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Towards smarter stormwater management: Challenges, opportunities and insights from a UK case study

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Abstract

Stormwater management is facing growing challenges, from climate change and environmental concerns to ageing infrastructure and urbanisation. Whilst hydraulic modelling and optimisation-based approaches have been used in water system planning and management for decades, the potential of 'smart' catchments and data-centric approaches is becoming increasingly recognised.
This paper presents the 'Blue Heart' case study, in which a catchment subject to complex flood management challenges and where there was historically a poor understanding of interactions between water from different sources has been transformed via a dense network of sensors to provide enhanced knowledge and facilitate smarter stormwater management. The process has been based on the iterative transition framework presented by Sweetapple et al. (2023), and key challenges and lessons learned are presented here. An example application of the collected data in which locations where rising fluvial water levels that are not rainfall-driven and may not be flagged in traditional model-based approaches are identified is also presented as an example of new insights obtainable.

Highlights

- Data from over 490 sensors in a 61km^2 area supplements traditional model-derived knowledge.
- Lessons and challenges associated with smarter stormwater management are captured.
- Gauge data reveal locations with rapidly rising water levels not directly attributable to rainfall.

Introduction

Hydraulic modelling is widely used to provide a greater understanding of stormwater system behaviour and responses; however, there are limitations on the information this can provide and how it can be used – for example, due to computational constraints, calibration challenges and input data requirements. Data-driven models have gained traction in water systems planning and management, but the current paradigm remains model-centric (Zolghadr-Asli et al., 2024). There is, though, increasing interest in and a gradual transition towards 'smarter' stormwater management systems (e.g. Webber et al., 2022), and Zolghadr-Asli et al. (2024) advocate a shift toward a more data-centric paradigm. This paper aims to explore the process of transitioning to smarter stormwater management and capture the key lessons learned and challenges faced, using the 'Blue Heart' project in the Eastbourne and southern Wealden area of the United Kingdom as a case study. It also provides an initial exploration of the real-world catchment insights and understanding provided by extensive monitoring and the further developments this facilitates.

Methodology

Case study and transition framework

Eastbourne and southern Wealden cover an area that is prone to flooding from multiple sources, including 4102 properties at risk from surface water flooding and 363 from fluvial flooding. Historically there has been a poor understanding and knowledge of how water moves around the catchment and how different sources interact, and there is no flood warning service in place for groundwater, surface water or sewer flooding. The Blue Heart project thus aims to reduce flood risk and build resilience to climate change via innovative actions.

Development of an integrated, 1D-2D hydraulic model has provided improved understanding of the catchment response to a library of different scenarios; however, the model is complex and slow to run (around two weeks per simulation), which limits how it can be used. Therefore, there has been interest in shifting towards a 'smarter' stormwater management system, incorporating widespread sensors and telemetry to provide real-time knowledge and utilising this data to provide further insights and improved control.

The transition to a smarter stormwater management system has been based upon the roadmap presented by Sweetapple et al. (2023), in which an iterative approach is proposed that enables rapid implementation with ongoing learning and adaptation (Figure 1a). This paper presents developments in the first three iterations (project phases 1-3), and the key lessons and challenges identified to date.

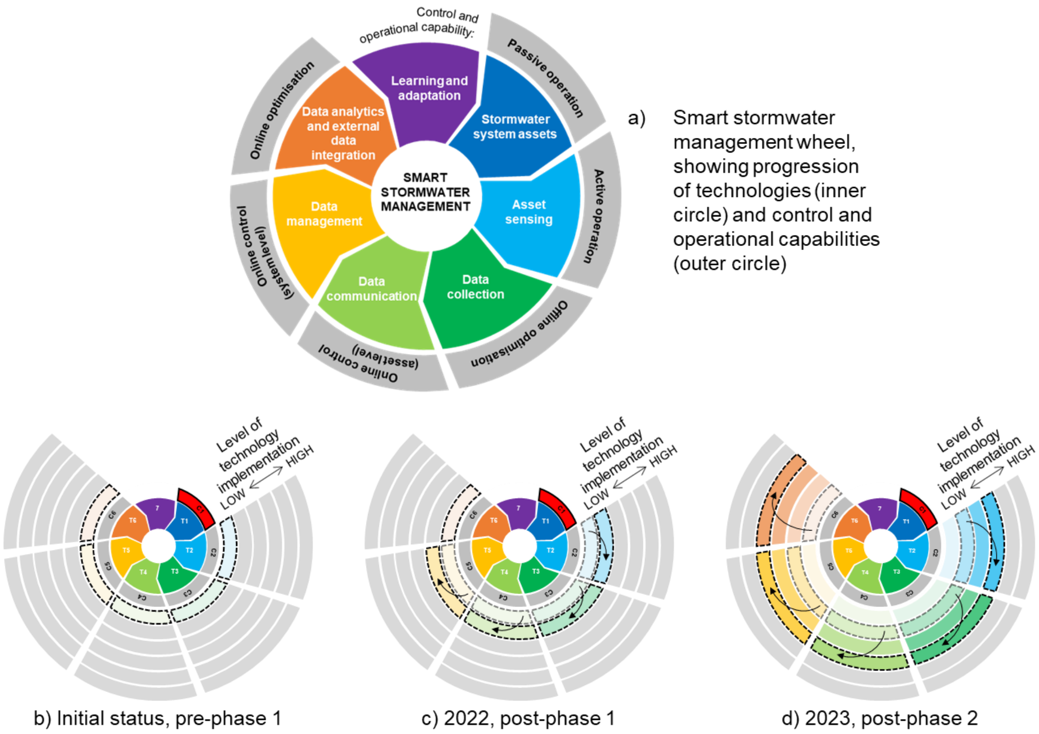

Figure 1. Conceptual illustration of the transition to smarter stormwater management in the Blue Heart case study, based on the framework presented by Sweetapple et al. (2023).

