

CHALLENGES, COMPONENTS & CONTINUITY TO ADOPTING HIGHER MATURITY AND SOPHISTICATION WITH DIGITAL TWINS

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ABSTRACT

Prescriptive solutions that answer "what should happen" with an optimal recommendation to control a given network and treatment plant asset may feel and be perceived as out of reach for many councils and utilities on their digital twin adoption journey. Anglian Water (UK) has implemented an AI platform working towards a resilient and optimised water supply. One of the key foundations of Anglian Water's smart water strategy, the AI platform, where initial modelling indicates savings of £150,000 can be achieved at Marcott/Wing treatment plants with potential to be rolled out to the rest of its networks and treatment plants.

INTRODUCTION

Descriptive, predictive, and prescriptive digital twin solutions have been emerging in the water industry as crucial components to describe digital twin maturity and sophistication levels as progression and realization of technological advancements within the space continue to occur globally. Prescriptive solutions that answer "what should happen" with an optimal recommendation to control a given network and treatment plant asset may feel and be perceived as out of reach for many councils and utilities on their digital twin adoption journey. There is a more critical need for optimal, proactive decision-making to combat the burdens of climate change, fast-evolving regulatory frameworks, market resistance to rate increases, and uncertainties posed by the anticipated retirement of highly experienced and skilled workforce talent.

HIGHLIGHTS

- Progressing from descriptive to prescriptive analytics for optimum operations in evolving conditions.
- Trusted predictive decisions for reduction of energy-chemical usage, water loss with system resilience.
- Prescriptive analytics (AI) is a key foundation for Anglian Water's smart water strategy and descriptive analytics the starting point for Goldenfields Water County Council's optimization roadmap.

PROCESS & TECHNOLOGY OVERVIEW

One of the main challenges when aspiring to progress into the prescriptive analytics phase of digital twin maturity is the natural and perceived complexity involved in automation and optimization components – core aspects of the 'higher' maturity stage. Real-time data integration can be integral to maintaining an accurate model, yet it often inhibits the essential first step to optimization; incorporating system limits and process knowledge into a systems decision workflow. The technological focus of this paper will be on the challenges, components, and continuity to enable progression from one phase to the next through the digital twin levels of maturity.

The framework with critical components for digital twin maturity is as follows:

Descriptive and Diagnostic Analytics: Ability to monitor, visualize, and report on the performance of assets across a system. Transparency and data are the first steps towards implementing an eco-efficient

system. Key ingredients to a robust descriptive analytics toolset:

- Gather and unify asset information via data aggregator and storage (IoT, Historians, SCADA, LIMS,).
- Data visualization and analytics interface.

Predictive Analytics: Ability to simulate system behaviour offline, provide predictive insight into expected performance and degradation rates. Simulating energy, water, and waste mass balances allows users to determine rules to re-allocate, repair, and/or re-use system by-products for more robust operations. Key ingredients to a robust predictive analytics toolset:

- Connect modelling, simulation, numerical analysis data within the data platform.
- Control logic for selecting best toolsets to forecast future data.
- Asset-based metadata.

Prescriptive Analytics: Ability to provide system-wide support and optimal recommendations on operations, maintenance, and planning to maintain operations within control limits. Key ingredients:

- Decision workflow matrix (logic and process expertise).
- System boundary conditions (market price, available resources, asset remaining useful life).

Continuity between Analytic Maturity Types

Prescriptive analytics (AI) enables plant and network operators to take a uniform approach for optimum operations amongst evolving conditions. The AI can abstract out process schematics (water, wastewater networks and treatment plants) into a real-time predictive model that advises ideal operating ranges (Figure 1). Digital twin maturity frameworks indicate the level of sophistication of models utilised and is often a common reference for describing digital twin adoption progress (Figure 2). From initial implementation, timeseries data connections are established with data availability assessments, gap analysis, and a system needs assessment utilising descriptive analytics providing the foundation and pathway to progress within the platform to prescriptive analytics for optimization use cases for energy, chemical and water use reduction (Figure 3).

Challenges with Implementation – Both People and Process

A key component to developing the maturity of digital twins is having an effective method of incorporating institutional knowledge in readable and actionable data formats. Operations personnel maintain organizational and system knowledge in natural language form and within their daily actions. Ensuring limitations that cannot be identified by simulations such as max tank levels and maximum material pressure properties is collected by operators in a standard format enhances the digital model of its respective physical system.

