SOUTH EAST WATER HOLISTIC CATCHMENT BASED MONITORING AND OPERATIONAL MODELLING OF A SEWER CATCHMENT

Joshua Finch [1], Riley Damnics [2], Patrick Bonk [3], Daniel Moreira [4]
1. South East Water, Melbourne, VIC, Australia
2. South East Water, Melbourne, VIC, Australia
3. Innovyze, Brisbane, QLD, Australia
4. Innovyze, Wallingford, Oxfordshire, UK

KEYWORDS

Monitoring Technology, Predictive Operational Models, Incident Management, Spill Mitigation

ABSTRACT

Elster Creek is a low-lying coastal catchment that historically suffered from surcharging, localised spills, and discharge to emergency relief structures during extreme weather events. Previously, SEW had no means of prediction or early warning for these events; as a result, intervention could not be taken to mitigate the consequences.

Outcomes provide a data driven and operational model approach to address operational challenges from a holistic catchment monitoring and modelling standpoint. A main ongoing objective is to further the technological toolset to contribute to the reduction of likelihood of spills to the environment and financial implications of such events.

INTRODUCTION

Elster Creek is a low-lying coastal catchment that has historically suffered from surcharging, localised spills, and discharge to emergency relief structures during extreme weather events. Previously, SEW had no means of prediction or early warning for these types of events and as a result intervention could not be taken to mitigate the consequences. In addition to wet weather issues at Elster Creek, the whole of SEW network experiences occasional pump station power failures and dry weather pipe blockages. These events also pose the risk of creating localised spills and discharge to ERS. The technological focus for this paper will be around Advanced Blokaid® sewer monitoring devices developed by SEW and predictive operational models, ICMLive developed by Innovyze, for predictive incident management and day to day decisions of network operations. The outcomes will focus on how the technologies align to provide a toolset to address operational challenges from a holistic catchment monitoring and modelling standpoint. Forecast rainfall data available within Australia (Bureau of Meteorology – BOM) has now improved in resolution to enable predictive use cases within Australian sewer catchments.

HIGHLIGHTS

- Blokaid sewer monitoring devices for a data driven approach to sewer asset management.
- Predictive operational models to inform network operations and performance for incoming events.
- Technological toolset to combat sewerage spilling, pump station failures and pipe blockages.
- Improved forecast rainfall data available within Australia for predictive use cases.

PROCESS & TECHNOLOGY OVERVIEW

Blokaids – Pump Station and ERS Monitoring

SEW developed sewer monitoring devices (Advanced Blokaid®) which are simple to install and do not require a confined space entry. These devices are designed to be cost-effective, resilient to the most aggressive sewer environment and have a battery life up to 10 years. The devices use low-cost, low-powered 4G or NB-IoT communications to send level data in addition to configurable level warning alarms to a centralised SCADA system as shown in Figure 1. The Elster Creek catchment has 25 Blokaid devices deployed at ERS locations and other high risk spill locations.

Operators monitor these devices for two alarm types: the Ultrasonic Alarm or the Float Switch Alarm. The ultrasonic alarm works by bouncing a high frequency sound wave off the surface of the sewer and calculating how long it takes for that signal to return, in turn calculating the level of the sewer flow. The float switch alarm is designed to act as a redundancy or confirmation in the case of potential false readings by the ultrasonic alarm. The float switch alarm has the capability to return one of two binary states based upon the level specified at installation.

Once an operator has been alerted to either of the alarms, based on the level trend and the corresponding information from the rest of the network the operator will request an action to be taken. Actions can range from organizing the proactive clearing of a blockage to identifying rising sewer network levels in a catchment to enable appropriate resourcing. These Blokaid devices have been successful in identifying several blockages (107 in FY 20-21 from ~ 950 devices) and other hydraulic capacity issues within the Elster Creek catchment and the overall entirety of the SEW network.

Predictive Operational Models – "What-If" Incident Management:

Operational modelling and predictive real-time decision support tools (ICMLive) are being utilised in sewer networks globally with adoption occurring by utilities. Utilising forecast spatial rainfall feeds from meteorological data, the predictive decision support tool provides a future and historical state of a network with a degree of trust. South East Water plan to utilise the technology for incident response management and day to day decisions around pump station failures and system blockage detection. Figure 2 shows the software's operator interface for discernment of hydraulic results on a particular asset such as a specific pipe, manhole or control structure.

The predictive operational model supplements the Blokaid monitoring system providing system forecasts and hydraulic insights where in locations without sensors, verification alerts can inform blockages in real-time, inform with alerts when a sensor failure has occurred, inform future placement of sensors and further improve model accuracy and representation of network as incidents and spills occur.

Transitioning from Planning Models:

Predictive operational models are composed of the same key model inputs and components that make up a standard hydraulic planning model: Infrastructure data, Inflows, Controls and Run Settings. Calibrated sewer models used for planning purposes are the norm across Australia. Model control data was derived directly from live SCADA feeds, available observed inflow data was taken from the Blokaid data with model runs kicking off at the present time on pre-defined model run intervals. Simulations will also commence if an incoming rainfall event was detected by the software.

