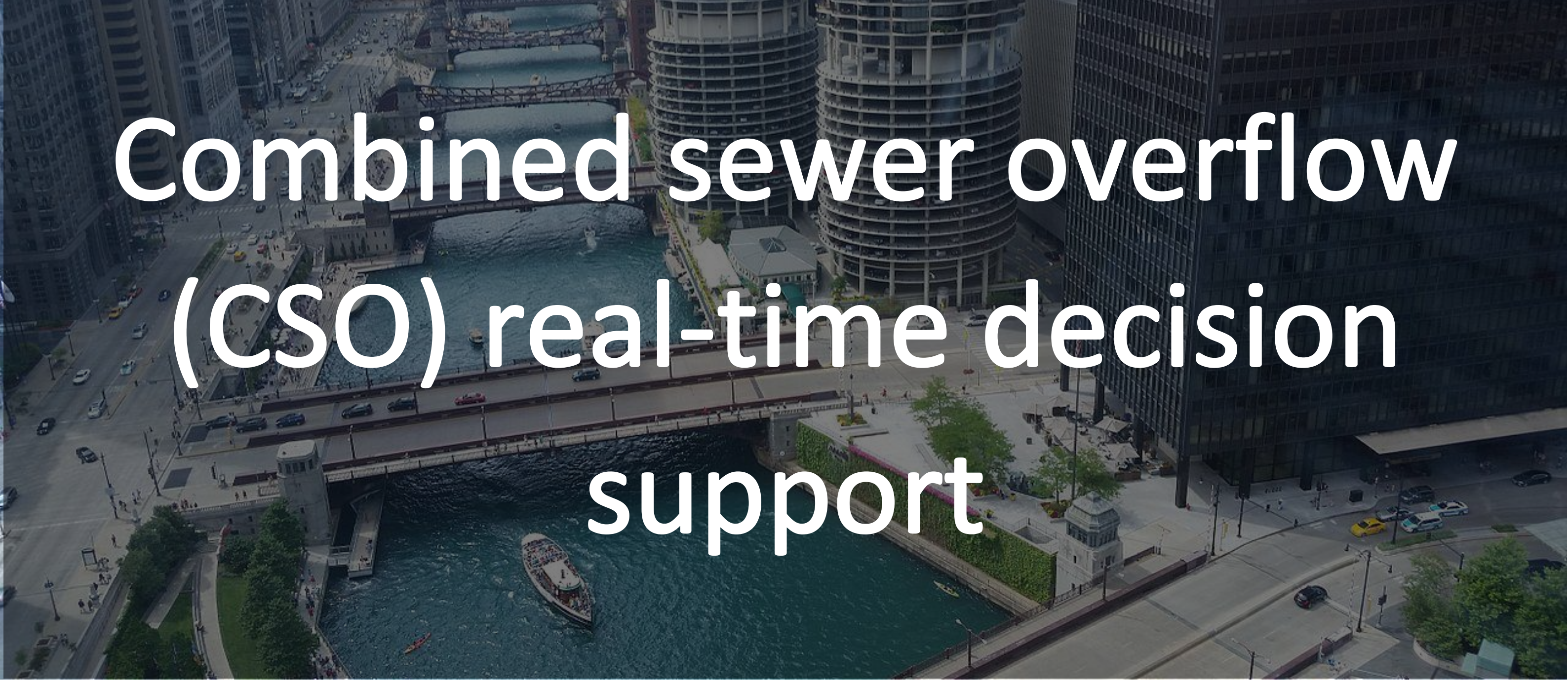
Combined sewer overflow (CSO) real-time decision support



DETAILS

SECTOR | Water

STAGE | Operations

TECHNOLOGIES | Data and Analytics

SUMMARY

Combined sewer systems collect rainfall runoff from hard surfaces (e.g. roads and buildings) and collect sewage (i.e. wastewater) from buildings. The combined sewer system then conveys this combined sewage and rainwater through a network of underground pipes adjustable gates/weirs (to change the flow of wastewater going past the gate) and pump stations (to move wastewater along a flat or uphill section of pipe). The use of artificial intelligence would provide predictive and decision support to operators to adjust pump gate and weir settings, so that operators can "flatten the curve" of the wastewater flow, such that no sewer over flows occur.

With heavy rainfall, the capacity of the combined sewer system pipes and wastewater treatment plants may be exceeded. This causes an overflow of untreated sewage into the environment (i.e. it causes a combined sewer overflow (CSO) event). Alternatively, if the pipes cannot convey all the wastewater, the CSO will occur at manholes, roadside drainage pits, and in toilets in people's homes. In 2004 in the USA alone, the United States Environmental Protection Agency (US EPA) estimated that more than 3,000 gigalitres of combined sewage was released without treatment into the environment[1].

A sewer overflow consists of both human and industrial waste. The wastewater can contain a wide variety of harmful substances including chemical pollutants (e.g. heavy metals, toxins, pharmaceuticals, and microplastics) and biological pollutants (e.g. bacteria, viruses, protozoa, and parasites). Due to these pollutants, wastewater affects the health of aquatic life in the environment as well as the suitability of that aquatic life for human consumption (particularly a problem with shellfish). It is also a risk to human health if the water is used for recreational activities (e.g. swimming). If the receiving water body is also used for water supply, then wastewater will make the water more difficult to treat. As a result of these significant environmental and health risks, sewer overflows are heavily regulated. For example, Southern Water (UK) received a £2 million fine in 2016[2] and Thames Water (UK) received a £20 million fine in 2017[3] due to sewer overflow events.