The fear of the unknown can act as a first obstacle to implementing change, with the biggest competitor of progress being to “do nothing.” Change management can be a complex process, and organizations often face obstacles during the implementation of change initiatives.

In implementing digital twins across teams within a water organisation common challenges include; resistance to change, communication breakdowns, lack of a champion, inadequate planning, and insufficient resources. Like many enterprise implementations, a change management plan should be in place to minimize disruptions to business operations, improve communications, increase adoption, and enhance employee belief in the proposed digital twin being a fundamental aspect of their day-to-day workings and decision processes.

Working with Operations Teams for Adoption

“Disruption” being a technology industry darling word, does not equate to the same sentiment when owning the responsibility of operating a water system. Our water systems being essential to the health of our communities with any downtime or drop in system resilience posing potential for high consequence with the end consumer – operators are understandably hesitant to change current practices.

As disruptive innovations and new technologies continue to shape our world, water organizations must have a strategy that enables operators and engineering teams to successfully make sense of operational technologies so that adoption actually enhances their ability to monitor, manage, mitigate risk and optimally operate the essential systems they are responsible for.

In building a change management plan, capturing staff knowledge through operator interviews is critical to properly utilizing time-series process data. While this data can effectively identify relationships

between factors like temperature and system performance, information like unregistered equipment use or visually inspected components that lead to operations changes can only be acquired from a water organization's daily operators and on the ground teams. By involving operators in the process of developing a roadmap strategy, organizations can ensure that they have the necessary knowledge to adopt operational technologies effectively while minimizing risks to the essential systems they manage.

Implementation Method

The core technology behind a digital twin is an effective data aggregator. Challenges may exist when data sources are siloed and scattered around an organization, however, an effective digital twin toolset can be utilized to properly comprehend and ensure data integrity for the digital twin.

Organizations tend to believe that data availability on its own paves the route to water digitalization. However, data quality is an essential requirement to model-based optimization through digital twins. The digital twin platform, Info360 has been designed and built to facilitate essential data cleanup, aggregation, and measure the integrity of the data, for effective use in simulations.

Upon consolidation of data sources (LIMS, SCADA, Weather, PLC, Hydraulic Model), simulation scenarios based on likely events are used to prop up data driven performance recommendations, to facilitate the transition to prescriptive modelling.

Learnings from project and personnel challenges have been incorporated into the digital twin implementation framework (Figure 4) as well as the software architecture to ensure a synchronous activity between operations and simulation.

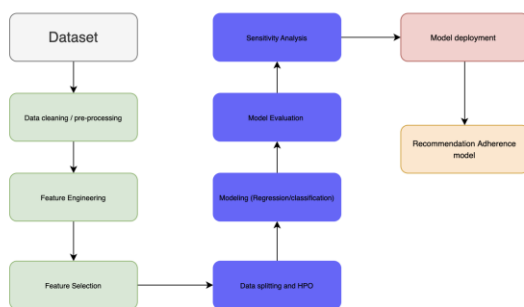


Figure 4 Timeseries forecasting workflow from datasets to a predictive recommendation model.

For incorporation of Machine Learning models, a feature engineering approach is utilized for time-series data forecasting. Feature engineering entails applying domain knowledge and relationship building between demand and forecast or outlining the principles of flow and pressure. Once the adequate feature sets have been evaluated, a feature selection exercise is used to evaluate a features performance and relevance to a models assumptions. Machine learning models such as a BSS-ANOVA (Gaussian process) utilise a hybrid data-physics model that ensure that results meet the laws of physics; useful where actual data may indicate conditions outside of the norm – that may have been caused by something as simple as a misaligned flow meter, uncalibrated sensor, or unreliable data stream. Upon the development of a model, a sensitivity analysis is then performed to establish the ability of a model to perform with input variables along a dynamic range. An adherence model is then utilized to measure the performance of the results against operator actions to determine whether or not the resulting recommendations are effective in achieving their intended purpose (pressure management, energy efficiency, water quality).

OUTCOMES

The outlined technology was applied to the following Anglian Water (UK) use cases.

Predictive AI Recommendations for WTW Energy Optimization Program - Anglian Water, UK:

Anglian Water has implemented an AI platform working towards a resilient and optimised water supply with an initial focus on achieving energy and chemical optimization within its Morcott and Wing Water Treatment works.

