The Use of Sub-Seasonal Forecasting to Improve Operational Decision Making

(Project Report)

Final

Thames Water Utilities Limited
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Executive Summary

The project, *"The Use of Sub-Seasonal Forecasting to Improve Operational Decision-Making,"* aligns with Ofwat's strategic innovation themes, addressing long-term operational resilience, proactive environmental management, and the adoption of innovative practices to benefit customers, society, and the environment. This project focused on bridging the gap left by traditional weather forecasting systems, which often provided insufficient notice for operational adjustments, leading to inefficiencies, increased risks, and potential environmental impacts.

The project served as a foundational step in strengthening the water sector's preparedness for extreme weather events by developing innovative sub-seasonal (up to 4 - 6 weeks ahead) forecasting models for predicting water demand and priority waste alarm events. By introducing advanced forecasting capabilities, the project enabled all participating water companies to anticipate and respond to extreme weather events more effectively, enhancing resilience, operational efficiency, and environmental protection in a rapidly changing climate.

The project's two primary work streams were successfully developed and delivered:

1. **Forecasting Water Demand**: Enhancing existing clean water forecasting systems to optimise production, storage, and maintenance planning.
2. **Wastewater Alarm Prediction**: Conducting feasibility trials for using sub-seasonal forecasting to predict priority waste alarm events.

Leveraging the Met Office's advanced forecasting tool, Decider and working closely with water companies and subject matter experts, the project successfully developed and tested tailored forecasting models. Key outputs include:

- **Clean Water Sector Models**: Enhanced tools for operational planning, improving scheduling efficiency, optimising resource allocation, and identifying low-risk periods for maintenance.
- **Wastewater Sector Trials**: Demonstrated feasibility for predicting priority alarm volume spikes or peaks, potentially, enabling earlier proactive responses to critical issues and informing future development.
- **Scalability and Collaboration**: Testing and scaling models with data from all participating companies provided valuable insights for tailoring solutions to diverse regional needs.

The project delivered immediate benefits across multiple areas. For customers, it improved service reliability and reduced interruptions. For society, it enhanced preparedness for extreme weather events, minimising environmental risks and potential reputation damage. Additionally, for the environment, it enabled proactive resource management and reduced ecological impacts, contributing to greater sustainability.

In the clean water sector, the models significantly improved resilience, preparedness, and operational efficiency. In the waste sector, while the feasibility trial was promising, further work is proposed to refine and expand these capabilities, enhancing resilience in critical operations.

The integration of forecasting tools into operational workflows remains a key priority to unlock their full potential. Collaborating with digital technology teams will ensure that outputs are effectively embedded, highly visible and readily accessible for decision-making. This integration will drive informed planning, operational efficiency, and improved decision-making across the water sector, supporting long-term sustainability and resilience.

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Introduction

Summary Details: The project, titled *"The Use of Sub-Seasonal Forecasting to Improve Operational Decision-Making,"* was awarded funding under the Ofwat Innovation Fund through the Water Breakthrough Challenge 02 (WBC 02). The project was aimed to enhance the water sector's resilience to extreme weather events by developing sub-seasonal forecasting models for water demand prediction. Additionally, it explored the feasibility of utilising these models to address operational challenges in the wastewater sector. By leveraging the Met Office's Decider tool and industry expertise, the project focused on optimising resource planning, improving scheduling efficiency and supporting proactive environmental management, thereby fostering sustainable and resilient water and wastewater operations.

Programme: The project officially commenced on 1st January 2023 and is set to conclude on 31st March 2025, spanning a duration of 27 months. It was structured into four distinct phases. The first phase focused on establishing the project framework and collecting input data for the trial services. In the second phase the forecast services were set up for both work streams and calibrated for each Partner. The third phase was to conduct the trials for 12 months, to be able to capture performance data for both extremely warm and cold weather events. Finally, in the fourth phase, that run parallel with the third phase's last 6 months, the trial services were refined for both water demand and wastewater operational challenges and that phase was also centred on evaluating outcomes, disseminating knowledge, and preparing for project closure.

The primary focus of the work was on water demand forecasting, which accounted for approximately 80% of the overall effort. This involved developing and optimising predictive models to enhance planning, reduce operational delays and optimise asset management, ultimately improving efficiency and cost savings. The remaining 20% of the work was dedicated to an exploratory trial on waste alarm volume forecasting.

At completion, the project's total cost amounted to £796,584 fully funded through the Ofwat Innovation Funding Stream. This includes contributions of £678,750 from Ofwat funding and £117,834 from project partners. Any future costs related to the project will be considered as Thames Water's in-kind contribution.

Intellectual Property Rights (IPR): The IPR arrangements shall be in accordance with the Ofwat Innovation Fund Collaboration Agreement (under Specific Background IPR). The Decider product has not been charged for over the course of the project, including the one-year trial of the water demand and waste alarm volume forecasting tools. However, following the trial period companies that wish to continue use the models operationally would need to pay for the Decider forecasts and agree a license with the Met Office.

IPR arrangements will be finalised through continued engagement with stakeholders to ensure mutual understanding and agreement on usage rights, ownership and responsibilities. Over the coming months, this process will aim to establish clear, consistent and transparent terms that support long-term operational use of the tools. These arrangements will be aligned with internal governance policies and broader industry standards, providing a solid foundation for collaboration and future development across all participating organisations.

Links to Other Ofwat Innovation Fund Projects: This project is a standalone initiative; it doesn't share synergies with other Ofwat Innovation Fund projects focusing on predictive modelling and resilience-building within the water sector. The exploratory work in the wastewater work stream helped us to seek further funding to expand and operationalise the short range (<15 days) models in a future project. This initiative also aligns with related innovation efforts in the sector, enhancing its impact and fostering collaboration.

We recently submitted a follow-on funding application (Water Breakthrough Challenge 5) aimed at advancing innovation in operationalising waste short-range forecasting. Unfortunately, we were not selected for funding on this occasion. We are now considering options for future funding. Further funding support remains vital to progress this work from an exploratory stage to a business-as-usual (BAU) tool. The insights and data gathered during this exploratory project have provided a robust foundation, clearly demonstrating the technical feasibility and practical benefits of these models. This groundwork not only validates the potential for short-range forecasting but also acts as a catalyst for further innovation across the sector.

By integrating our findings with broader innovation initiatives across the waste network and at operational sites, we are positioning ourselves to significantly enhance overall impact. This collaborative approach is designed to foster synergies among related projects, ensuring that best practices and emerging technologies are shared widely to improve efficiency and resilience.

In summary, although the current waste project is primarily exploratory, its promising initial outcomes are paving the way for a new phase of development. The proposed short-range forecasting models, supported by our pursuit of additional funding, underscore our commitment to advancing predictive capabilities within the water sector. Ultimately, these efforts are expected to contribute to improved operational performance, more effective risk management and greater overall resilience in our water infrastructure.

Innovation Challenge

Project Background: Historically, water companies have struggled to respond effectively to extreme weather conditions due to insufficient forecasting capabilities. This limitation affects the ability of water companies to plan medium-term operations, which are heavily influenced by weather conditions. This project aligns with three of Ofwat's Strategic Innovation Themes:

1. ***Understanding Long-Term Operational Resilience:*** By identifying risks associated with extreme weather, the project fosters sustainable and efficient solutions to safeguard customers and the environment.
2. ***Testing New Ways of Conducting Core Activities to Deliver Wider Public Value:*** The application of sub-seasonal forecasts to optimise water and wastewater operations represents a novel approach in the industry.
3. ***Responding and Adapting to Climate Change:*** The project addresses climate adaptation by enhancing preparedness for increasingly variable and extreme weather patterns, contributing to the sector's net-zero ambitions.

Innovation Challenge: Previous forecasting tools for the water sector have relied on short-term weather forecasts, which are typically accurate up to 10 to 14 days in advance (Buizza and Leutbecher 2015). Providing skilful weather-based forecasts beyond this horizon is a major challenge, due to the chaotic nature of the atmosphere. Small differences in the atmosphere at the time of forecast (often referred to as the initial conditions) can result in large differences at the end of the forecast period i.e. the butterfly effect. To provide a skilful and above all accurate, forecast further into the future requires separating the signal we can predict from that which we cannot.

One approach to meeting this challenge is to focus on Weather Patterns or Regimes. The hypothesis of this method is that weather forecasts are skilful at predicting the overall mean circulation (i.e. dominance of high- or low-pressure systems) past the 10-to-14-day horizon, even when not skilful at predicting specific location of features such as fronts. This information can then be combined with historical observations of the weather to make predictions based on the forecast weather type. For example, a weather pattern dominated by low pressure over the UK will historically be associated with higher rainfall, therefore increasing the risk of flooding.

Weather Patterns, as analysed by Neal et al. (2016), serve as a valuable resource for medium-range forecasting, typically spanning 15 to 30 days. Neal et al. (2016) used a clustering approach to classify atmospheric conditions in the UK and North Atlantic into 30 different regimes (Figure 1). These regimes have been combined with a range of weather forecast products, by determining which regime is most closely correlated with the forecasted weather. This tool is commercially available through the Met Office and is referred to as Decider(1). An example of the weather pattern associated with the severe weather event of March 2018 is shown in Figure 2, alongside the synoptic forecast chart. The low pressure to the west of the UK, observed in the forecast chart, was well correlated with the selected regime 28, which is shown to be historically linked to snowfall throughout the UK and Europe.

This methodology enabled the identification of clear correlations between specific weather patterns and corresponding fluctuations in demand. As a result, it improved the accuracy and reliability of decision-making processes. Furthermore, the approach demonstrated a proven economic advantage over traditional climatological forecasts, as highlighted by the SECLI-FIRM project(2).

[1] https://www.metoffice.gov.uk/services/business-industry/energy/decider
[2] https://www.secli-firm.eu/project/

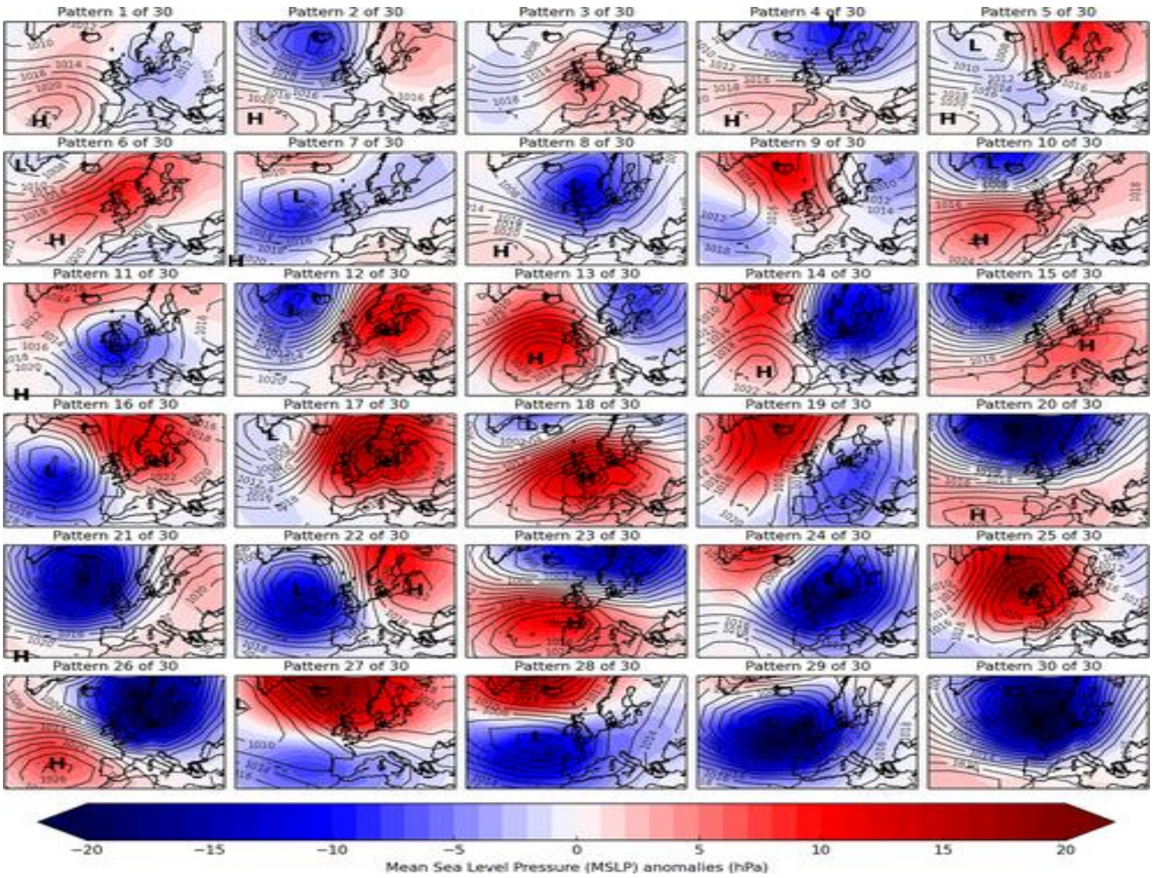

Figure 1: Thirty weather patterns for the North Atlantic UK region, as defined by Neal et al. 2016.