An Operational Interface:

The application has two main views -the overview page and the network page. The overview page provides a visual summary of the alerts, grouped within areas of interest. The network pages allow operators to access live data from modelled network objects in greater detail. Through the application's Operator Interface, users have the ability to initiate additional runs and view observed data (rainfall, flow, level, pump status etc) and results from any of the simulation runs (automated or user initiated) in the form of dynamically themed maps, tables or graphs. The decision support tool based on the future state of a network enables users to carry out "user-runs" in which initial conditions are manually selected for a run, initiate runs based on previous forecasts and edit any of the observed or forecast data to be used in the run. Figure 3 shows schematically how the operational model incorporates the existing planning model, receives inputs from spatial rainfall (BOM data) and produces predictive outputs to inform operations and field crews for various forecast incident scenarios.

Adding "What-ifs" to Network Decision Support:

For the derivation of operational strategies, user-run simulations will carry out a sequence of model runs where scenarios differ only in the operation of selected control structures. Users can run alternative scenarios (close this valve, activate a weir, start/stop this pump etc) to work out a strategy to minimise detrimental effects and mitigate consequential events. The networks decision support systems can now utilise forecasts to send and direct tanker trucks to pump out a critical section of a system or to alert crews onsite and even potentially customers to evacuate their homes. Alerts can be generated, and information can be disseminated to the relevant stakeholders via email notification and results made available for updating websites.

Simulation Server and Automatic Model Runs:

Simulations of the model(s) can be set up to run automatically –how frequently this happens can be changed depending on the incoming data or the model results. The application's simulation server allows real-time data to be fed directly into the software as well as manages automatic simulations based on user defined run intervals and run types.

Whenever a new forecast is initiated, the various live (external) data sources are queried to ensure the most recent available data has been loaded into the software's built-in database. The up-to-date data is automatically validated (an example being data remaining between user specified maximum and minimum thresholds) to ensure its reliability. With validation complete, the data required for the duration of the forecast simulation, utilising both the hindcast and forecast periods, is loaded and the simulation is carried out. Simultaneously the application utilises suitable initial conditions from earlier model runs for the simulation. The model's accuracy and level of trust in the forecast period is understood based on the differentiation of observed and modelled data during the hindcast period.

Discernment of Predictive Results:

The software allows users to derive meaning and system context through alert themes (colour coordination and symbolic representation of network events), a grid summary table that provides a grid view of alert start and end timings along with the viewing of coloured graphs for flow, levels, and water quality. Graphs automatically display both observed (measured) and forecast data.

Application results analysis also includes:

- Special alerts can be assigned to increasing the run frequency (i.e. Rainfall intensity, level readings) to trigger the application to adjust the frequency of the automatic simulations.
- The areas of interest which can be themed to indicate the severity of any alert occurring within its boundary, showing a simple yet effective view of the current forecast.
- The software's network view showing the location of the objects generating any alerts.

Main High-Level Alert Categories Implemented:

1) Cumulative rainfall in each rainfall cell over any 1h period for different severities: >5mm, >10mm, >15mm and >20mm. ICMLive performs on-the-fly statistical analysis on rainfall intensities calculating its integral over a user defined period.
2) Alerts on pumping stations when all respective pumps fail; including logic to avoid false positives when the pump is being maintained by on-site crews. ICMLive taps into SCADA feeds informing about the status of the station door (open or shut).
3) High observed levels. Blokaids in the network feed level data to ICMLive, which alerts if observed levels are less than 0.5m from the modelled ground level at any location.
4) Observed spills. Blokaids indicate when spillage has occurred.
5) Predicted spills. The catchment's hydraulic model predicts spillage for the next 12h using BoM's spatial rainfall forecast data and wastewater disposal patterns.
6) Model deviation. Modelling results for levels are compared to the observed Blokaid levels. Deviations in modelled vs observed highlight network blockages or areas where the accuracy of the model could be improved.

OUTCOMES

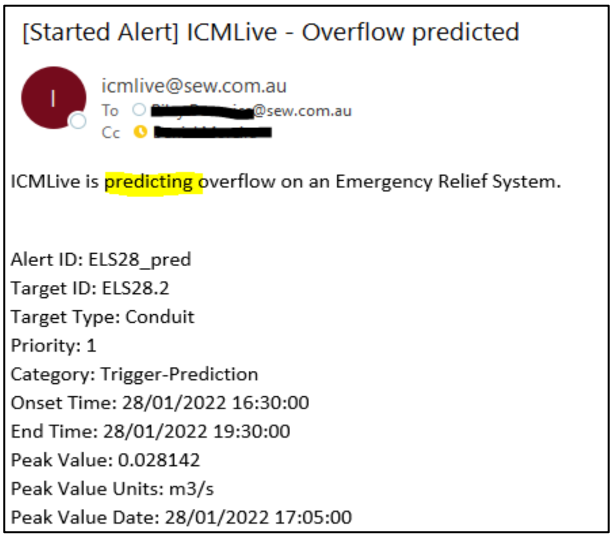
As described, sewer monitoring devices (Advanced Blokaid®) and operational models (ICMLive) are being used within the Elster Creek catchment for a holistic approach to addressing challenges attributed to significant incoming rainfall events, pump station failures and pipe blockages.

Incoming Rainfall Events of Significance

Significant wet weather events in catchment areas that have a lot of infiltration resulting in inflow to pump stations that exceed the pump capacity, resulting in a reactive response of eduction and/or holding back of other sites. These significant wet weather events with large magnitude can have the worst case outcome of causing sewage to spill to the environment. Blokaids have provided a means of early identification to allow control room and field operators to take action to reduce the likelihood of these spills. ICMLive allows prediction of rainfall quantity and simulation of potential impact on sewer levels to alert the operations teams 4-6 hours before the event itself allowing for time to plan a response. Rainfall visualisations used in ICMLive can be seen in Figure 4.

