of the crops is required.

In helping government agencies (and their related districts and irrigation units), this product/service shall help guide the use in making the relevant decisions using space-based technologies to help predict water demand.

The final product/service shall be easy to access on a web viewer platform but also be able to provide the required outputs in an easy-to-use format to allow for the results to be consulted quickly and effectively.

2.3.2. Use Case 15 – Impact/Monitoring Flooding due to Hydrometeorological Phenomena

Some areas of Mexico are at risk of flooding more so than others. Space assets can provide the images and the precise localization required for decision-making and identification of urban or agricultural areas affected by flooding caused by hydrometeorological phenomena, such as tropical cyclones. In addition, the monitoring of hydrometeorological events for disaster prevention and early warning is required.

By integrating space-assets, the resulting system shall allow for the consultation and retrospective spatial monitoring for the prediction and projection of hydrometeorological events which pose a flooding risk to Mexico.

The users can be both government agencies that are dedicated to the management of plans and procedures that involve an area of interest, as well as individuals. This as support for decision-making in the face of natural phenomena.

The final product/service shall be easy to access on a web viewer platform but also be able to provide the required outputs in an easy-to-use format to allow for the results to be consulted quickly and effectively.

2.3.3. Use Case 16 – Dam Monitoring to Support Decision Making (CONAQUA Only)

The failure of a dam, causing a large body of water to flood into a valley can cause catastrophic damage and a large loss of life. To help prevent disasters such as these, constant monitoring of dam infrastructure is required throughout the year. By using satellite imagery and displacements monitoring techniques augmented with technologies such as AI or deep learning, this use case addresses the need for the monitoring of the 210 main dams within Mexico. Areas of interest within this use case are in the case of hydrometeorological phenomenon prediction to ensure dam damage is not at risk and to support operational decision-making.

Currently geographic information systems such as NOAA information, satellite images and forecast models such as the GFS and WRF are used. In addition, meteorological, climatological, and hydrometric stations through CONAGUA's Hydrological Information Systems (SIH) are used to augment the data collection system.

The main users of this product/service would be Civil Engineers, Hydrologists, Meteorologists and Geo-informaticians whose responsibilities would include the safe operation of dams within Mexico.

Key aims of the proposed product/service are a safe and efficient monitor of the dam's infrastructure in the presence of any hydrometeorological phenomenon and the delivery of mapping flood zones throughout the country.

2.3.4. Use Case 17 - Monitoring of Water Quality at a National Level (CONAQUA Only)

Monitoring of water quality is required not just for public health but to also ensure future water security. This use concerns both the monitoring of water quality in both coastal and continental waters within Mexico.

Currently, water quality surveillance is done through manual measurements and carried out by the National Network for Water Quality Measurement (RENAMECA). However, by taking advantage of the use of space applications to obtain precise, continuous and "real" time information, a product/service is required to diagnose the water quality of coastal and inland waters in Mexico to help augment the RENAMECA service.

It is proposed to evaluate water quality through space-based techniques integrated with terrestrial technologies, with the aim of obtaining results at regional scales quickly, efficiently and economically in real time. In addition, temporal resolution in different seasons throughout the year is required. This use of space technology makes possible to analyse small or extensive areas, reducing analysis time and costs and facilitates the analysis of certain parameters in bodies of water, such as: chlorophyll a, transparency, total suspended solids, among others.

The proposed product/service would be delivered through an online portal, ensuring that key decisions can be made effectively and efficiently. In addition, a manual and training must be provided to ensure smooth operation of the proposed system.

The use of data regarding the water quality on the surface and underground from 2012 to 2022 at the national level generated by the National Water Quality Measurement Network can be used for the calibration of the models proposed.

Planned users of the proposed product/service would be mainly technical personnel specialising in water quality administrations.