Project goals included leveraging sensor data to build prescriptive analytics models to develop a framework for operations of the Wing and Morcott Water Treatment Works and Anglian Water's network as well as optimize control inputs for key energy intensive pump stations and valves associated with reservoirs. The project's success criteria focussed on reducing the pump operation while ensuring reservoir levels remained within constraints. The optimization for the Wing/Morcott inlet feed pumps involved a strategy that ensured constraints were not violated, demand prediction accuracy was maintained with a decision to focus on cost savings achieved through tariff reallocation (Figure 5). Figure 6 provides an example of actual operator and AI recommended performance shown

in pink and dark blue respectively. Referring to Figure 6, the first and second graphs highlight Morcott and Wing treatment plants water volume respectively, with the third graph showing the plant's combined volumes. The fifth graph shows the tariff/cost schedule for a specific day in October of 2022.

Existing pump rotation schedules were identified for improvement at Empingham Wing and Empingham Morcott pump stations as they were demonstrating to be inefficient; as the program logic control (PLC) was not showing an evenly distributed operation across its given pumps.

A new rotational schedule was created to expand the operational lives of the pumps and reduce operations and maintenance (O&M) costs. Tables 1 and 2 show the pump rotation schedules for the Empingham Wing and Morcott pump stations with the following operational constraints being applied:

- Maximum step changes for pumps: 20 RPM per 2 minutes to avoid disruption of the sludge blanket.
- Maximum pump runtime of 300 hours (open for adjustment over time)
- If a flow setpoint overlaps with another set of pumps, the current number of pumps will be maintained. I.e., When reducing flow, 3 pumps speed setpoint will be decreased instead of turning a single pump off.

Table 1 Empingham Wing Pumps rotation schedule.

Number of Pumps ON	Flow (TCMD)
1 Pump	< 40
2 Pumps	40 – 80
3 Pumps	75 – 160
4 Pumps	155 – 200
5 Pumps	195 - 250
6 Pumps	215 - 278

Table 2 Empingham Morcott Pumps

Number of Pumps ON	Flow (TCMD)
1 Pump	<25
2 Pumps	25 – 45
3 Pumps	45 – 90
4 Pumps	>90

The AI solution will provide recommendations that will meet future customer demand while optimizing energy consumption. The setpoint recommendations will be displayed on the intelligent control page. The intelligent control page for Anglian Water's Wing and Morcott inlet pumps, shown in Figure 7, where the user receives predictive recommendations on optimal control setpoint schedules. Manual control options have been put in place for a pump flow setpoint and individual pump speed setpoints at Wing and Morcott's Inlet pump stations, where pump rotation benefits would not be realized.

Managing Risk

Minimizing false negatives within the AI recommendations is a top priority in sustaining a workable and productive predictive decision support system. Models have been trained using an extended historical dataset of 1-2 years and have been tested and validated.

A reliability model has been built to define scenarios with inaccurate readings (flatlines, outliers etc) and missing data points that may lead to inaccurate predictive recommendations. Several algorithms were developed to detect these anomalies to notify the operator with "greyed-out" setpoint recommendations for the respective timeline within a given scenario where data inaccuracy impacts a given predictive recommendation.

A reinforced learning model with a query based warm start approach was built to incrementally introduce optimal control from the Anglian operations team current operational routine which makes the overall optimization routine less susceptible to simulation error.

The query-based approach includes the following scenarios for operators:

Scenario 1: If Morcott or Wing WTW alarms are triggered from the contact/storage tanks.

- Open Upton and Chesterton valves

Scenario 2: If both Morcott and Wing WTW Alarms are activated.

- Open Upton and Chesterton valves, if WRs are close to being filled, then:
 - Increase speed at Beanfield Pump HL (5 & 6)
- If both Hannington WR and Beanfield WR2 are close to being filled, then:
 - Reduce inlet flows at WTW.

Energy Cost Savings Analysis

With an optimization strategy that includes tariff reallocation and pump rotation efficiency, an initial savings analysis conducted on the inlet feed pumps (May 2021-April 2022) showed a savings achieved of £27,000. Cost savings were achieved through accurate demand forecasting to allow the system to run during low tariff time periods (Figure 5).