In addition, data from Blokaids allows for real life sewer level rise to be trended parallel to predicted level rise, as shown in Figure 5, to inform model accuracies/inaccuracies and inform updates to the planning model.

An example where ICM Live predicted a sewer spill as the result of a forecasted rainfall event is shown in Figure 6 where for a particular ERS, the operations team was notified via an alert email of an incoming spill 4 hours prior to the predicted time of spill. The alert email includes location, asset type, alert category, onset and end of spill time, peak values associated with spill and an associated predictive hydrograph at the respective location.

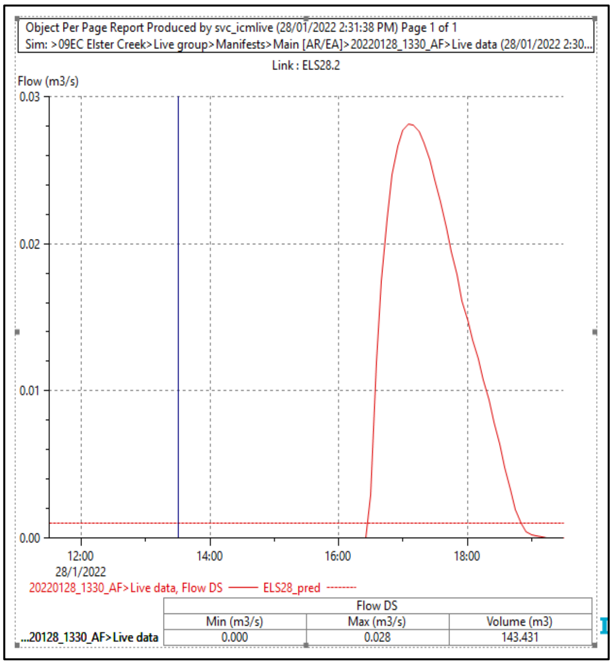


[Started Alert] ICMLive - Overflow predicted

icmlive@sew.com.au
To [redacted]@sew.com.au
Cc [redacted]

ICMLive is predicting overflow on an Emergency Relief System.

Alert ID: ELS28_pred
Target ID: ELS28.2
Target Type: Conduit
Priority: 1
Category: Trigger-Prediction
Onset Time: 28/01/2022 16:30:00
End Time: 28/01/2022 19:30:00
Peak Value: 0.028142
Peak Value Units: m3/s
Peak Value Date: 28/01/2022 17:05:00

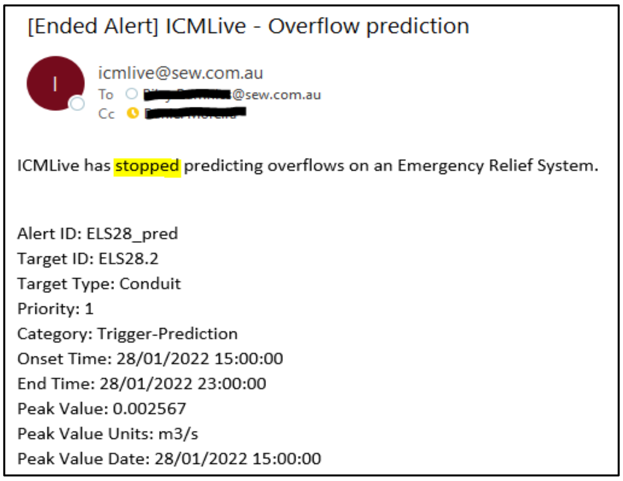


Object Per Page Report Produced by svc_icmlive (28/01/2022 2:31:38 PM) Page 1 of 1
Sim: >09EC Elster Creek>Live group>Manifests>Main [AR/EA]>20220128_1330_AF>Live data (28/01/2022 2:30...

	Flow DS		
	Min (m3/s)	Max (m3/s)	Volume (m3)
...20128_1330_AF>Live data	0.000	0.028	143.431

Figure 6 ICMLive forecasted an overflow at an ERS structure sending a notification and event overview.

The operational model updates its predictions over time based on evolving and updated rainfall predictions from BOM data as the event approaches. Essentially, the closer to the event itself operators will have the most up to date sense on how the respective event will impact network hydraulics and spillage prediction accuracy. For this particular predicted spill event, as shown in Figure 7, the forecasted BOM data was updated closer to the actual event and in turn the operational modelling software sent an updated notification email to indicate the predicted spill event was no longer going to occur for this particular location.