(Note: They are ordered by historical frequency, with Pattern 1 occurring the most frequently and pattern 30 the least)

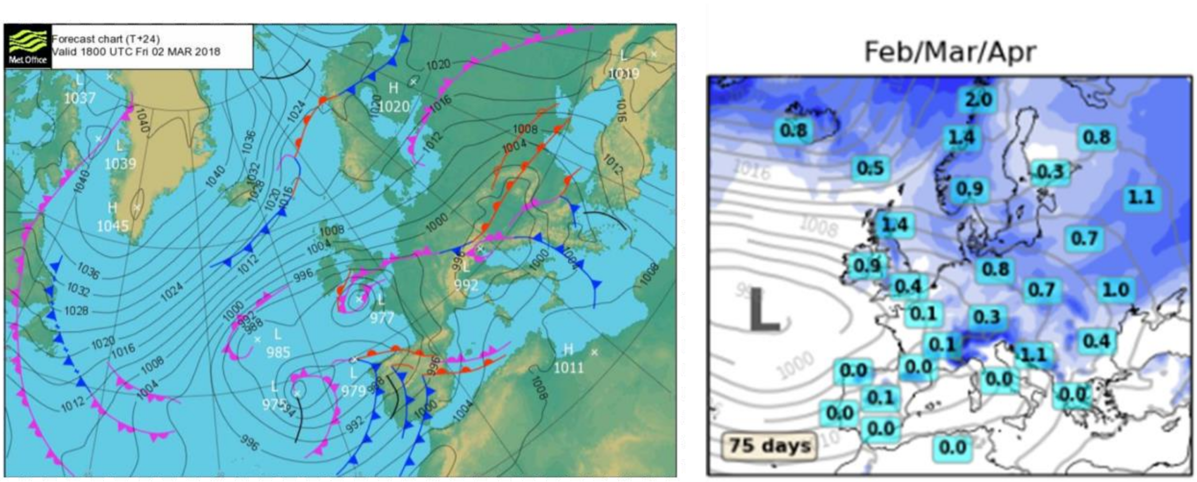

Figure 2: Left, the Forecast chart during the impactful March 2018 storm. Right: Historical snowfall for February to April associated with Regime 28 (mm/day equivalent)

This project focused on developing sub-seasonal forecasting models to enhance decision-making in both water demand management and wastewater operations. By leveraging advanced meteorological tools, such as the Met Office's Decider forecasting system and building on insights from the Horizon 2020-funded SECLI-FIRM project, this project introduced innovative solutions to optimise operational efficiency and resilience across the sector.

This project represented a significant innovation for the water sector. Unlike conventional operational planning, which often relied on short-term weather forecasts or historical data, the project integrated advanced meteorological science and probabilistic forecasting into operational workflows. It also fostered collaboration across multiple water companies, a first-of-its-kind initiative that pooled resources and expertise to scale up sub-seasonal forecasting across the UK water industry. This collaborative, data-driven and predictive approach was transformative, providing a foundation for more resilient, efficient, and sustainable water and wastewater management practices in the face of climate change.

Project Aims and Objectives

Project Aim: To enhance water demand and wastewater management by developing and deploying advanced sub-seasonal forecasting models, enabling the water sector to adopt innovative approaches to operational planning and environmental resilience.

Objectives:

1. **Develop Sub-Seasonal Forecasting Models:** Enhance existing forecasting tools, such as the Met Office's Decider system, to deliver accurate weather impact forecasts at a 2-4 week lead time. This involves calibrating and scaling models for broad application across multiple water companies.
2. **Test and Validate Forecasting Applications:** Conduct real-world trials to evaluate the performance of forecasting models in water demand and wastewater management scenarios. Assess their ability to predict weather impacts and identify operational efficiencies that reduce customer and environmental disruptions.
3. **Optimise Operational Decision-Making:** Provide actionable insights that support better resource planning, maintenance scheduling and environmental risk mitigation. By shifting from reactive to proactive measures, improve the sector's preparedness for extreme weather events.
4. **Foster Collaboration and Knowledge Sharing:** Engage with multiple water companies and stakeholders to co-develop, refine, and adopt forecasting solutions. Facilitate the exchange of best practices and lessons learned to drive innovation and sector-wide improvements.

By achieving these objectives, the project seeks to deliver more accurate and actionable forecasts, support efficient resource management, and establish a robust framework for future operational management during extreme weather across the water industry.

Project Governance and Equality, Diversity and Inclusion (EDI)

Partnering: The project was led by Thames Water, with partners including the Met Office, Northumbrian Water, United Utilities, Anglian Water, Severn Trent Water, Southern Water, South West Water and Wessex Water. The delivery team featured a high-level structure comprising:

- **Project Lead (Thames Water):** Coordinated overall project delivery and managed resources and timelines.
- **Technical Leads (Thames Water and Met Office):** Oversaw model development, calibration, testing and implementation.

- **Water Company Partners**: Contributed operational data, tested forecasting models, and provided feedback.

The Met Office, as the primary solution provider, was instrumental in adapting its Decider tool for broader application, leveraging its meteorological expertise. Non-financial contributions included the Met Office's provision of background IPR during the trial phase at no cost. This collaborative approach allowed pooling of expertise across organisations, fostering innovation beyond traditional silos.

The partnership arrangements were effective, combining well-established relationships, such as those between Thames Water and the Met Office, with new collaborations across multiple water companies. These partnerships encouraged a sector-wide perspective and promoted new ways of working.

Sponsorship and Leadership: The project was sponsored by Ops Service & Control Centre Director at Thames Water, providing executive support. Leadership roles were clearly defined, with strong involvement from both senior sponsors and technical leads to ensure alignment with strategic goals.

The governance structure comprised two Project Steering Groups - one for Water Demand (Clean Water) forecasting and another for Waste Alarm Volume (Wastewater) forecasting. Each Steering Group included representatives from all partners involved in the workstream's trials. These groups oversaw progress, approved milestones and addressed any challenges during the project lifecycle. The governance and leadership arrangements were effective, enabling timely decision-making and providing a clear escalation path. A key lesson learned was the value of proactive communication between partners to ensure alignment across diverse teams.

Stakeholders:

The project engaged key stakeholders across both clean and wastewater domains. We had eight water company partners actively involved in the Water Demand Forecasting (Clean Water) workstream, contributing valuable insights and data to enhance model predictive capabilities. Additionally, three water companies participated in the Alarm Volume Forecasting (Wastewater) area, supporting the exploration and feasibility of wastewater sector solutions for improved monitoring and response strategies. The table below provides a list of participating companies and their respective roles in the project.

Water Demand Forecasting	Waste Alarm Volume Forecasting
Thames Water Utilities Limited *(Lead)*	Thames Water Utilities Limited *(Lead)*
Met Office *(Partner and Solution Provider)*	Met Office *(Partner and Solution Provider)*
Northumbrian Water Limited *(Partner)*	Northumbrian Water Limited *(Partner)*
United Utilities Water Limited *(Partner)*	United Utilities Water Limited *(Partner)*
Anglian Water Limited *(Partner)*	
Severn Trent Water Limited *(Partner)*	
Southern Water Services Limited *(Partner)*	

Wessex Water Limited *(Partner)*	
South West Water Limited *(Partner)*	

In addition to the core partners, key stakeholders included:

- **End-users from participating water companies**: Engaged through workshops and feedback sessions to ensure the forecasting tools met operational needs.
- **Industry regulators**: Ofwat was informed throughout the project.

Engagement was effective in refining project deliverables and ensuring alignment with the broader water sector's goals. Stakeholder feedback was critical in identifying practical applications of the forecasting models and validating their utility.

The project adopted an inclusive approach by ensuring representation from diverse partners and stakeholders. Workshops and training sessions were accessible to all participants, considering varying levels of technical expertise. The team actively sought input from all participating water companies to ensure the tools addressed the needs of a broad spectrum of end-users.

The project demonstrated that fostering an inclusive environment and addressing diverse stakeholder needs were instrumental in achieving its objectives and ensuring sector-wide applicability of the innovations.

Project Delivery Team: The delivery team included the following roles:

- **Project Director** (Thames Water): Person with overall accountability for the project
- **Project Manager** (Thames Water): Person with overall responsibility for managing the project delivery to meet time, quality and cost objectives.
- **Water Demand Technical Lead** (Thames Water): Person with overall responsibility to define technical activities and ensure scientific quality of products and deliverables on the Water Demand work stream.
- **Wastewater Technical Lead** (Thames Water) Person with overall responsibility to define technical activities and ensure scientific quality of products and deliverables on the Wastewater work stream.
- **Product Development Lead** (Met Office): Person with overall responsibility for developing products for both the Water Demand and Wastewater work steams. Manages a team of data scientists who develop, calibrate and test forecasting models.
- **Steering Group members** (All partners): Project-level decision making and providing direction to the project teams.

The team's multidisciplinary expertise and collaboration were instrumental in the project's success. GitHub was used for version control, collaboration, and model development, ensuring flexibility and enabling the team to adapt to challenges while incorporating feedback effectively. The platform supported agile methodologies through various features, including:

- *Issues & Pull Requests:* Facilitated work management, tracking and collaborative model review.

- *Milestones & Labels:* Assisted with sprint planning, release tracking and task categorisation.
- *Continuous Integration & Deployment (CI/CD):* Enabled automated testing and deployment, aligning with Agile's emphasis on continuous improvement.

A lesson learned was the importance of maintaining robust communication channels across geographically dispersed teams to avoid delays.

Equality, Diversity and Inclusion (EDI): Throughout the project, Thames Water's EDI (Equality, Diversity and Inclusion) framework was fully integrated into decision-making, governance and stakeholder engagement. All lead team members completed mandatory annual e-learning modules on diversity and inclusion, ensuring alignment with Thames Water's Diversity & Inclusion Policy and Strategy. Additionally, the project team contributed to Thames Water's broader EDI targets, supporting increased representation across diverse demographics.

Adjustments included offering flexible meeting schedules to accommodate diverse team availability and tailoring training materials to meet different learning needs. While these measures were largely successful, a challenge was maintaining consistent engagement across all participants. In future projects, incorporating more structured mechanisms for continuous feedback could further enhance EDI outcomes and ensure sustained involvement.

The project scope was designed to ensure that benefits would be achievable in all areas of the UK, regardless of geography or demography. This ensured that project outcomes benefitted the diverse spread of UK water industry customers, with no disadvantages to any particular group.