One of the key foundations of Anglian Water's smart water strategy, the AI platform, where initial modelling indicates savings of £150,000 can be achieved at Marcott and Wing plants with potential to be rolled out across the rest of its networks and treatment plants. Additional benefits being pursued with the platform (example workspaces shown, Figures 8 and 9) include utilising plant forecasts to allow for supplemental analysis highlighting when and where operators are most effective, prolonging equipment life by remaining within equipment boundaries, early detection on equipment issues and utilising AI to help fill the gap when operations staff retire for knowledge retention and sharing to upskill employees.

Next steps for the project include training of operations staff to determine how best for system recommendations to be incorporated with operations. Additional priority measurements include understanding metrics for knowledge transfer and operational efficiencies around staff scheduling.

Working Towards Operational AI for All Utilities

The Info360 digital twin platform has been built to enable prescriptive analytics to be attainable for small and medium size water utilities. Organisations can now begin with the simple step of initial data connections through to data integrity assessments, incorporation of process controls and ongoing review of potential model performance – enabling assessments that will accurately measure the potential for optimization with prescriptive analytics for demand forecasting, energy (pumps, aerators, dewatering etc) and energy optimization.

Goldenfields Water, Australia is currently implementing descriptive analytics within its Jugiong WTP facility with the goal to reduce associated effort and costs while making enhancements to monitoring, visualization and reporting on the performance of their treatment assets and systems.

Initial project priority includes identifying high energy consuming areas of the plant and network to further establish Energy Conservation Measures (ECMs) to

meet energy reduction goals as well as building a list of projects to incorporate into digital workspaces and workflows that includes event monitoring, sustainability, and energy audits as well as staff training workspaces for knowledge sharing, retention, and progression.

From initial implementation at GWCC, timeseries data connections are being established with data availability assessments, gap analysis, and a system needs assessment utilising descriptive analytics providing the foundation and a practical, replicable pathway upfront to progress within the platform to prescriptive analytics for optimization use cases for energy, chemical and water use reduction.

CONCLUSION

Prescriptive solutions that answer "what should happen" with an optimal recommendation to control a given network and treatment plant asset may feel and be perceived as out of reach for many councils and utilities on their digital twin adoption journey. Prescriptive analytics (AI) enables plant and network operators to take a uniform approach for optimum operations amongst evolving conditions.

Anglian Water (UK) has implemented an AI platform working towards a resilient and optimised water supply. One of the key foundations of Anglian Water's smart water strategy, the AI platform, where initial modelling indicates savings of £150,000 can be achieved at Marcott/Wing treatment plants with potential to be rolled out to the rest of its networks and treatment plants.

Goldenfields Water County Council (GWCC), Australia is currently implementing descriptive analytics within its Jugiong WTP facility with the goal to reduce associated effort and costs while making enhancements to monitoring, visualization and reporting on the performance of their treatment assets and systems. to progress within the platform to prescriptive analytics for optimization use cases for energy, chemical and water use reduction.

The aspiration for prescriptive analytics is attainable when starting with the simple step of initial data connections and descriptive analytics, and with progression across analytic types enabled, the water industry continues its pursuit to building resilient and circular systems to optimally address its challenges.

ACKNOWLEDGMENTS

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Why Prescriptive Analytics?

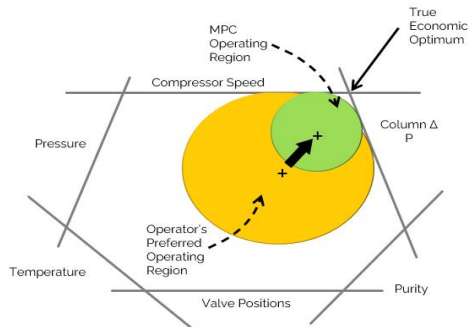


Figure 1 Prescriptive analytics enables plant and network operators to take a uniform approach for optimum operations amongst evolving conditions. The green circle is the AI advised operating range relative to the operator's comfortable region of operation (orange circle).