However, it is difficult for operators to know how much flow will be coming from each of the many sections of pipe that they may be dealing with, and therefore which settings are most appropriate for the gates, pump

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[1] 2004 Net Pollutant Discharge Elimination System (NPDES) CSO Report to Congress, US EPA, https://www.epa.gov/npdes/2004-npdes-cso-report-congress

[2] https://www.theguardian.com/environment/2016/dec/19/southern-water-fined-record-2m-sewage-leak-kent-beaches

[3] https://www.bbc.com/news/uk-england-39352755

stations, and storages. The use of artificial intelligence in this space would provide operation decision support to operators.

The use of AI in this requires a significant level of digitisation of sewer assets. As a minimum, flow sensors or level gauges would be required throughout many sections of the sewer network. With flow sensors or gauges, the AI would be able to see which upstream sections of the sewer network have the greatest amount of flow, and therefore predict the likely flows of wastewater in downstream sections and at the WWTP. These predictions would be improved with the use of hydraulic models of the sewer system and the implementation of sewer settings would be improved if operators (or the AI itself) could remotely control these settings through SCADA systems.

A more advanced AI may also use weather reports or rainfall radars to spatially analyse rainfall in real-time or predict future rainfall. This would allow it to predict future flows in each part of the sewer system, and make choices that reduced the likelihood of a CSO.

VALUE CREATED

Improving efficiency and reducing costs:

- An AI that adjusts settings of sewer infrastructure allows that infrastructure to handle larger volumes of water with fewer CSOs.

Enhancing economic, social and environmental value:

- Reduced frequency and magnitude of sewer overflow events provides improved environmental and human health outcomes.
- Improved corporate reputation due to fewer environmental impacts and fewer beach/lake/park closures after a CSO event.

Reshaping infrastructure demand and creating new markets:

- Reducing CSOs can offset the cost of building larger sewerage infrastructure or storage systems to deal with excess flows. Increased efficiency with the current infrastructure in the sewer system allows the deferral of large capital infrastructure that would increase capacity.

POLICY TOOLS AND LEVERS

Legislation and regulation: Environmental regulations tend to increase over time. This puts pressure on wastewater service providers to reduce sewer overflow events (e.g. the large fines received by some UK water utilities in recent years). Additionally, regulatory bodies often require that wastewater service providers serve their customers at present-day or lower costs, despite increasing population and increasing environmental regulatory requirements. This requires utilities to achieve more with less and artificial intelligence can achieve this.

Procurement and contract management: Governments could include the use of such technologies in planning and design phases to improve infrastructure outcomes in planning, delivery and operation.

Transition of workforce capabilities: Training and upskilling of engineers is required to effectively explore the decision-support options provided by AI, since an AI will be able to provide a variety of options that represent different trade-offs (e.g. different options could put different WWTPs at risk of a sewer overflow event).

IMPLEMENTATION

Ease of Implementation 	The main challenge of implementation is the existence and completeness of a model that represents the sewer system. This would be used by AI to determine how upstream flows will affect the flows at the wastewater treatment plant. Additionally, it needs to know which options are available for changing the system (e.g. which gates or pumping settings can be changed), and it needs to have an accurate model of how the selection of these settings affects the flows in the system. Building an accurate model generally requires specialists and additional training may be required to formulate the problem so that the AI can interact with the model.
Cost 	The cost of the AI and computational power is relatively inexpensive compared to the cost of regulatory fines for excessive sewer overflows. Installing a sensor and associated communications network can present a cost issue when at significant scale.
Country Readiness 	As mentioned above, these AI techniques require an accurate and complete model of the system of interest. In many developed countries, utilities have been creating these models in recent years and therefore can use AI. However, developing countries may have no digital model of the system in which case this model must be created first, generally requiring many hours of specialist work. Developing countries will also have to develop and enforce regulations to drive compliance by water and wastewater authorities.
Technological Maturity 	The underlying AI techniques are mature, however there are few examples of them being applied in this context. Wastewater service providers are (for good reason) risk averse when it comes to sewer overflow events (because of the significant consequences of getting it wrong) and will be reluctant to make use of unproven AI technologies.

RISKS AND MITIGATIONS

Implementation risk

Risk: The plans created by artificial intelligence are dependent on a complete and accurate model of the system being planned. If the model is incorrect (e.g. not validated, system changes over time not reflected in model), then the plans will be optimised for a different system which doesn't exist in reality and therefore will not be optimal for the real system. This could result in incorrect calculations of cost, sewer system capacity, environmental outcomes, etc.

Mitigation: Any use of this AI must be preceded by the development, calibration, and validation of a system model, to ensure that the model is an accurate representation of the system. Additionally, plans should be developed to consider multiple future projections of uncertain variables such as population growth, population density, and climate change.

Risk: Engineers who are involved in the operations of sewer systems will in some cases be suspicious of the abilities of an AI. They may have concerns about the ability of the AI to produce feasible and pragmatic plans. They are risk averse by nature because of the significant consequences of making poor decisions.

Mitigation: An AI generally performs better than humans, if the AI has been built with the help of subject-matter experts. Proper training and upskilling of engineers would show engineers that they are in control the feasibility of what the AI produces.

Safety and (cyber)security risk

Risk: Models of any critical infrastructure (including sewer networks) may reveal vulnerabilities to the smooth running of society. Vulnerabilities are at risk of being exploited by bad actors. For this reason, there is a risk to putting these models into the Cloud.

Mitigation: Modern cybersecurity provides many solutions to this problem that can prevent these models being accessed by those who should not have access to it. This includes that it should be possible for an AI company to provide their AI services to a client without the AI company having access to any of the client's models or data.

EXAMPLES

Example	Implementation	Cost	Timeframe
South Bend, Indiana, USA	EmNet (now Xylem) implemented their BLU-X software for real-time control of 13 gates and valves. CSO volumes reduced 70%.	ROI estimated to be 30-40x, due to savings in Capital Improvement Program.	Sensors installed in 2008. Real-time control added in 2010.