Project Methodology/Approach/Delivery

Approach: The project was divided into two primary workstreams:

- **Water Demand Forecasting:** Scaling up the Met Office's Decider tool for use across multiple water companies, fine-tuning the model and validating its accuracy through a one-year trial.
- **Wastewater Management:** Exploring potential applications of sub-seasonal forecasting for wastewater operations, identifying the most promising areas, and conducting feasibility trials.

This approach was chosen for its ability to deliver incremental value throughout the project while allowing adjustments based on stakeholder feedback. The innovative aspects included applying sub-seasonal forecasting, a capability previously underutilised in the water sector, to both water demand and wastewater operations. Additionally, the co-production model fostered collaboration across eight water companies (Water Demand) and three water companies (Wastewater), which is uncommon in traditional business-as-usual approaches.

Initially, several workshops were organised to engage all relevant stakeholders. These sessions served to collect input, address concerns and promote collaboration among the involved parties. Throughout these workshops, a detailed service setup flow process was crafted, delineating the required steps and protocols for developing and implementing the forecasting system. Each stage of the process was thoroughly reviewed and adjusted based on stakeholder feedback, ensuring it was both clear and efficient. The finalised flow process, depicted in Figure 3, provides a well-defined roadmap to guide the methodology and support model development activities.

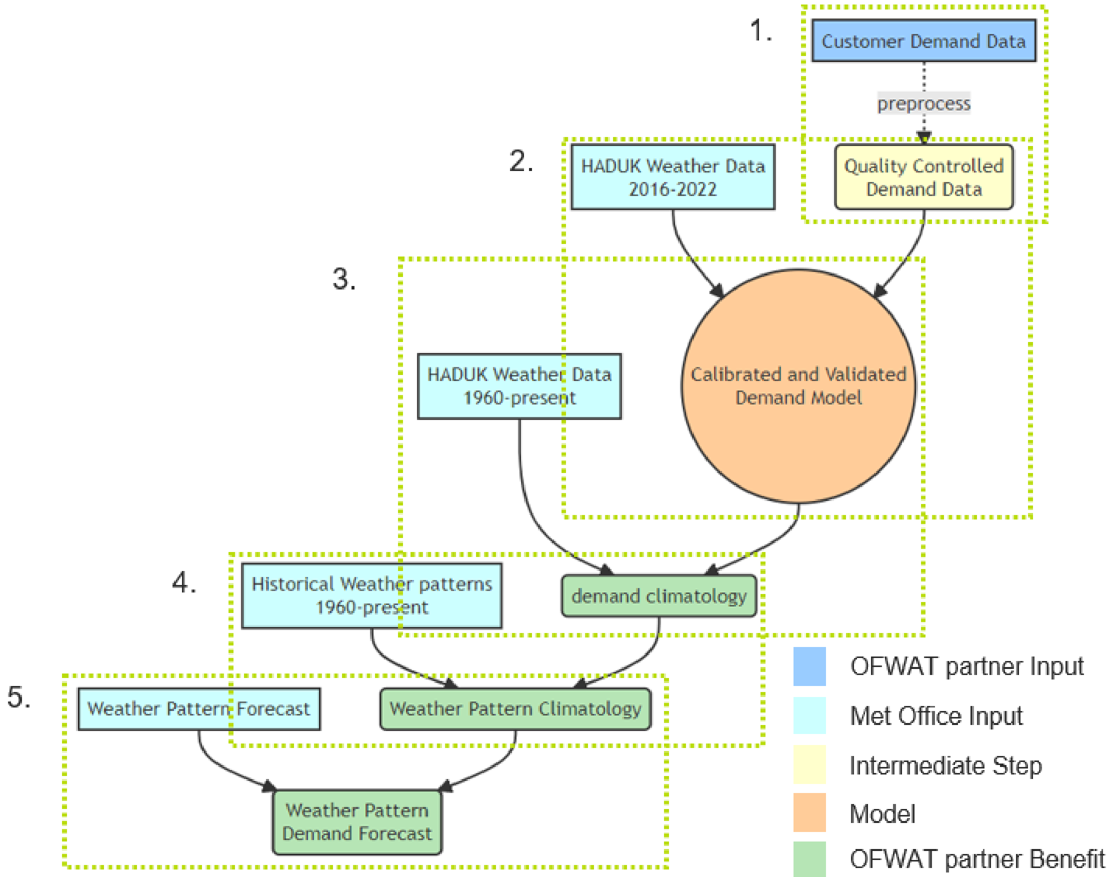

Figure 3: Service Setup Process Flow

Data processing: Data processing was a critical component of the project, involving the collection, cleaning and standardisation of diverse datasets, including historical water demand data and waste alarms. Quality checking and validation ensured accuracy, which included verifying maximum and minimum values, performing quality checks to identify unit or data entry errors, and ensuring consistent recording throughout the time series. By transforming raw information into reliable, well-structured inputs, data processing laid the foundation for accurate and actionable sub-seasonal forecasts. Figure 4 below shows the water demand time series data.

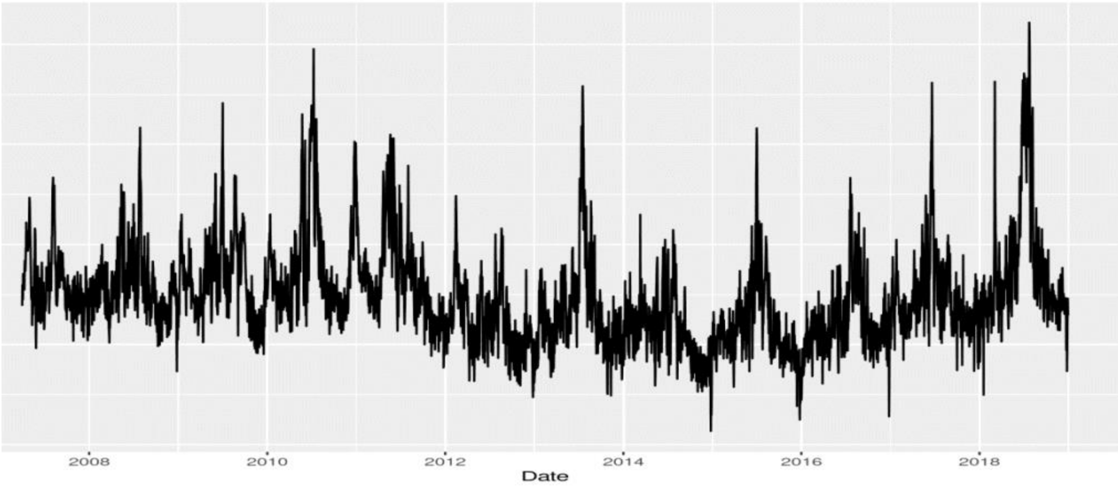

Figure 4: Cleaned and Processed Timeseries Data (Water Demand)

Model Calibration and Verification: Both the demand and wastewater models were calibrated using a statistical modelling technique known as a Generalised Additive Model (GAM). This type of modelling was chosen as it considers non-linear relationships and interdependencies between variables. Daily demand or number of alarms were modelled using variables that will capture the impact of changes in base usage including day of the year, day of the week, year and month of the modelling period, as well as the impact of weather variables such as maximum temperature and rainfall.

Next the relationships between demand and the weather variables of interest were explored – this can indicate which combinations of variables are expected to have a significant effect in the statistical usage model for each of the regions and what their component of the model is expected to look like (i.e., a positive or negative relationship and how steep it may be compared to others). As an objective measure of model skill, the Akaike information criterion (AIC) was calculated for each weather variable individually and for combinations of each of the weather variables. This was used along with the physical interpretability of the weather variables to determine the final model variable selection. Once the weather variables were selected, each model was calibrated using a random sample of 80% of the available data so that model predictions for the 20% of unseen data can be compared to the true values to assess the skill of the model.

An example of the final demand model output is shown in Figure 5. The red line on the left graph shows the base demand, which varies based on the day and month of the year. The black line indicates the observed demand and the light blue the predicted demand. The right-hand graph shows the relationship between observed demand and predicted demand within the model.

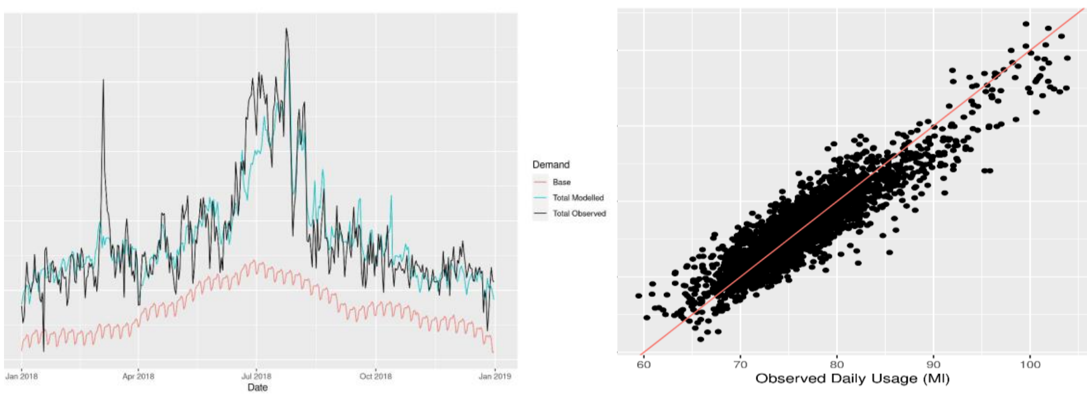

Figure 5: Statistical analysis and modelling

Building a Demand Climatology: A baseline representation of demand patterns over a long-term period was created (Figure 6). This involved aggregating and analysing historical demand data to establish average conditions, seasonal trends and typical variations, providing a reference point for evaluating deviations. This provides a model estimate of demand or alarm numbers for the period over which the weather patterns have been assigned, a necessary requirement of building a weather pattern climatology and producing the forecast.

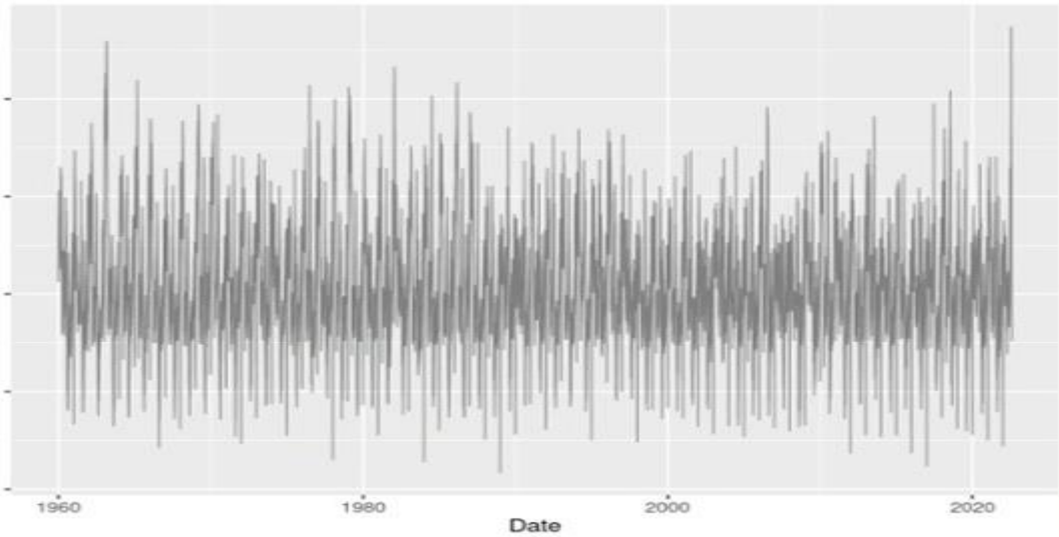

Figure 6: Demand Patterns over a long period of time

Building a Weather Pattern Demand Climatology: Weather pattern information was combined with demand data to understand how specific weather regimes influenced demand (Figure 7). This step linked meteorological patterns - such as recurring pressure systems, temperature anomalies or precipitation regimes - with corresponding shifts in demand, resulting in a climatology that reflected the interplay between weather regimes and demand dynamics. The forecasted weather regime can then be associated with a range of historical values which occurred during that same regime.