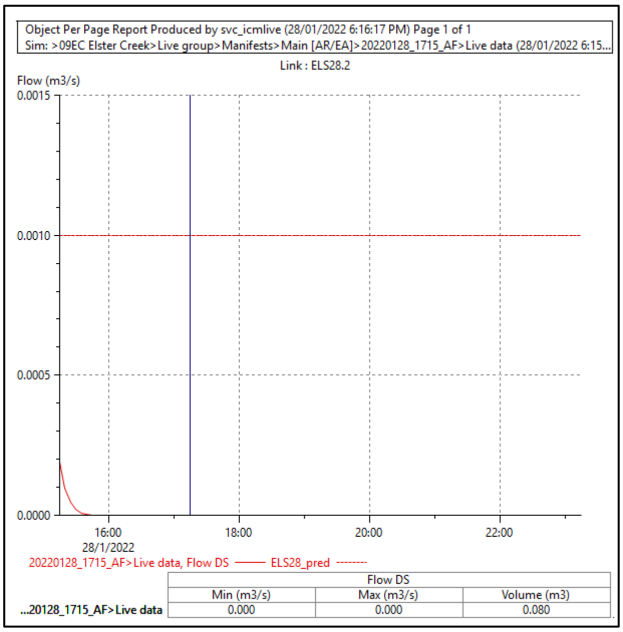


[Ended Alert] ICMLive - Overflow prediction

icmlive@sew.com.au
To [redacted]@sew.com.au
Cc [redacted]

ICMLive has stopped predicting overflows on an Emergency Relief System.

Alert ID: ELS28_pred
Target ID: ELS28.2
Target Type: Conduit
Priority: 1
Category: Trigger-Prediction
Onset Time: 28/01/2022 15:00:00
End Time: 28/01/2022 23:00:00
Peak Value: 0.002567
Peak Value Units: m3/s
Peak Value Date: 28/01/2022 15:00:00



Object Per Page Report Produced by svc_icmlive (28/01/2022 6:16:17 PM) Page 1 of 1
Sim: >09EC Elster Creek>Live group>Manifests>Main [AR/EA]>20220128_1715_AF>Live data (28/01/2022 6:15...

	Flow DS		
	Min (m3/s)	Max (m3/s)	Volume (m3)
...20128_1715_AF>Live data	0.000	0.000	0.080

Figure 7 ICMLive forecasted closer to the event notified operations a spill was no longer imminent.

SEW envisions model predictions could be used to proactively organise sufficient resourcing to mitigate any impacts the event might have on the surrounding environment. Solutions and mitigation efforts would potentially include proactively arranging for eductor trucks to be on standby, arranging for additional operations personnel to be on duty or holding back upstream pump stations to maximize available network capacity. All said measures can help to mitigate spilling events, these can be initiated sooner due to Blokaid devices. The intention is that even more pre-warning will be available due to operational models to allow forecasting and prioritization of response.

Pump Station Failures

During unplanned power outages, burst rising mains and other operational issues where the pump station cannot operate, the alarm operators are relying on holding times that can be ‘old’ and outdated or contextually inaccurate to make decisions. This can result in unnesecary urgent requests for eductor trucks or in more severe cases insufficient eduction/bypass pumping capacity being supplied to keep up with station flows. ICMLive allows the level rise to be simulated for each specific pump station failure so that an accurate and dynamic time to spill forecast can be provided to operators. See Figures 8 and 9 for examples of the visualisation. On initiation of power failure/ stoppage of all pumps, or when a large storm is forecast (thresholds adjustable by operations), the live model has the ability to automatically simulate future flows and level changes of the affected network to obtain calculated holding times. The user can also model different scenarios to aid operational decision making. Based upon the respective holding time, the operator can then make decisions such as:

- In the case of a mass network failure the prioritisation of resource allocation to stations with lower holding times.
- In the case of power outages, the decision on whether a resource (generator, eduction truck) is required based on the service return time.
- In the case of a burst rising main, using the inflow to calculate the required bypass pumping volumes.

Pipe Blockages

Blokaids have been placed in critical parts of the network (ERS locations, upstream of pump stations and sections of pipe susceptible to blockages) to provide early identification of sewer surcharge and the opportunity to prevent or mitigate spills. ICMLive provides the ability to simulate the level rise caused by the blockage and estimate the time until spill in addition to the spill location based on input levels to the model. Similar to the pump station failure scenarios, based upon the information received from the model, SEW Operators could make decisions on resource allocation and urgency. Lowering operational costs and the personal fatigue of operators are key benefits along with meeting environmental responsibilities.

Next Steps for Operational Modelling of Sewer Catchments:

- For all catchments in the South East Region, deploy operator client style dashboard for operators to include a visual prediction of incoming rainfall events of significance (4-6 hours prior to event – spatial intensity and cumulative volume) allowing time to plan a response.
- Refine models (calibration and alerting) for Elster Creek for predictive hydraulics on the pump station failure and pipe blockage use cases. Planning team will assess where calibration data is showing a discrepancy between observed data for a 14 day and multiple month historical period. Iteration of operational model calibration will help develop best practice for model information exchange between Operations and Planning teams.
- For predictive hydraulic use cases (pump station failures, pipe blockages) select next catchment area based on events of significance statistics regarding catchment spills & blockages.

CONCLUSION

Sewer monitoring with Blokaids and operational models with ICMLive have been deployed to combat issues associated with incoming significant rainfall events, proactive management of pump station failures and early identification of blockages while simulating level rise for time to spill conditions.

The Elster Creek ICMLive model is still in the early days of implementation in the network so as real-world events occur and the above scenarios have been tested this will allow for further learnings and updates to models, further refining the strategy of how SEW responds to these types of events. The next steps of the project are to develop sufficient trust in the accuracy of the live model such that it can inform operational decision making. Decisions such as identifying the need for sewer eduction in advance of a storm and having crews on standby, or prioritising eduction to certain stations in situations where a number of stations become overwhelmed to reduce overall risk of a spill. Additionally, provide in advance to crews, as deployment is happening, the calculated number of eductor trucks required. A main ongoing objective is to further the technological toolset to contribute to the reduction of likelihood of a spill to the environment and financial implications of such events.