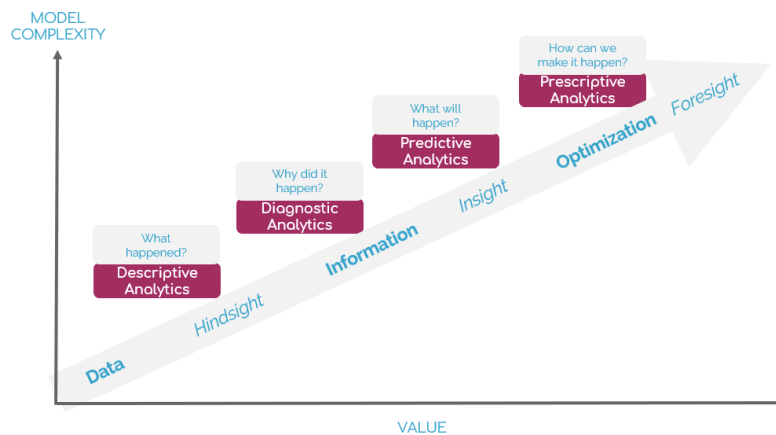


Figure 2 Digital twin maturity framework indicates the level of sophistication of models being utilised in pursuit of value and is often a common reference for describing progress achieved within water digital twin adoption.

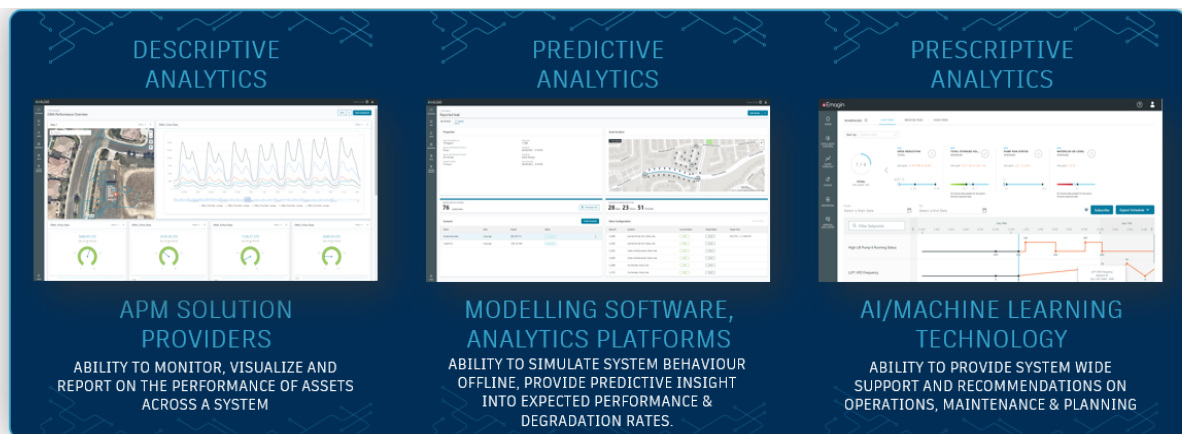


Figure 3 From initial implementation timeseries data connections, data availability assessments, gap analysis then a data availability and a needs assessment occur via descriptive analytics to progress to prescriptive analytics for optimization use cases for energy, chemical and water use reduction.

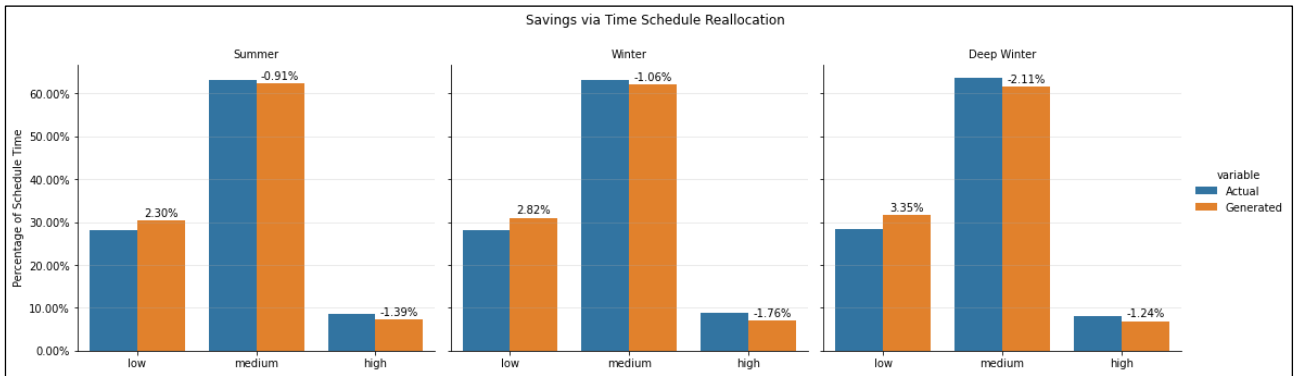


Figure 5 Initial cost savings at Anglian Water's Wing and Morcott plants achieved with prescriptive analytics (AI predictive recommendations) were through demand forecasting which allowed the system to run during low tariff time periods.