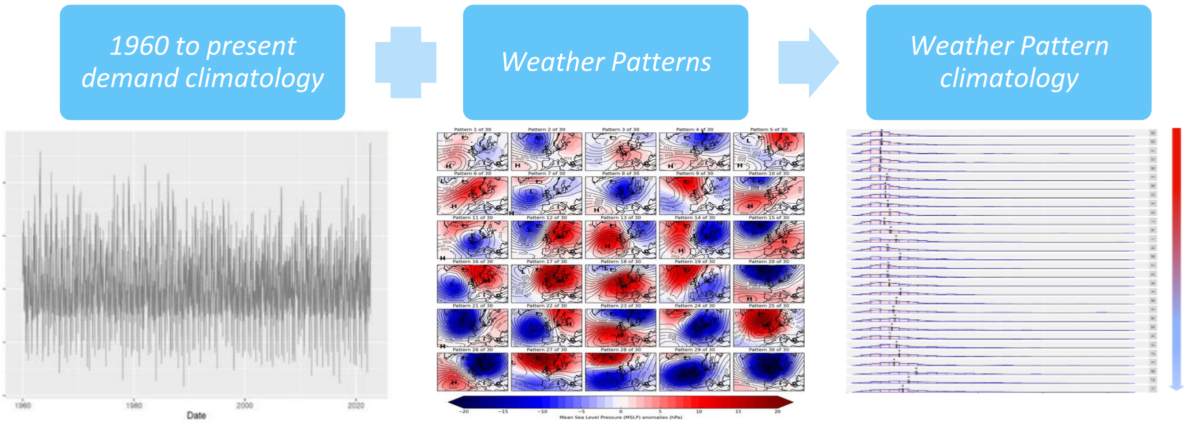

Figure 7: Process of Building the Demand Climatology

Weather Pattern-Based Forecast: Identified weather patterns and their associated demand impacts were used to produce a forecast (Figure 8). By leveraging established correlations and climatological insights, this approach enabled more targeted predictions. It helped anticipate future demand changes based on expected weather developments, improving the ability to make proactive, informed decisions beyond the 10-14 day short term forecast horizon.

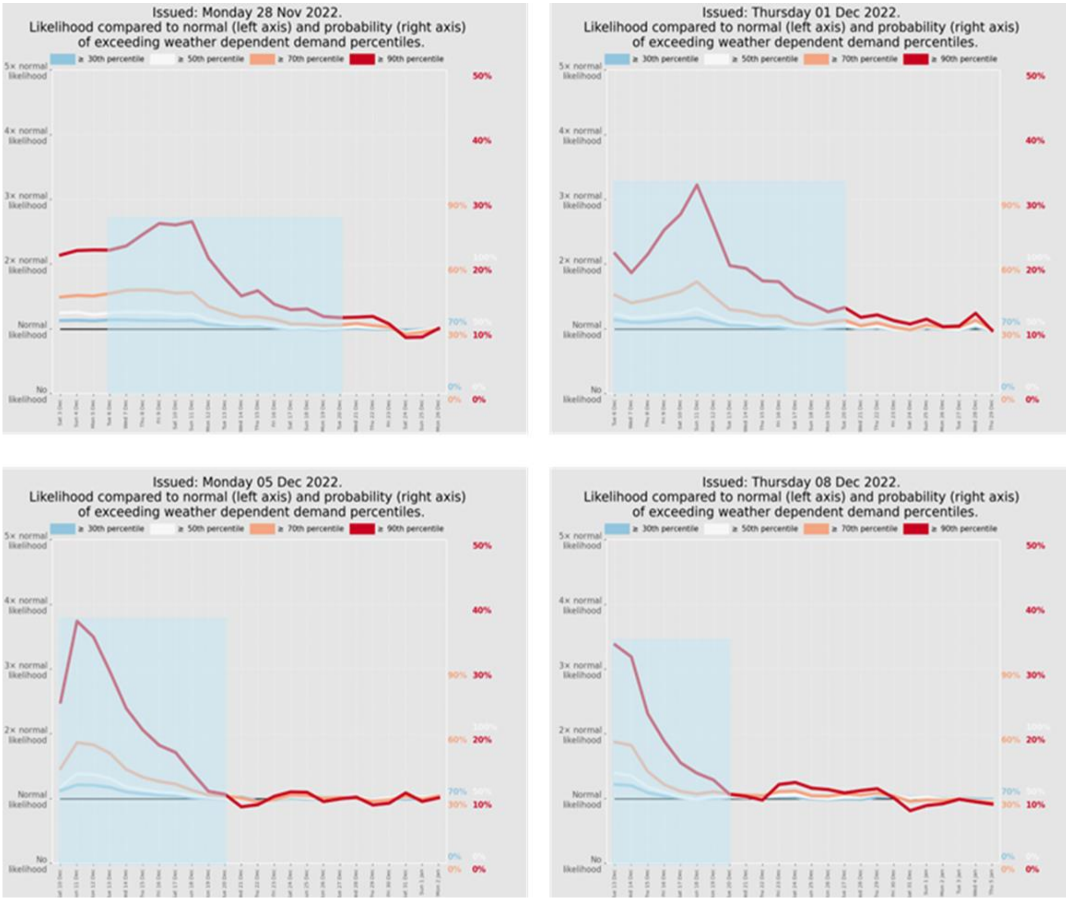

Figure 8: Example forecast product from Monday 28 Nov 2022 (top left) to Thursday 08 Dec 2022 (bottom right) associated with a cold event (dates shown in blue rectangle).

(Note: Coloured lines indicate likelihood of that threshold being exceeded, as compared to the baseline likelihood for that date.)

Project Delivery: The project adopted a collaborative methodology focused on co-development and iterative refinement of sub-seasonal forecasting models. The approach was designed to ensure flexibility in addressing the diverse needs of participating water companies while leveraging the Met Office's advanced forecasting capabilities.

The project adhered to its initial programme structure, progressing through defined phases of development, validation and trial implementation (Figure 9). While the overall programme and budget remained on track, some adaptations were necessary:

- Programme Adjustments: Delays in collaboration agreement signing and data sharing from some water companies required re-prioritisation of tasks, particularly in the initial calibration phase. This impacted the timelines but did not compromise project outputs.
- Budget Management: Non-financial contributions from the Met Office, such as the free use of the Decider tool during the trial phase, helped mitigate cost pressures.
- Achievements: The project successfully delivered calibrated forecasting models, conducted extensive trials and gathered valuable feedback to refine the models for operational use.

These adaptations demonstrated the project team's ability to remain flexible and responsive to emerging challenges, ensuring the project objectives were met without significant compromise.

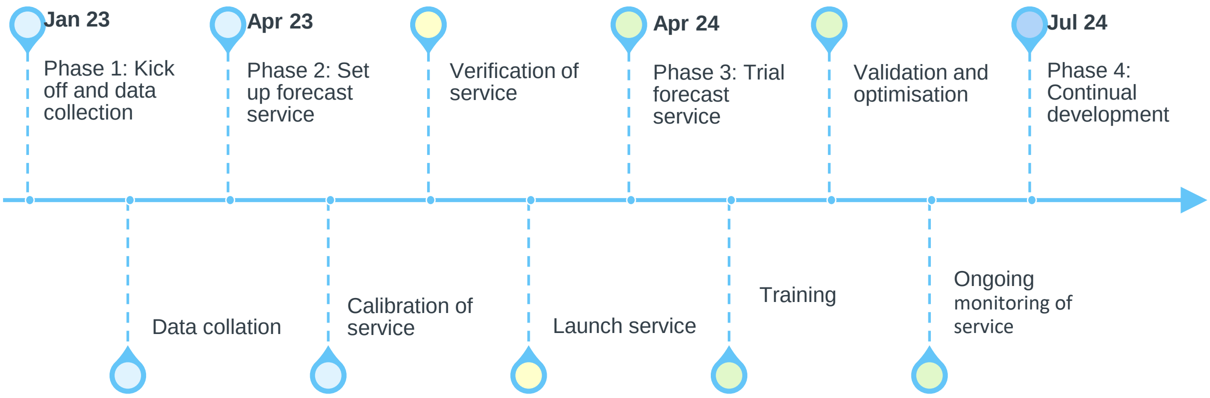

Figure 9: Service Setup Process Flow

Risk Management

Although the project successfully achieved significant milestones, it faced several risks and issues that had to be resolved during the projects. These were detailed below:

Data Availability & Quality: Limited access to complete, high-quality data impacted various aspects of model development and validation. Specifically, delays in obtaining consistent data from water companies posed a risk to model calibration. This issue was particularly evident with the wastewater stream. Due to the lack of an industry-wide standard for alarm categorisation, the Risk Assessment product had to be tailored for each partner, unlike the standardised model used for the Water Demand Product. Additionally, retrieving large volumes of wastewater alarm data proved to be technically challenging, time-consuming and expensive.

Impact: Reduced the ability to fully optimise the models and limited the scope of operational insights.

Resolution: Stronger data-sharing agreements and mechanisms were established at the project outset, ensuring consistent access to necessary datasets. Also involved in early engagement with data teams and building in buffer time for data processing.

Model Forecasting Accuracy: Inconsistent data quality and gaps in calibration data undermined the accuracy of our predictive models, particularly for the wastewater stream. Additionally, the inherent uncertainty of sub-seasonal forecasts made it challenging to build user confidence.

Impact: Decreased reliability of predictions and reduced confidence (Waste Alarm Volumes) in some outputs.

Resolution: Steps were taken to improve data quality and enhance calibration processes, leading to refined model precision.

Stakeholder Engagement: Integration challenges with existing operational workflows delayed the adoption of the developed tools and methodologies, particularly for the wastewater stream. Additionally, maintaining consistent engagement with all participating water companies proved difficult. Although attendance levels at regular workshops and progress updates were less than desirable, these meetings still played a key role in keeping stakeholders aligned and involved.

Impact: Slower progress and transition of innovation outputs into practical applications, limiting immediate operational benefits.

Resolution: Efforts were made to involve operational teams at an early stage, creating clear integration plans and providing tailored support.

No significant risks materialised that fundamentally impacted the project's intended outcomes. However, the iterative nature of the methodology allowed the team to adapt effectively to minor challenges as they arose.

Moving forward, certain challenges require special attention. For the wastewater stream in particular, the persistent lack of access to comprehensive datasets may have limited long-term improvements. Additionally, gaps in stakeholder buy-in might have affected the full implementation of the tools and the absence of a long-term strategy for maintaining and enhancing the solution's capability and accuracy post-project remains a concern.

Lessons Learned

The project provided several valuable lessons about delivering innovation in the water sector. The project achieved several notable successes, demonstrating effective collaboration, sound methodologies and impactful results.

Key aspects that **worked well** include:

Project Management and Processes, including Collaboration:

Effective Project Management Practices: The application of structured project management practices ensured the project stayed on track, with clear milestones, deliverables and effective communication across all stakeholders.

Continuous Feedback Loops: Regular feedback and communication from partners throughout the project lifecycle enabled to manage adaptability. Early and consistent engagement with users was crucial in ensuring that project outputs aligned with operational needs.

Regular Collaboration with the Met Office: Regular sessions with the Met Office facilitated effective collaboration, aligning expertise and resources to address project objectives efficiently.