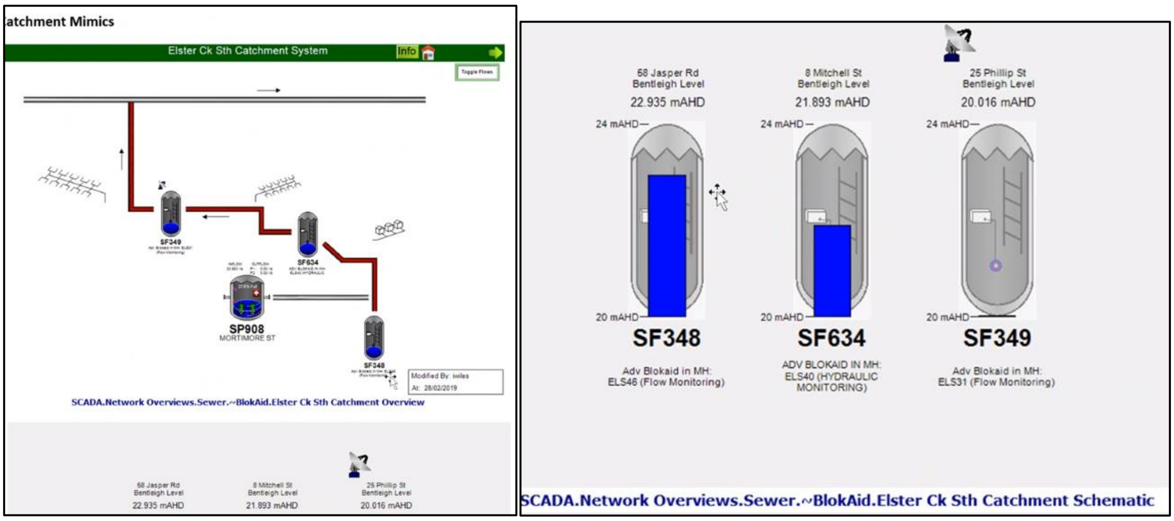
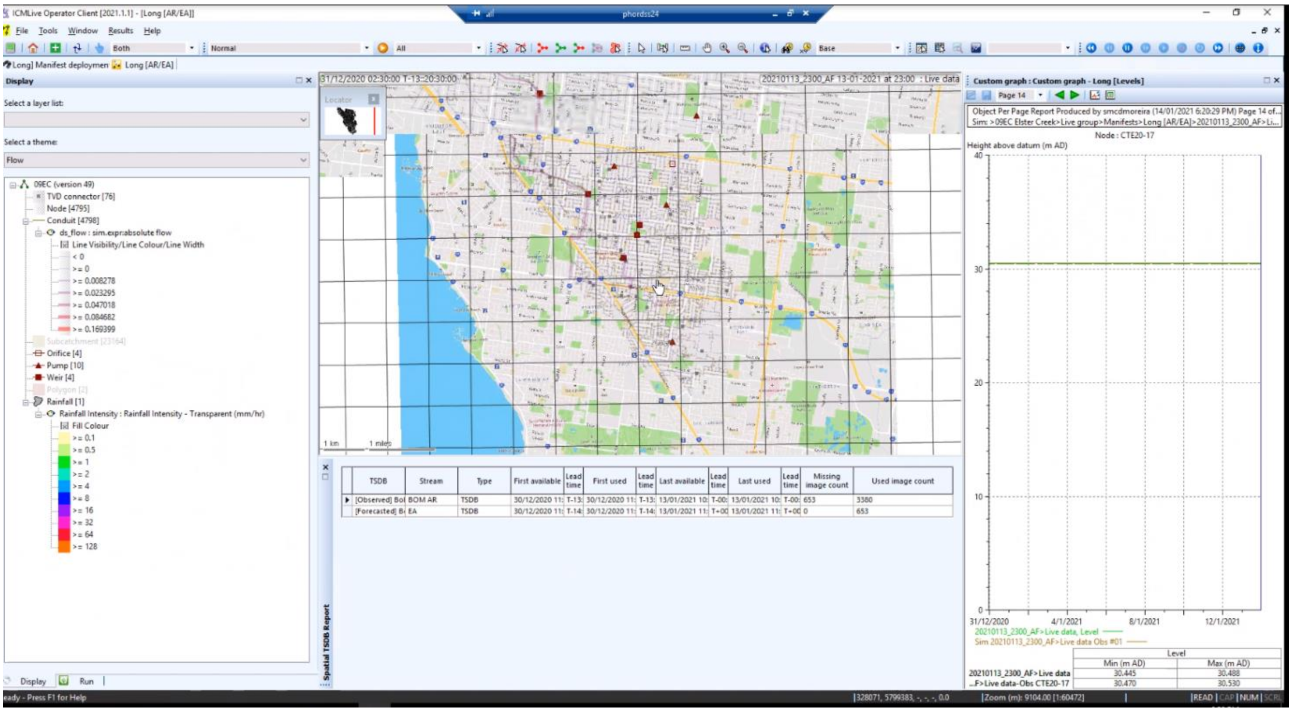


Figure 1 Blokaid data with network overview and station data within a centralised SCADA system deployed across catchments at ERS locations and high-risk spill locations.