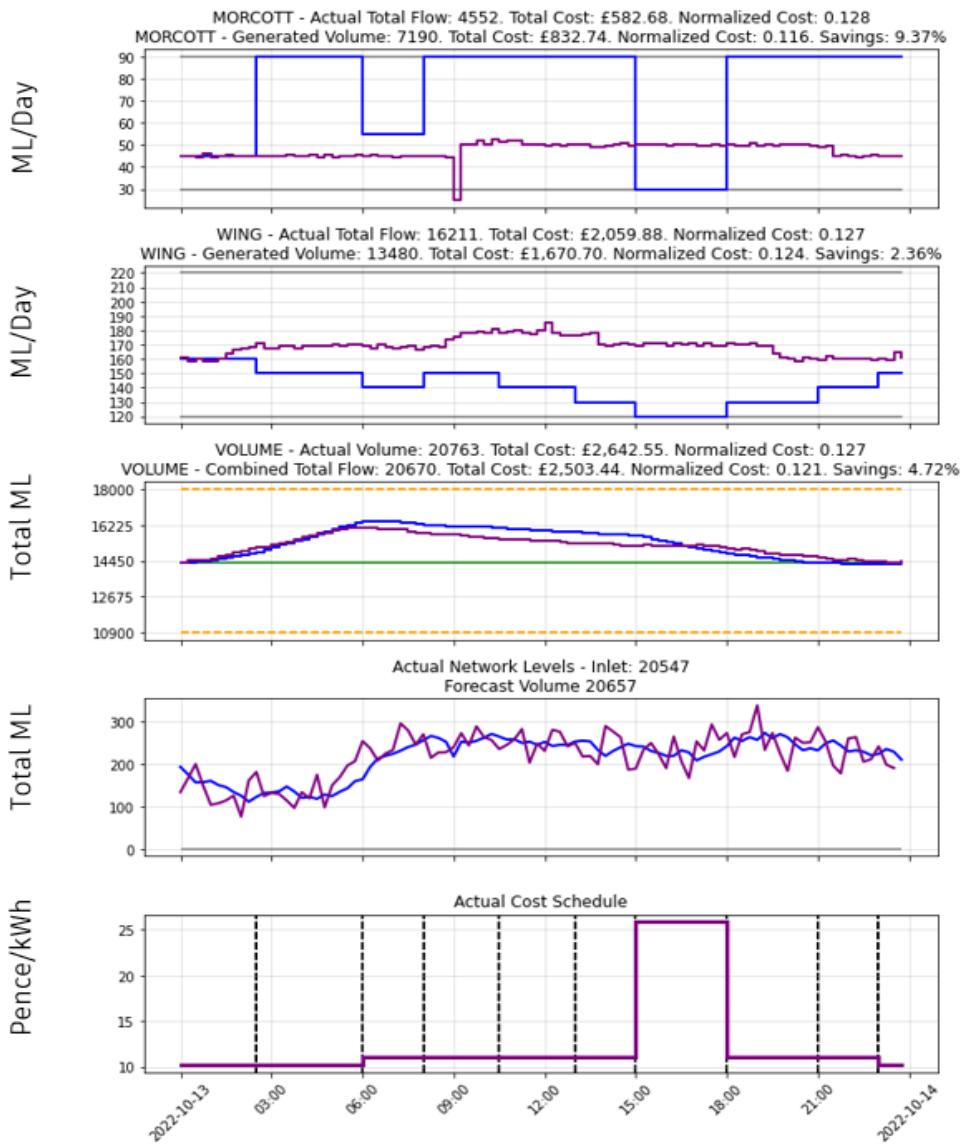


Figure 6 Actual operator and AI recommended performance are shown in pink and dark blue respectively. The first and second graphs highlight Morcott and Wing treatment plants water volume respectively, with the third graph showing the plant's combined volumes. The fourth graph shows the tariff/cost schedule for a specific day in October 2022.