Technical and Methodological aspects:

Methodology and Tool Development by the Met Office: The Met Office's robust methodologies and tool development contributed significantly to the project's success, delivering outputs tailored to the project's needs.

Clean Water Demand Prediction and Operational Integration: The development and successful operational integration of clean water demand prediction models provided valuable insights, enabling more efficient and informed decision-making.

The following areas were **identified for improvement** to enhance the effectiveness and outcomes of future projects. These are all **Stakeholder Engagement and Collaboration focussed**:

Partner Contributions: Active and consistent engagement from all partners was not always achieved. Co-production with multiple stakeholders ensured the tools were relevant and applicable, but it also required significant coordination. Future projects should allocate dedicated resources for managing multi-partner collaborations, ensuring that the person representing each partner is an end user and as such a subject matter expert, as there is significant skill in interpreting the output of the product.

Recommendation: Enhance participation in regular technical and steering meetings by fostering more ad-hoc discussions for system refinement, supporting continuous learning and improvement. Additionally, adopting an Agile project management approach will encourage iterative collaboration, structured feedback loops and well-defined roles, ensuring all partners actively contribute data, insights and expertise. This will strengthen model development and overall project outcomes. Establishing an end-user subgroup could further enhance engagement by providing a dedicated platform to discuss the service's use and interpretation.

Business Engagement: Some areas could have benefited from early engagement by business units.

Recommendation: Foster stronger collaboration between innovation, engineering, digital, asset management and operational teams, as appropriate. This alignment can enhance the adoption and impact of new technologies, improve operational efficiency and decision-making and maximise the return on investment in innovation.

Integration of stakeholders into verification process: Partners would have benefited from more support on forecast verification, demonstrating the added value of the service. Verification of the forecast was based on metrics developed by the Met Office and the value was not always apparent to those using the service in a decision-making capacity.

Recommendation: Establish a process for verification of the forecast across all water company partners at the beginning of the project, with data populated by the forecast as the project develops.

Key Findings and Outputs

Outputs

Key outputs include the Sub-Seasonal Rainfall Prediction Model, offering 30-day forecasts and Enhanced Water Demand Forecast Updates. The project also explored Waste Alarm Volume Forecasting, assessing the feasibility of sub-seasonal predictions for wastewater alarms.

Sub-seasonal water demand forecasting, implemented across eight water companies and wastewater forecasting models, tailored for trial use by three water companies. The three key outputs are outlined below:

Deliverable	Description	Status	Notes
Sub-Seasonal Rainfall Prediction Models	*Advanced models providing reliable rainfall forecasts up to 30 days ahead.*	*Completed*	*The model has been developed and trialled for forecasting by all participated water companies*
Enhanced Water Demand Forecast Updates	*Twice-weekly updates on water demand forecasts shared with participating water companies*	*Completed*	*Updates were shared regularly; weekly feedback established with stakeholders.*
Waste Alarm Volume Forecast Updates	*Twice-weekly forecasts for waste alarm volumes delivered via email, spreadsheet, or slide deck.*	*Completed*	*Preferred format finalised and weekly feedback is captured.*

The following sections detail these forecasting models, trial results and industry feedback.

Sub-Seasonal Weather Prediction Models: Development and delivery of advanced sub-seasonal weather prediction models, designed to provide reliable weather forecasts up to 30 days ahead, enabling water companies to better anticipate and plan for weather impacts. IPR owned by Met Office.

Enhanced Water Demand Forecast Updates: Regular updates on water demand forecasts shared with all participating water companies on a twice weekly basis. These updates include insights derived from the sub-seasonal forecasting models, helping companies optimise resource allocation and operational planning.

Figure 10 below presents an example of a likelihood of weather dependent water demand output generated by the model. The forecast indicates a higher likelihood of exceeding normal weather-dependent demand levels in early January 2025, particularly above the 70th and 90th percentiles. This is indicated both by the middle graph, which shows the likelihood change from the baseline and the Red-Amber-Green status at the top, in which the red triangles indicate a higher likelihood of high demand. The probability of extreme demand events is notable during the first week but gradually declines as the month progresses. By mid-to-late January, demand is expected to return closer to normal levels, reducing the risk of significant deviations.

Historical climatology data suggests that total demand remains relatively stable throughout January, with the 90th percentile around 650 MLD and the 50th percentile near 600 MLD. The 10th percentile and annual minimum values are much lower, closer to 575 MLD, indicating that even in low-demand scenarios, the variation is limited. This suggests a predictable and manageable demand pattern.

Overall, the data shows that while demand fluctuations are expected, they are within historical norms. The early January period poses the highest risk of exceeding normal demand thresholds, but the probability diminishes over time. This insight supports better planning and risk-based decision-making for operational activities.

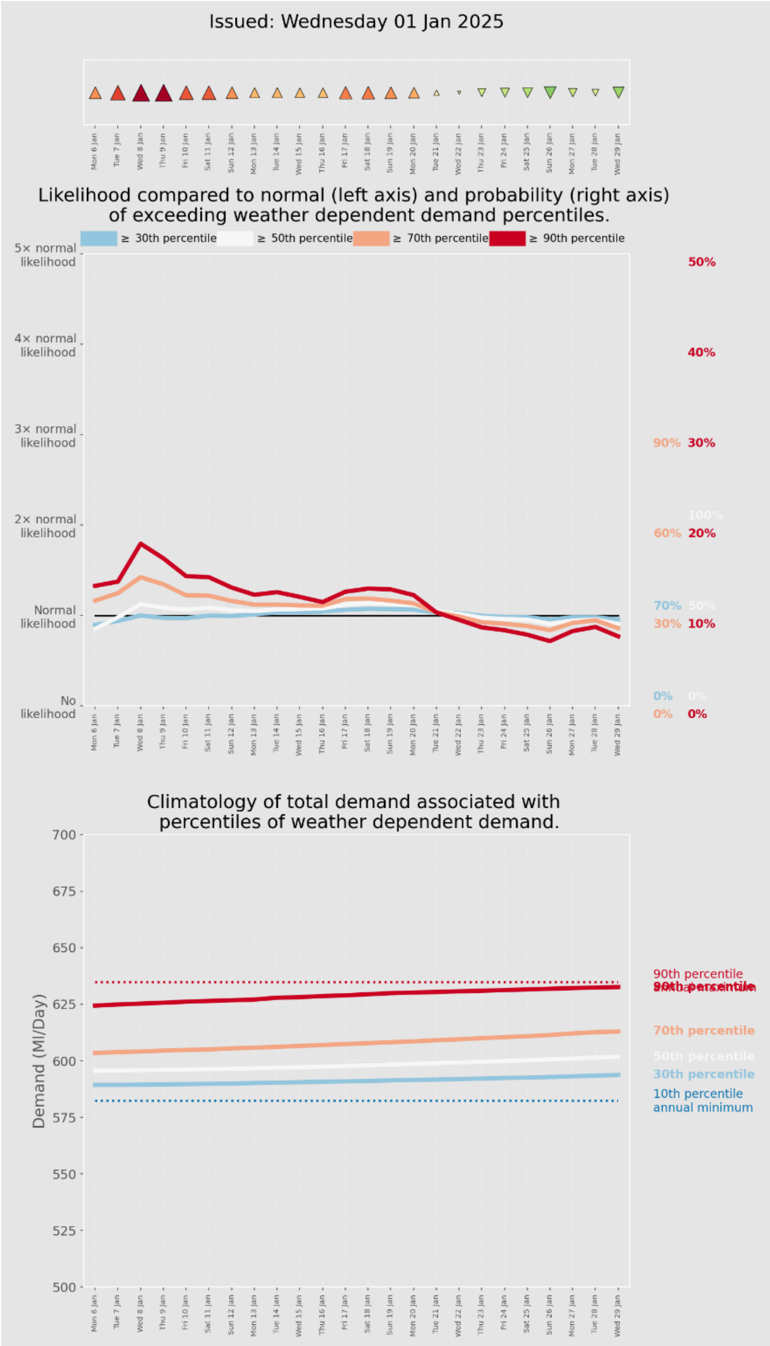

Figure 10: Probability of Water Demand

Total Water Demand Probability Updates: The model was designed to assess and classify the likelihood of total water demand surpassing certain thresholds, helping to identify potential risks and operational challenges. By calculating probabilities of demand exceeding both normal levels and established upper and lower thresholds, the model provided a comprehensive overview of potential demand scenarios. These probabilities were then used to develop a RAG (Red-Amber-Green) status framework, enabling quick visual identification of demand conditions that might require attention or intervention. Figure 10 illustrates these probabilities, showing how the model can effectively forecast different levels of demand risk, supporting more proactive decision-making and resource planning.

Waste Alarm Volume Forecast Updates: Over the course of this project, the waste work stream examined the feasibility of a sub-seasonal forecasting approach for predicting waste alarm volumes. The model provided twice weekly updates, enabling stakeholders to anticipate potential operational challenges and refine decision-making processes. Figure 11 illustrates an example of these updates, produced by combining the Met Office's "Decider" model with the historical climatology of high alarms generated. Here, the forecasts compare the probability of high alarms (shown as a black line) to the long-term, climatological average (depicted by a dotted line). Red shading highlights periods where forecast probabilities exceed the climatological norm, while blue shading points to below-average probabilities.

Throughout the pilot phase, the forecasts clearly identified patterns of elevated and reduced alarm volumes, sometimes falling below typical levels and at other times peaking well above them. The trial has provided insights beyond forecasting, allowing for the exploration of new features and data sources for future enhancements. While immediate actions based on forecasts have been limited, a clear path forward has been mapped out for execution. With further refinement, the system can become more precise, comprehensive and better aligned with operational needs, ultimately enhancing its value for decision making.

The exploratory work has showcased the potential for practical benefits of early-warning updates like high alarm volumes in the waste sector using sub-seasonal forecasting. Expanding the model to include more wastewater-related variables and regional segmentation could further enhance predictive capabilities, enabling water companies to proactively address challenges and improve operational efficiency.