	TSDB	Stream	Type	First available	Lead time	First used	Lead time	Last available	Lead time	Last used	Lead time	Missing image count	Used image count
▶	[Observed] Bo	BOM AR	TSDB	30/12/2020 11:	T-13:	30/12/2020 11:	T-13:	13/01/2021 10:	T-00:	13/01/2021 10:	T-00:	653	3380
	[Forecasted] B	EA	TSDB	30/12/2020 11:	T-14:	30/12/2020 11:	T-14:	13/01/2021 11:	T+00	13/01/2021 11:	T+00	0	653

	Level	
	Min (m AD)	Max (m AD)
20210113_2300_AF>Live data	30.445	30.488
...F>Live data-Obs CTE20-17	30.470	30.530

Figure 2 Operational interface receives forecast spatial rainfall for discernment of predictive results on incoming storm events to inform incident management scenarios.

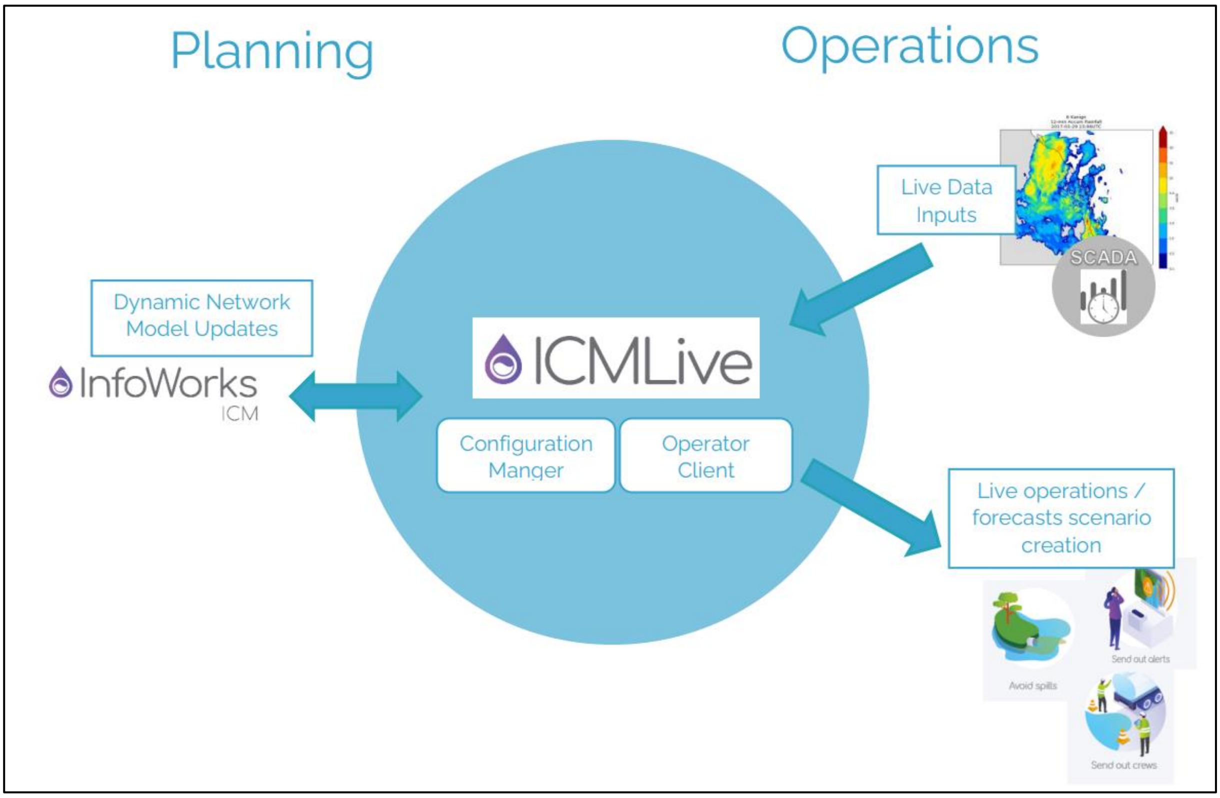


Figure 3 The operational model incorporates the existing planning model, receives inputs from spatial rainfall (BOM data) and live inflow (Blokaid) data and produces predictive outputs to inform operations and field crews for various forecast incident response scenarios.