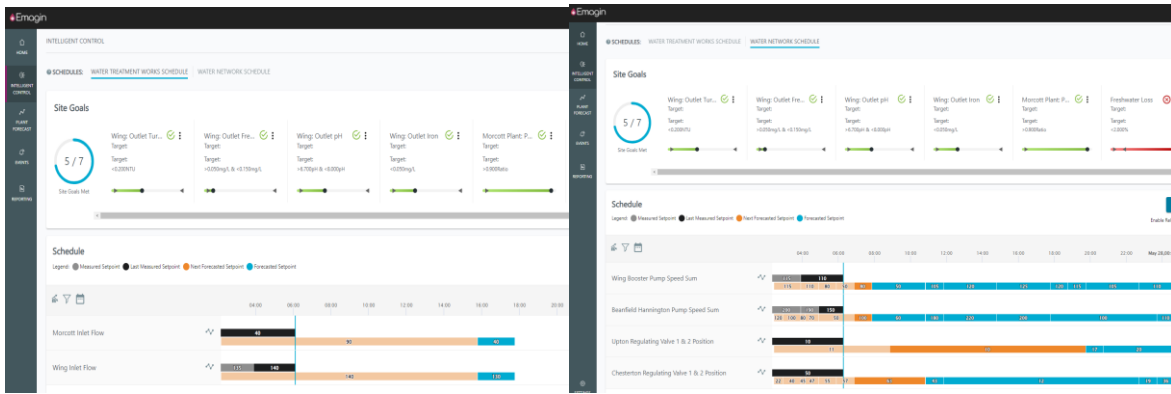


Figure 7 The intelligent control page for Anglian Water’s Wing and Morcott inlet pump stations (left) and network booster pump stations and tank valves (right) where the user receives predictive recommendations on optimal control setpoint schedules – black setpoints are measured values, orange setpoints are current to be followed and blue represent upcoming forecasted recommendations.

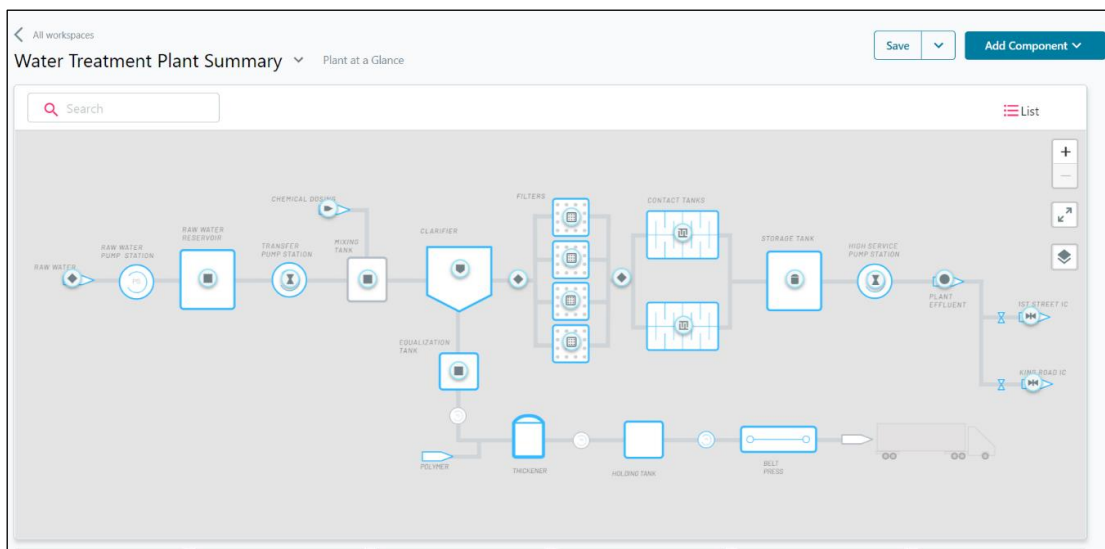


Figure 8 Treatment plant schematic representation with definable facilities (pre-treatment, clarifiers, disinfection etc) with ‘taggable elements’ within a user definable workspace to associate data streams and analytics with process flows.



Figure 9 Analytics viewable within a user defined workspace for daily use that incorporates process flow diagrams, network maps, associated sensors and analytics, alert summaries, and data visualisation of live, forecast, and historical data.