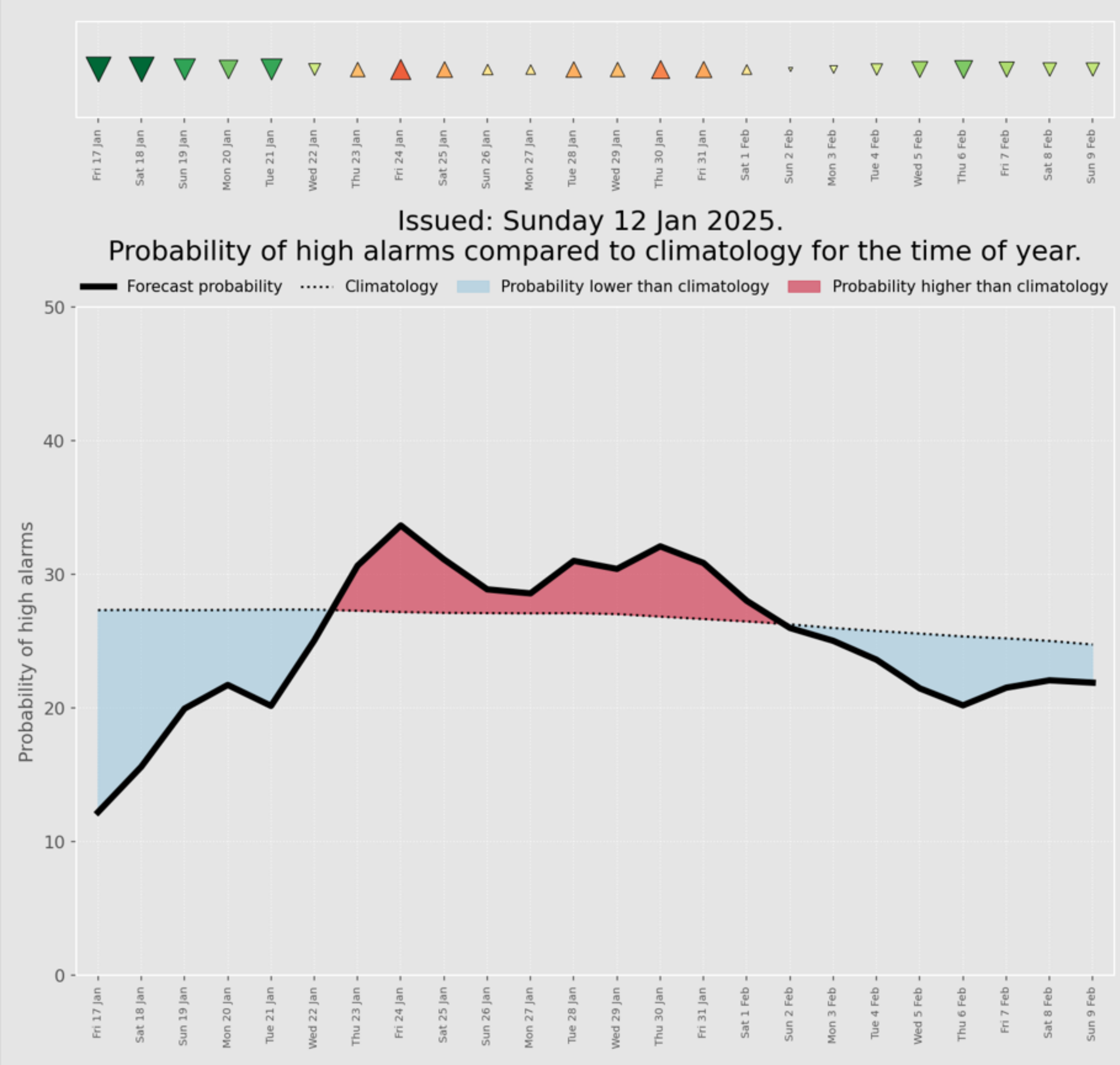

Figure 11: Probability of high alarms compared to climatology for the time of year

In addition to the three main outputs outlined above, the project has delivered additional outputs, including:

Technical Report: A comprehensive technical report will be produced summarising the project's methodology, findings and outcomes. This report will include detailed insights on model performance, case studies and recommendations for future work, ensuring a valuable resource for continued innovation in water and wastewater operations.

Training Resources: Bespoke training materials and recorded sessions to support the integration of forecasting tools into operational workflows.

Knowledge-Sharing Workshops: A series of stakeholder workshops that facilitated cross-company collaboration and feedback.

Implementation Plan: A roadmap for scaling and operationalising the forecasting tools across the UK water sector.

Feedback from Water Companies: The table below provides a few examples of feedback from participating water companies on key outputs, focusing on the quality of delivered outputs, results achieved and any additional observations. This feedback provides insights into the effectiveness of the project deliverables, highlighting strengths, areas for improvement and potential refinements for future works.

Water Demand Forecasting	
(Water Company 01)	The weekly report was valuable for assessing risks within a 2 to 3-week window, particularly when planning asset outages. Having visibility into baseline demand allowed for better decision-making and risk management. This was especially important for outages requiring enablers and external contractors, as it provided the necessary insights for effective planning.
(Water Company 02)	Receiving weekly updates provided timely notice of weather events that could impact demand. The accompanying graphs allowed for comparisons between forecasted and actual demand on a weekly basis, helping to assess accuracy. While no prolonged periods of high demand were experienced in this water-stressed area, these updates remain a crucial source of information for preparedness in the event of such occurrences.
(Water Company 03)	The Water Demand Model has supported the Operational Control team by enhancing risk visualisation and decision-making for weather-related incidents. It has been instrumental in determining when to set up incident calls, deploy standby power generation and allocate additional resources. The model is also incorporated into the Weekly Risk Summary on Fridays, providing the business with a clear assessment of risk levels heading into the weekend.
(Water Company 04)	We have been pleased with the outputs generated by the project and the increased detail provided for near term weather impacts on demand. The probability forecasts have proved accurate in terms of indicating near term risk. We are currently integrating the application of this into our production planning processes, for additional weather-based demand peak understanding.
(Water Company 05)	Provided insights into sub-seasonal forecasting of water demand. Further validation is required to compare actual versus forecasted data. Potential to improve operational efficiency through better planning, though additional validation is needed to fully assess the benefits.
Waste Water Alarm Volume Forecasting	
(Water Company 01)	The twice weekly forecasts have been valuable in facilitating discussions and providing a picture of anticipated wet weather conditions. This, in turn, allows for better planning and preparedness in operational activities, helping to mitigate potential risks and improve response strategies.

	The trial has offered important insights beyond just forecasting. It has enabled us to explore additional features and data sources that could enhance future iterations of the service. By identifying these potential improvements, we can refine the forecasting system to make it more accurate, comprehensive and tailored to operational needs. This collaborative approach ensures that the service continues to evolve in a way that maximises its value for operational decision-making.
(Water Company 02)	Previous comments have been provided on this, but in the current iteration of the forecast model, there have been very few tangible benefits or actions/decisions taken as a direct result of the forecasts. This is not a criticism of the work or its future potential, as there are significant benefits to be realised. Limited involvement in its early phases. However, it appears that insufficient analysis was conducted at the outset when selecting the base data set, which may have impacted the model's success. The base data should have been standardised across the industry and focused on specific alarm types to better capture demand peaks during particular weather patterns. Additionally, agreements should have been established from the beginning to: A) Continuously feed new data into the model to enhance its accuracy and relevance. B) Use historical data to validate forecast accuracy, helping to build confidence in the model's reliability.

Innovation Maturity Level (IML):

At the project's inception, the Innovation Maturity Level (IML) was at Level 2 – Concept and Feasibility, with the primary focus on testing the applicability of sub-seasonal forecasting models for water demand and wastewater operations. By project completion, the IML had progressed to Level 5 – Deployment and Post-Launch, reflecting the development, trialling and refinement of operational forecasting models used by multiple water companies. This aligns with the intended IML progression outlined at the start of the project. The achieved IML underscores the project's success in translating a conceptual forecasting approach into practical, operational tools adopted by key stakeholders.

Key Findings and Conclusions: The project provided several key findings and conclusions:

Sub-Seasonal Forecasting Value: Sub-seasonal forecasting models using the Decider tool were shown to be effective in improving operational decision-making for water demand management.

Collaborative Development Success: Collaborative partnerships across eight water companies facilitated knowledge-sharing and enhanced the applicability of the models to diverse operational contexts.

Understanding Probabilistic Forecasting: Stakeholder workshops and training sessions revealed that clear communication and education on probabilistic forecasting are critical for building user confidence and fostering adoption. It has become clear during the trial that there is significant skill with interpreting the output of Sub Seasonal Demand risk service, which requires the end user to have extensive knowledge and awareness of the current operating environment (i.e. current; demand level, production capability and planned and unplanned outages) to be able to convert the output of the service to a widely understood risk assessment.

Operational Benefits: The models enabled better resource planning, reduced operational costs and minimised environmental risks by providing actionable insights at a 2-4 week lead time.

The project demonstrated that tailored, longer-range forecasts could address operational inefficiencies and enhance resilience, paving the way for broader application within the water sector.

In the London supply area, the Sub Seasonal forecast is used to create an optimal Production Plan for the next six weeks. This process establishes clear output expectations and enables the timely development of resource and maintenance plans.

Development of waste alarm impact model: While the demand model had previously been applied to short-range forecasting, the model developed for the wastewater alarm data was an entirely new application.

This model can be leveraged in future to short-term forecasting applications and the lessons learned will be valuable for further developing such a service.

Changes to Intended Outputs: While the outputs aligned closely with the original project plan, certain adjustments were made during delivery:

- Scope Refinements: The wastewater forecasting focussed to specific areas like waste alarm volumes, where operational impact was most promising.
- Extended Stakeholder Engagement: More time was allocated to workshops, data collation and training sessions to address varying levels of familiarity with probabilistic forecasting among water companies.

These changes enhanced the project's relevance and ensured its outputs were practical and applicable, without compromising the intended outcomes or impacts.

Intellectual Property Rights (IPR): The IPR arrangements shall be in accordance with the Ofwat Innovation Fund Collaboration Agreement. The Decider tool, owned by the Met Office, was made available to partners during the trial phase at no cost. The default IPR position for Ofwat Innovation Fund projects was maintained, including the use of specific background IPR, ensuring accessibility for sector-wide adoption post-project.

The Foreground IPR generated by the project, including the sub-seasonal forecasting models and associated implementation guidance, will be made available to the water sector under the terms of the Winners Agreement. Practical steps for adoption include:

- Licensing the Decider Tool: Water companies can subscribe to the Met Office's Decider service to operationalise the forecasting models. This will be advertised via the Met Office website. The cost has been kept low and can be considered value for money.
- Access to Training Materials: All training resources will be shared with participating water companies.
- Knowledge Dissemination: Insights from the project will be shared through webinars, reports and conferences, fostering broader uptake and integration of sub-seasonal forecasting in the water industry.

These measures ensure that the project's outputs are not only operationally impactful but also accessible to the wider water sector, supporting long-term resilience and innovation.

Outputs, Adoption and Foreground IPR;

The use of each tool will be chargeable to each water company. The cost of usage is estimated at £10K to £15K per annum, not including VAT. The final costs are still being confirmed and will reflect the current market value.

The following additional costs may also be payable to the Met Office:

- Maintenance and regular review of the service, including additional email summaries and quarterly meetings.
- Additional set up fees for those water companies that were not involved with the original project or new regions.
- Annual service charges.
- Any applicable additional charges, required by the Met Office including any applicable inflation increases.

Pricing per tool:

Water Demand Forecasting: £10K to £15K

Wastewater Alarm Volume Forecasting: £10K to £12K

Rollout Plan:

Following 31st March 2025, the rollout will focus on supporting company-specific configurations and ensuring a smooth transition to business-as-usual operations. Alongside this, we will engage in further discussions to finalise key aspects such as IPR, licensing terms and data governance to ensure clarity and consistency across all participating organisations.

Our initial estimates provide a broad view of the expected costs and rollout approach, but these figures and timelines are subject to further internal discussions. We will be engaging in more detailed legal and commercial reviews to ensure that the pricing structure, contractual terms and overall implementation process align with internal policies and industry standards. These discussions will help finalise the framework for engagement with all water companies and confirm the operational and financial aspects before proceeding with the rollout. As discussions progress in the coming months, we will refine the rollout approach to provide greater clarity and ensure alignment across all elements.

Outcomes: The key outcomes are:

Development and Validation of Sub-Seasonal Forecasting Models: Steered the creation and validation of sophisticated sub-seasonal forecasting models in collaboration with the Met Office. These models provided all water companies with predictive capabilities extending beyond traditional weather forecasts, enabling better planning for weather-related impacts on operations.

Enhanced Rainfall Forecasting Integration into Water Demand Prediction: Integrated advanced rainfall forecasting models into water demand prediction systems, significantly enhancing the capability of sub-seasonal demand forecasts. Enhanced the existing sub-seasonal water demand prediction model by incorporating refined data inputs and scaling its application to serve all participating water companies. This approach helped standardise demand prediction across the sector, adopting collaboration and consistency.

Introduction of a Waste Alarm Volume Forecasting System: Conceptualised and deployed the first-ever sub-seasonal waste alarm volume forecasting system, targeting improved operational efficiency and response planning. Designed innovative sub-seasonal forecasting models tailored for wastewater operations, focusing on high-priority areas such as Sewage Treatment Works (STW) and Sewage Pumping Stations (SPS) alarm volume forecasts.