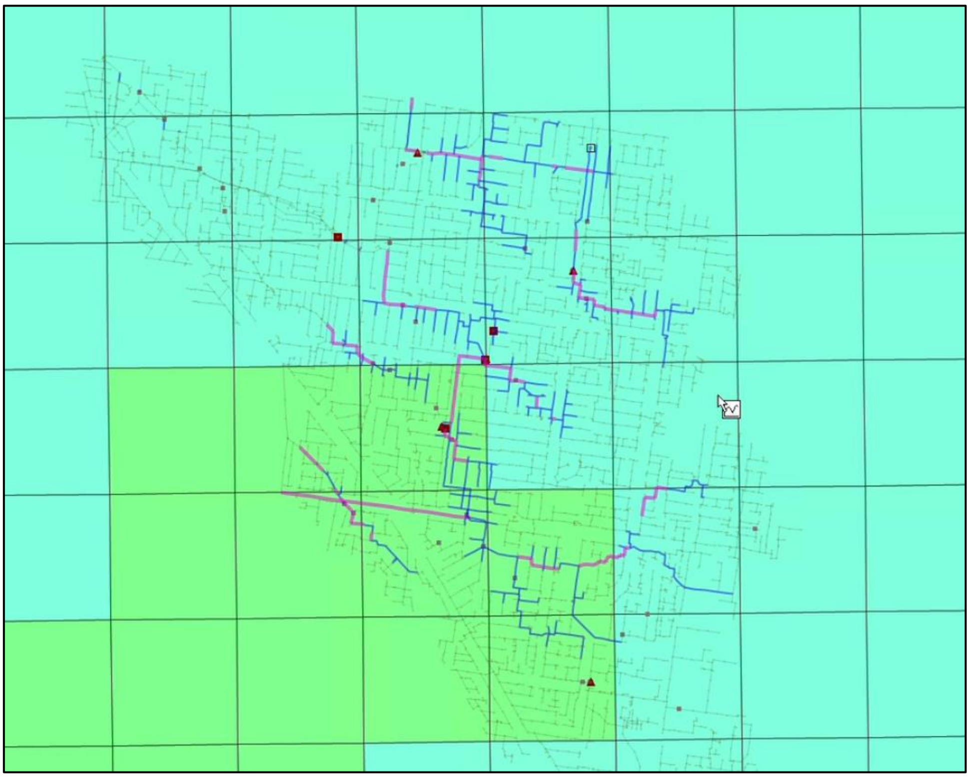


Figure 4 Overview page with forecast spatial rainfall intensities and accumulations as a starting point for determining areas of concern for incoming rainfall event.

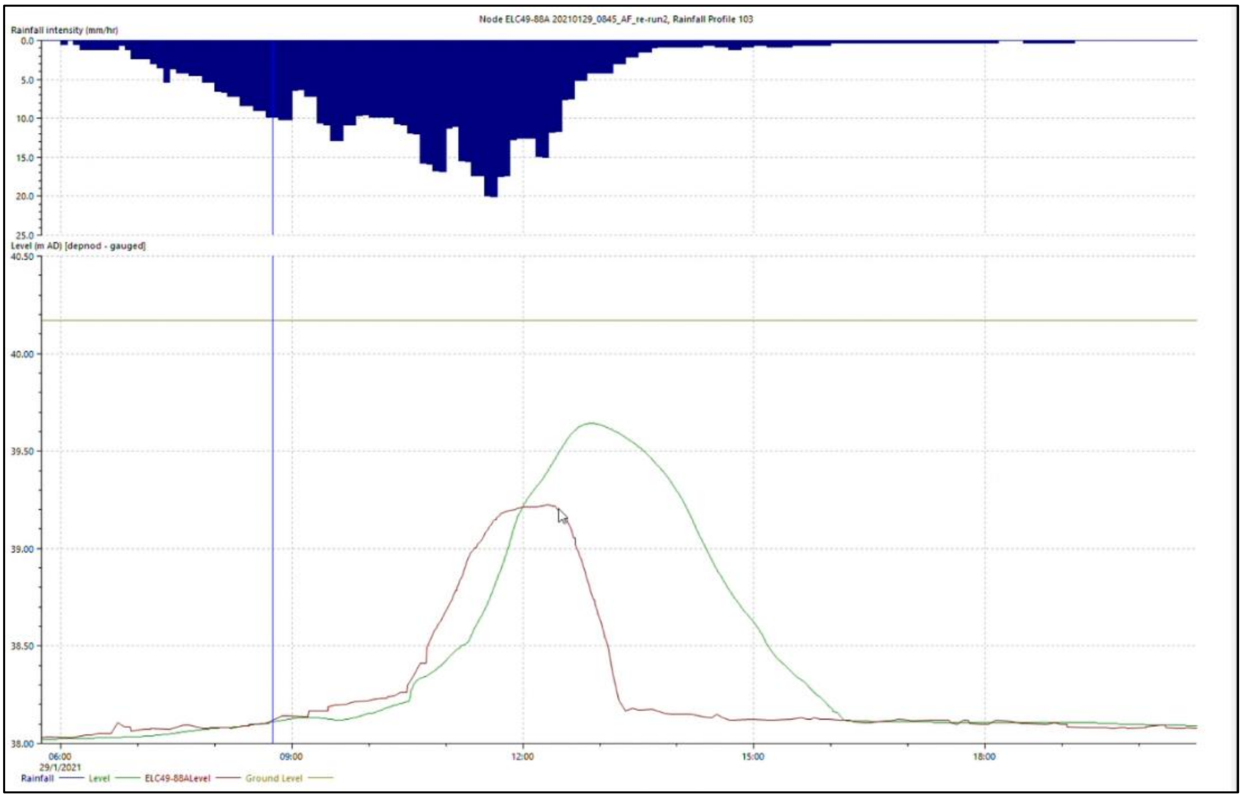


Figure 5 Ability to trend Blokaid observed data against predicted levels and observed rainfall to understand model accuracy.

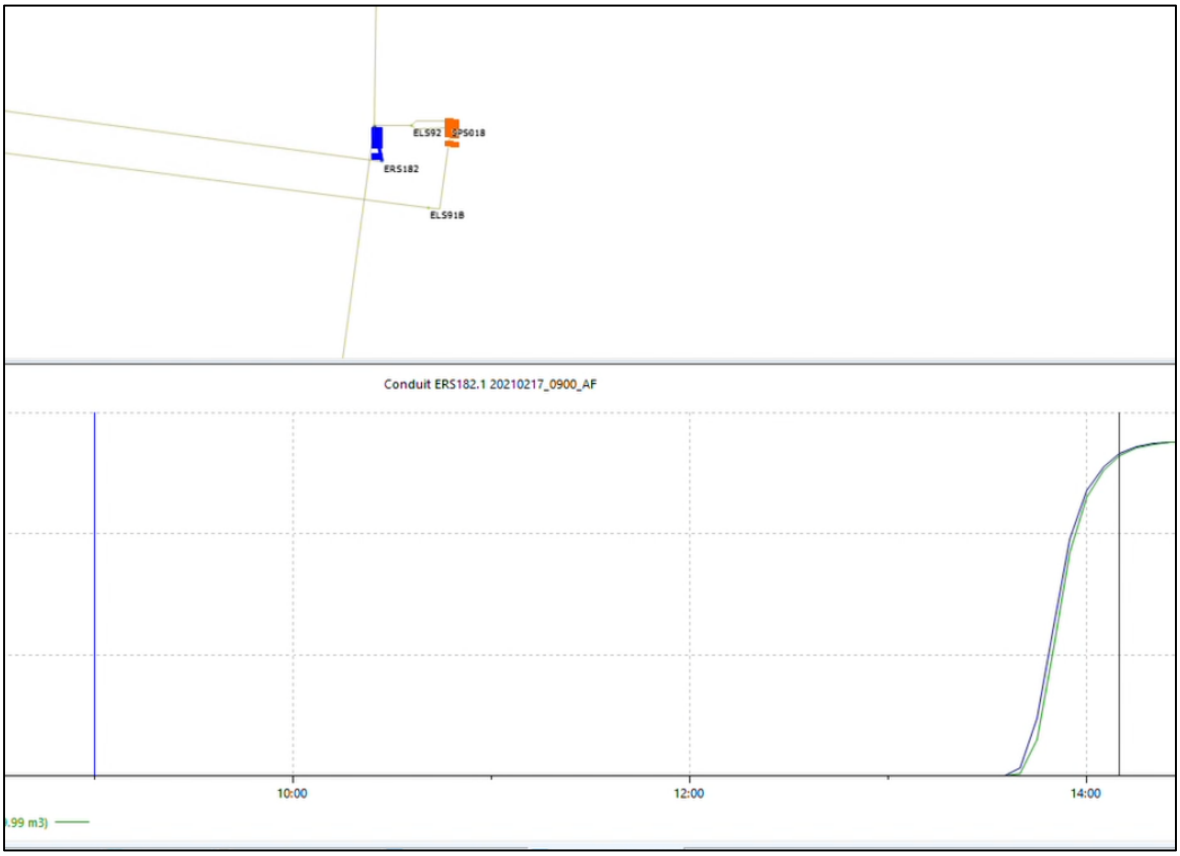
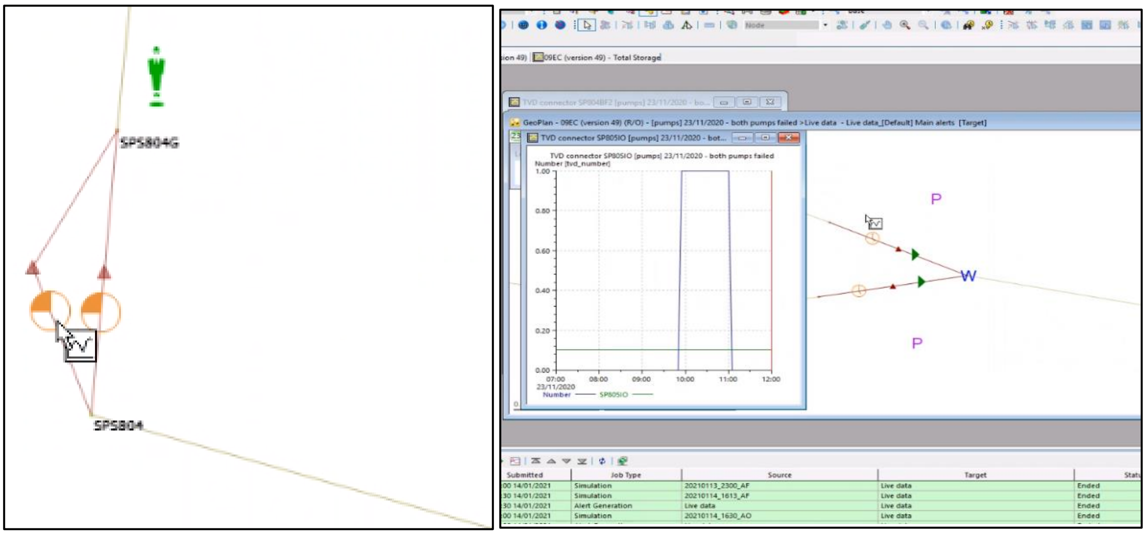


Figure 8 Pump station failure scenario where model informs via visualisation of level rise, up until predicted spill time.



Submitted	Job Type	Source	Target	Statu
00 14/01/2021	Simulation	20210113_2300_AF	Live data	Ended
30 14/01/2021	Simulation	20210114_1613_AF	Live data	Ended
30 14/01/2021	Alert Generation	Live data	Live data	Ended
00 14/01/2021	Simulation	20210114_1630_AO	Live data	Ended

Figure 9 Theming logic allows for maintenance activities to be differentiated from true events i.e. Only alert if both pumps have failed and door is closed.