Strengthening Collaboration Between Water Companies and the Met Office: Played a pivotal role in collaborating with Met Office and other water companies to establish an integrated framework for water demand sub-seasonal forecasting. Worked extensively to align the forecasting tools with the strategic needs of water and wastewater management, ensuring seamless integration and adoption by stakeholders across the sector.

Strategic Advancement of Water Sector Capabilities: Demonstrated leadership in promoting the use of forecasting systems to address emerging challenges in water and wastewater operations. Supported the water sector in transitioning towards proactive management practices, leveraging forecasting tools to anticipate and mitigate risks associated with seasonal variability and climate impacts.

The project achieved its intended outcomes for the partners, primarily focusing on enhancing operational resilience and efficiency through sub-seasonal forecasting models. Key outcomes include:

- Improved decision-making capabilities for water demand across all partner water companies.
- Development and adoption of tailored sub-seasonal forecasting models for use in operational planning.
- Strengthened collaboration among water companies and the Met Office, creating a foundation for ongoing innovation.

Although the project successfully achieved many of its goals, it became evident that the direct correlation between rainfall and alarm volume is limited. This finding highlights the importance of integrating additional data sources in future iterations to improve accuracy and predictive capabilities. Expanding the range of variables considered will enable a deeper understanding of the factors influencing alarm volumes, ultimately enhancing operational decision-making.

The project delivered benefits for customers, society and the environment, aligning with Ofwat's Strategic Innovation Themes:

- Customers: Reduced service interruptions, ensuring reliable water supply management and assists with ongoing weather resilience to improve resource planning etc.
- Society: Improved resilience to extreme weather events, minimising the risk to water supply and of pollution incidents and their impact on public health.
- Environment: Strengthened environmental protection through proactive operational measures, including optimised pump usage and reduced overflows. Continuous learning from this project will inform future initiatives, driving more effective and sustainable environmental management.

Residual Activities to Achieve Outcomes: Most intended outcomes were achieved; however, full realisation of benefits will depend on:

- Continued use and refinement of forecasting models by partner companies.
- Broader sector adoption of the developed tools.
  Thames Water and the Met Office will lead ongoing efforts to support adoption, including

additional training and operational integration. Residual risks include slower-than-expected uptake due to resource constraints.

Organisational Innovation Capability: The project enhanced innovation capabilities across all partners by:

- Building expertise in sub-seasonal forecasting and probabilistic decision-making.
- Discussions to establish framework for cross-company collaboration and knowledge sharing. The delivery approach and collaborative environment are now used as best practices for driving innovation within the sector.

Impacts

The following sections outline key impacts, quantifiable benefits, environmental contributions and sector-wide innovation potential, along with insights into project performance, lessons learned and future opportunities.

Impacts and Benefits for the Water Sector:

The project delivered immediate benefits to the water sector by enhancing resource planning, operational efficiency and improving customer experience during extreme weather events and will provide long-term advantages by strengthening sector-wide resilience to climate variability and ultimately supporting net-zero sustainability goals. The anticipated impacts align closely with initial expectations, water demand forecasting has shown clear operational value, while wastewater forecasting requires further development.

Feedback from Water Companies:

Water Demand Forecasting	
(Water Company 01)	The benefit of the tool is that because we have more confidence in planning outages it means that we can carry-out essential maintenance and statutory inspections when we may have been risk adverse. These benefits are over system resilience as well as our regulatory compliance. It probably took us sometime to understand the benefits of the tool, once we went back and compared predictions against what happened, it allowed us to understand the forecast better and how we could use it as an early warning.
(Water Company 02)	The key benefit achieved from this project was up to 6 weeks' notice of high demand events, significantly longer than the normal 10 day. This has been useful to prepare in advance for potential leakage events during winter and high customer demand events during the summer. The advance notice can allow operational activities to be prepared in advance of an event to reduce the impact of the high demand on both our customers and the business. It also has the potential to reduce demand from these events, therefore benefiting the environment from lower abstraction. For example, sending out customer communications to encourage using water wisely prior to a hot and dry weekend in the summer.

(Water Company 03)	Although there is no data on measurable impact, the risk to our customers is reduced by the timely implementation of such measures ahead of a higher demand period. This may also have a positive impact upon company expenditure if the need to deploy alterative response is reduced and Unplanned Outages events mitigated.
(Water Company 04)	A longer observation period is necessary to gain a clearer understanding of the impact. The project has provided valuable insights, but further assessment and refinements are needed to determine its long-term value.
Waste Water Alarm Volume Forecasting	
(Water Company 01)	Over the past year, we have been utilising and refining the Waste Alarm Forecasting System to enhance its effectiveness. We expect the system to provide several benefits with further development, including the ability to anticipate potential unsettled periods within a 30-day window, strengthening both weather resilience and operational response. Our ongoing collaboration with the Met Office has been invaluable, offering regular updates and opportunities for continuous improvements to the system. Using forecasting models, we have also identified key areas for further development. One significant opportunity is the integration of additional data sources, such as groundwater levels, to enhance the system's predictive capabilities and improve waste alarm accuracy.
(Water Company 02)	Great start but we need to go further and be more specific to really use this for operational and business insight. First step on a journey. I have no doubt this is the right thing to be looking at.

Quantifiable Benefits:

The benefits are challenging to quantify due to variations across activities and differing priorities among water companies. The impact is influenced by local operational challenges, existing infrastructure, and specific regulatory requirements, making a standardised assessment difficult.

Cost Savings: Initial estimated benefits for specific water demand forecasting activities provide early insights into potential efficiencies and operational improvements. Below are a few examples of the estimated cost savings:

Sub-seasonal demand forecasting has significantly improved water companies' ability to plan and execute work with greater confidence, reducing cancellations and associated costs.

Example 01: By shifting start dates ahead of mobilisation, we have minimised expensive on-site delays. The forecasting also allows us to extend our traditional autumn/spring working periods, enabling shorter maintenance tasks during high-demand risk periods and longer outages with a risk-based approach. This has helped us proactively manage contingencies and optimise asset availability, as demonstrated by the Hampton Court Site in West London. Additionally, we can now begin longer projects earlier, effectively extending our working season and improving overall efficiency.

The reduction in operational risk has improved decision-making, allowing for a more measured response to short-term demand fluctuations. While precise quantification of delay cost savings is challenging, estimates indicate over £5 million in delay costs were reported in AMP6 from just one joint venture, suggesting actual figures were much higher. Comparisons between AMPs remain difficult due to varying plan sizes, but early estimates suggest a significant reduction in AMP7, potentially conservatively at £1 million. Improvements in tunnel inspection compliance have also been a major success and the forecast tool will be playing a crucial role in supporting the record investment planned for AMP8.

By optimising mobilisation timelines and extending maintenance windows, sub-seasonal demand forecasting has significantly improved Thames Water's operational planning, reducing cancellations and costly delays. This has enhanced asset availability, enabling proactive contingency management and minimising service disruptions.

Example 02: The use of sub-seasonal forecasting in Thames Water's London region has already generated £910k in operational efficiency savings this financial year and is on track to achieve an annual saving of £1.5 million.

It is expected that other water companies will experience similar benefits in the future as confidence in the forecasting increases and expertise in interpreting risk assessments continues to develop. As more utilities adopt the forecasting model and refine their ability to analyse and respond to its insights, they will be better equipped to optimise resource management, enhance operational efficiency, and mitigate risks associated with extreme events. This gradual improvement in understanding and application will lead to broader industry-wide benefits, contributing to more sustainable water management practices and greater resilience to environmental and operational challenges.

However, waste alarm forecasting was primarily an exploratory effort, with no immediate benefits identified at this stage. Although the Wastewater product has been successful in early identification of high alarm periods, it has proved of limited value, without the development of a short-term Weather impact model.

Customer Reach: The water demand and waste forecasting solutions will/has the potential to deliver significant benefits to customers, including:

- Service Reliability Improvements: Enhanced reliability benefiting over 10 million customers in the Thames area, with variations depending on the water company and regions.
- Weather Resilience: The solution strengthens resilience against extreme weather events, reducing disruptions to customers across different service areas.
- Proactive Planning: Early warnings enable better operational preparedness, allowing for timely interventions to minimise service disruptions.

Environmental Impact:

- Optimising Response to Demand Fluctuations: By responding appropriately to alerts of potential demand increases & decreases environmental impact can be minimised. This may be through reduced abstraction, balancing sudden flow changes that could disrupt delicate biological processes and subsequent consequences and energy management, overall minimising climate impact.

With further development, the predictive capabilities of the waste forecasting model can generate significant environmental benefits, a list of possible areas outlined below.

- Reduced Pollution Incidents: Improved monitoring and proactive interventions have led to a decrease in pollution events, minimising environmental impact.
- Optimised Energy Usage: Enhanced operational efficiencies, such as improved pump scheduling and flow management, have contributed to lower energy consumption in wastewater operations.
- Enhanced Compliance: Strengthened regulatory adherence by reducing unauthorised discharges and ensuring wastewater management meets environmental standards.
- Lower Reputational Risks: Proactive pollution control and sustainable practices have helped mitigate reputational damage, reinforcing public trust and regulatory confidence.

Timescales for Realising Benefits

- **Immediate Benefits**: Enhanced planning and operational efficiency were evident during the trial phase of the water demand forecasting tool. With the right resources in place, this resulted in improved operational performance, increased customer satisfaction, and strengthened environmental compliance. However, waste alarm forecasting was primarily an exploratory effort, with no immediate benefits identified at this stage. The study of weather pattern impact on wastewater alarm volumes served as a valuable exploratory exercise, providing insights for potential future developments.

- **Medium-Term Benefits**: Sub-seasonal weather predictions have contributed to greater operational weather resilience, ensuring that adequate resources are available during adverse weather conditions for water demand forecasting. Full adoption of water demand forecasting tools by partner companies is expected within 1–2 years post-project. If pursued further and funded, we anticipate tangible benefits from waste forecasting within the next two years, as further refinements and the integration of high-resolution data sets enhance the existing model.

- **Long-Term Benefits:** Increased sector-wide resilience to climate variability, supporting net-zero ambitions. Over the next 5–10 years, ongoing development, widespread adoption, and integration of forecasting tools across the industry will drive sustained operational improvements, leading to long-term operational efficiencies and environmental benefits in both the water and waste sectors.

Sector Innovation Capability: The project contributed to cultural and operational innovation across the sector by:

- Demonstrating the value of cross-company collaboration.
- Building technical expertise in sub-seasonal forecasting.

These achievements have inspired a more proactive approach to innovation and climate resilience across the water sector.

Dissemination and Knowledge Sharing

Dissemination activities: The project engaged in the following dissemination efforts to ensure knowledge sharing, stakeholder engagement and sector-wide learning. These activities were designed to communicate project outcomes, gather feedback, and encourage broader adoption of the forecasting tools and key outputs. Key dissemination efforts included:

- **Workshops and Webinars**: Regular sessions were conducted with partner companies to share findings, discuss implementation challenges, and gather feedback for continuous improvement. These interactive discussions played a crucial role in refining the forecasting approach and aligning it with operational needs.

  A key dissemination event was organised by Spring in collaboration with Thames Water and the Met Office. A video of the event is available on the Spring website to ensure that the knowledge can continue to be accessed in the future. This event provided a platform to showcase the project's scope, key objectives, and early findings to a wider audience. To ensure transparency and knowledge transfer, a follow-up event will be arranged upon the project's completion, where final outcomes, lessons learned and recommendations for future development and adoption will be discussed with industry stakeholders.

- **Publications**: To document and communicate findings effectively, the project publications are intended to support training and decision-making within water companies and will be made accessible via the Thames Water website.

  The Met Office is preparing a detailed technical paper, which will provide a comprehensive overview of the methodologies, data analysis and forecasting improvements developed during the project. Alongside this, an End of Project Technical Report will be shared with all participating partners. The Met Office will endeavour to develop it into a peer-reviewed paper, as our own undertaking, to ensure that the learnings can be shared with the wider sector and/or other interest parties.

  Conferences and Events: Raising awareness and driving adoption within the industry the project team plans to deliver presentations at key industry conferences and innovation forums to engage with experts and operational teams. These sessions will provide an opportunity to highlight the benefits of sub-seasonal forecasting and demonstrate real-world applications.

Efficacy and Leanings from Dissemination: The planned activities include:

- **Training and Support**: Some bespoke training and material has been developed as part of this project. The lessons learned were the company tailored approach is the best. Future workshops and training sessions are essential to support the widespread adoption of forecasting tools. However, from a wastewater perspective, no further training sessions are currently planned. The next steps will depend on further funding to support and develop an enhanced model in this service.
- **Water Sector Engagement:** Continued collaboration with water industry will ensure the continued model development and understanding.
- **Knowledge Sharing:** Initially, outputs that are available for sharing will be hosted on the Thames Water website, with a link provided for requesting additional materials, such as technical reports. Looking ahead, a dedicated online resource hub could be developed in future project phases to centralise project insights, tools, and best practices. This platform

could serve as a repository for technical reports, case studies, training materials and forecasting models, ensuring broader accessibility and long-term knowledge retention.

Future and Ongoing Communications: The project team will focus on:

- Supporting partner companies in operationalising forecasting tools.
- Exploring opportunities and further development of wastewater forecasting applications.
- Promoting adoption across the wider water sector through training and collaboration.

Key activities include refining tools, hosting workshops and engaging with stakeholders to drive adoption.

Also, we are planning an end of project dissemination event that will focus on the benefits that the Ofwat Innovation Fund has brought in making this project a success. At present, this is in the planning stages, but options include an in-person event and/or a video summary.

Next Steps for Adoption and Implementation

Next Steps: As part of the stakeholder review and through a structured questionnaire, each participating water company provided insights into their next steps and the extent to which the forecasting outputs have been integrated within their organisations. This feedback includes details on implementation progress, challenges encountered and planned enhancements to optimise adoption. Also, a few companies shared their next steps on operational handover and long-term plan for the models. The information gathered highlights key trends, best practices and areas requiring further support or refinement. The detailed responses are outlined below.

Response from Water Companies:

Water Demand Forecasting	
(Water Company 01)	Greater confidence in planning outages which in turn gives better system resilience and compliance. Need to use over a longer period to really understand benefits, • Share weekly report with our operational colleagues and gain feedback. Continue, useful and comparison of forecast v actual.
(Water Company 02)	Our next steps as a business is disseminating the full 12 months results to the wider business which compares actual demand to forecasted demand from this project. This will then inform the cost-benefit assessment of this project internally. We would like to continue using this Met Office service, as it has shown benefits from knowing of high demand events in advance.
(Water Company 03)	Further refinement is needed to integrate forecasting into operational processes. While the forecasting method performed well for larger areas, our sample model did not achieve the same level of accuracy as others when applied to a single catchment. Further evaluation is required before considering adoption.

<table>
<tr><td></td><td>Enhancing the output format would make the forecasts more practical for use.</td></tr>
<tr><td colspan="2">Waste Water Alarm Volume Forecasting</td></tr>
<tr><td>(Water Company 01)</td><td>We will continue working with the Met Office until 31st March 2025, with any future development efforts subject to budget approval. The refinements needed to make it operationally valuable include: (1) Catchment/regional breakdown, (2) Provision of more alarm information to the met office and (3) Wider scope of weather and environmental data (e.g., Groundwater).</td></tr>
<tr><td>(Water Company 02)</td><td>Unlikely to continue to use the forecast in its current format.
Model validation needs to occur and needs to be easy. From this a forecast accuracy % could be devised to provide assurance and validate response
Short and long term models need to be visible together
Some talk about now casting recently which sounds interesting.
The forecast needs to be broken down into areas e.g. 4x4 mile polygons or a county.
New data to feed the model to be agreed upfront e.g. data transfer every 3 months or something.
As AMP 8 kicks off it is likely the landscape and correlation will begin to change
Weighting added to specific events e.g. first flush events, longer periods of dry weather e.g. 10+days, freezing temps – industry insight to help set thresholds.
Review cascading impacts for other industries e.g. power companies (ENW) their risk is sometimes our risk.
Track benefit realisation to validate success.</td></tr>
</table>

Wider Implementation: We have had a series of discussions, and it is evident across all participating companies that a seamless handover of water and waste forecasting tool outputs to operational teams is essential to maintaining continuity.

- *Handover of Forecasting Model Outputs:* Each business unit will determine whether the model output will be used as multi-user outputs, ensuring proper access and integration into operational workflows.

- *Training & Documentation:* Training has been provided on model results and their interpretation. Over the past two months, structured training sessions, along with supporting materials, have facilitated a smooth adoption process.

- *Support & Ongoing Maintenance:* A structured support plan will be in place, outlining responsibilities for updates and maintenance to ensure continued effectiveness. This includes defining roles for ongoing model adjustments and addressing operational needs.

Additionally, continuity of service from the Met Office will be ensured to provide necessary support and expertise.

Regular check-ins and feedback mechanisms will be implemented to address challenges. The objective is to enable operational teams with the necessary knowledge, tools, and support for effective long-term utilisation.

The project's methodology and outputs are scalable and replicable across the water sector. Plans for scaling include:

- Expanding collaboration with additional water companies and industry stakeholders.
- Leveraging the Met Office's expertise to explore new applications of sub-seasonal forecasting in other areas of water and wastewater operational areas.

These efforts aim to drive sector-wide adoption and amplify the project's long-term impacts.

Outturn Monitoring Data

Project Start Date	01/01/2023
Project Technical Completion Date	31/03/2025
Total Original Project Budget (per Winners Agreement) Total funding awarded + total financial contributions from partners (excluding the financial value of any in-kind contributions).	£796,584
Total Amount of Funding Awarded by Ofwat (per Winners Agreement) Amount of funding initially awarded by Ofwat.	£678,750
Originally Planned Partner Financial Contributions (per Winners Agreement) Financial contributions that were planned from partners at the outset of the project.	£117,834
Finalised Amount of Funding Awarded by Ofwat Finalised amount of funding awarded by Ofwat, where this has been increased through approved Project Change Requests (note this applies to a minority of projects and only for specific reasons).	£678,750
Finalised Partner Financial Contributions Finalised number of financial contributions required from partners to cover the project costs.	£117,834

Final Reflections and Concluding Remarks

The Use of Sub-Seasonal Forecasting to Improve Operational Decision-Making project has demonstrated the potential of advanced forecasting models to enhance water demand management operations across the UK water sector. Through a collaborative effort between Thames Water, the Met Office and multiple water companies, the project has established the integration of sub-seasonal forecasting into operational workflows, providing predictive insights that extend beyond traditional weather forecasting capabilities.

This project has laid the foundation for a more proactive, data-driven approach to operational decision-making in the UK water sector. By leveraging sub-seasonal forecasting, water companies now have greater visibility into potential risks, enabling smarter planning, improved resilience, and cost savings.

The water demand forecasting models have been widely adopted and proven effective, enabling better resource planning, maintenance scheduling and risk management. The wastewater alarm forecasting trials, while still in an exploratory phase, have highlighted key areas for further refinement, particularly the need for higher-resolution data and short-range forecasting tools to complement sub-seasonal predictions. Appendix A includes a list of both Water and Waste workstream recommendations, as well as general recommendations.

While water demand forecasting has matured into an operational tool, the wastewater forecasting workstream requires further refinement and investment. Future developments should focus on expanding predictive capabilities, integrating real-time environmental data, and enhancing model validation.

The project has proven the value of collaboration, innovation, and forecasting-driven decision-making in the water industry. As the sector moves towards greater climate resilience and operational efficiency, the outputs of this project will serve for future advancements.

References and Links

- *Angus, R., Rust, F., Rushby, I., Osborne, J., Savage, I., Valappil, S., and Pocze., K. The Benefit Sub Seasonal Forecasting Provides to The Water Industry – A Technical Report, March 2025.*
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Appendices

Appendix A: Final Recommendations: Water/Waste/General

Focus Area	Recommended Actions
Water Work Stream	
Enhancing Forecast Accuracy & Predictive Capabilities	✓ Incorporate higher-resolution data and additional environmental variables to improve predictive accuracy. ✓ Explore advanced machine learning techniques for better adaptability to different scenarios and weather conditions. ✓ Validate model performance by systematically comparing forecasted vs. actual demand, ensuring reliability for decision-making.
Strengthening Operational Planning & Risk Management	✓ Extending the Met Office forecasting service to all operational areas (all water company areas). ✓ Improving long-term tracking of forecast performance to build confidence in predictions and response planning.
Scaling & Industry Adoption:	✓ Encourage cross-functional adoption beyond core operational teams, integrating forecasts into all site operations, maintenance scheduling, resource planning etc. ✓ Explore the feasibility of integrating demand forecasting with energy demand insights to anticipate cascading risks.

	✓ Facilitate knowledge-sharing across water companies to refine methodologies and standardise forecasting practices.
Long-Term Sustainability & Business Support	✓ Secure funding and sponsorship to maintain and improve the forecasting model. ✓ Conduct a cost-benefit assessment to quantify financial and operational impacts, ensuring business value. ✓ Establish Key Performance Indicators (KPIs) to measure forecasting effectiveness and track improvements over time.
Waste Water Work Stream	
Enhancing Model Validation & Usability	✓ Ensure the outputs are truly operationally valuable, it is necessary to go further and provide more specific details, enabling deeper insights. ✓ Consider introducing a catchment or regional breakdown to address localised needs ✓ Standardise the base data set across all participating water companies to enhance consistency. ✓ Introduce event-based weighting mechanisms to refine accuracy for critical scenarios (flooding, pollutions, pump run, sewer levels, outfall events etc). ✓ Improve forecast visualisation and risk indicators to enhance usability for operational teams.
Optimising Operational Use & Integration	✓ Continue working with the Met Office, with potential future enhancements subject to further funding support. ✓ Improve forecast granularity by developing localised risk assessments (high resolution data). ✓ Make short-term and long-term forecasts visible together to enable better risk tracking. ✓ Explore nowcasting techniques for enhanced short-term responsiveness and real-time risk monitoring.
Addressing Technical Challenges & Industry Collaboration	✓ Simplify data extraction and validation processes to ensure seamless adoption across operational teams. ✓ Strengthen face-to-face collaboration sessions to enhance knowledge transfer and engagement. ✓ Establish a structured data-sharing schedule (e.g., quarterly updates) to ensure continued accuracy and relevance. ✓
Long-Term Strategy & Business Support	✓ Secure continued funding and sponsorship for ongoing model development and industry adoption. ✓ Promote cross-company collaboration to refine methodologies and standardise best practices. ✓ Implement a benefit realisation tracking framework to quantify and validate the impact of wastewater forecasting models.
General	
Enhancing Stakeholder Engagement & Training	✓ Schedule regular (monthly) forums to discuss the previous month's performance, current outlook and associated risks. These sessions would help integrate sub-seasonal forecasting into business-as-usual (BAU) processes and procedures, adopting continuous improvement and informed decision-making. ✓ Conduct more regular training sessions and user group sessions to ensure all companies fully understand and utilise forecasting tools effectively. ✓ Develop an interactive knowledge-sharing platform to facilitate best practice sharing across the industry. ✓ Establish a structured feedback mechanism to track model performance and drive continuous improvement.

Leveraging Emerging Technologies & Future Development	✓ Investigate the potential of AI-driven analytics and cloud-based solutions for better scalability and efficiency. ✓ Assess the impact of real-time sensor data integration to improve forecasting accuracy and responsiveness. ✓ Ensure automated alert systems are in place to provide early warnings for water and wastewater risk.

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