Example analytics

Data analytics and generation of insights using this data is a key component of a smart stormwater system (see orange step in Figure 1a). The Blue Heart Project has amassed a vast quantity of data, with over 775 time series to date for a 61km^2 area. This provides opportunity for a broad range of research; however, as an example of the insights that can be obtained, this paper presents an exploration of the relationship between rainfall and rising water levels – in particular, identifying locations and times at which rapid level rises occur that cannot be attributed directly to a rainfall event.

At all fluvial gauge locations, the rate of change of water level is calculated at every time step; rates that exceed 5% of the maximum observed range for the corresponding gauge per hour are categorised as rapidly rising. The total precipitation recorded at the rain gauge nearest to fluvial gauge in the preceding 24 hours is calculated, and occurrences of rapidly rising levels with no preceding rainfall are flagged for further investigation.

Transition to smarter stormwater management

The process of transitioning the case study catchment to a ‘smarter’ system has been split into three phases to date, with the third phase still in progress. Figure 1 provides a conceptual illustration of the transition through the first two (completed) phases of the project: Figure 1a shows the technologies and capabilities involved; 1b shows the initial (no smart functionality) status; and 1c and 1d show the increased level of asset sensing, data collection, data communication, data management, and data analytics and external data integration provided by Phases 1 and 2 respectively.

Briefly, Phase 1 focussed on rapid installation of sensors at a small number of locations identified as priorities (7 boreholes, 7 fluvial levels, and 6 surface water sewer levels), to enable challenges to be identified and lessons learned before wider rollout in subsequent phases. Key challenges faced in Phase 1 include cellular network connection failures; insufficient cellular data plans resulting in interruptions and unplanned costs; poor battery performance; need for timely maintenance; and potential for damage during maintenance of existing assets.

Phase 2 included installation of 53 water level sensors, 30 rain gauges and 15 water butt monitors. It also included provision of data and analytics via the ‘datasphere’ web platform, which also offers automated alarm functionality and provides integrated access to Environment Agency gauge data. As a result of lessons learned, maintenance visit provision was included in the Phase 2 delivery agreement, and new installations were sited so that they would not impact maintenance of existing assets and so that they can be easily maintained. Alternative sensor and telemetry units that offer improved power management and dynamic logging and variable upload interval capabilities were selected for further installations. Continued data provision was included in the contract, and any communication failures are identifiable in the datasphere platform. Furthermore, automated low battery level alarms have been implemented to enable proactive maintenance and minimise measurement gaps. Further challenges and learning from Phase 2 include difficulties associated with site access and installation (e.g. dense vegetation or unexpectedly shallow water); network connectivity issues; and the need to set up devices to report levels with respect to a consistent datum.

Phase 3 is currently in progress and will provide further expansion of the telemetry network and integration of data from different owners in the datasphere platform. This includes 400 sewer level monitors installed by Southern Water under their Network Digitisation 2022 Programme (Southern Water, 2024) and 15 level sensors from Natural England and the Pevensey Cuckmere Water Level Management Board (integration complete), as well as 15 highway gully monitors, 5 outfall flow sensors, and 25 sustainable drainage system level sensors (in progress through 2025).

Figure 2 shows the location of fluvial and borehole level sensors and rain gauges installed or integrated to date in each phase of the project. A key novelty here is the provision of data from a local authority, water company and Environment Agency on the same platform for the first time, thus providing a more comprehensive understanding of water in the catchment.

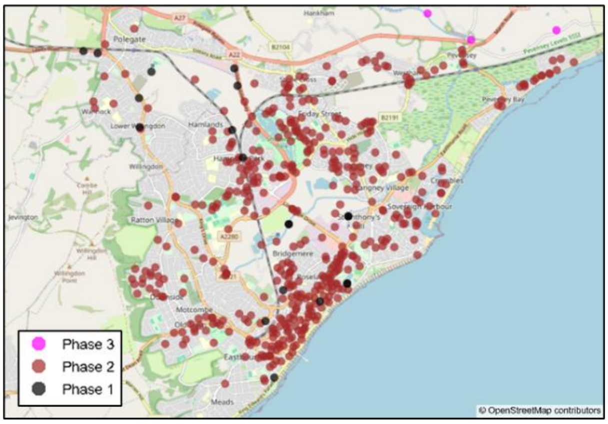

Figure 2. Location of sensors installed or integrated to date in each phase of the project

Catchment insights

As illustrated in Figure 3, rapid water level rises at monitored locations are predominantly rainfall driven; however, 9 sites are identified where more than 20% of rapid level rises identified occurred when no rain had been recorded at the nearest rain gauges in the preceding 24 hours.

This enables further investigation into these locations to determine whether this is anticipated behaviour. For example, one site is explainable by the presence of a pumping station (Figure 3a), one by tidal influence (Figure 3d), and one potentially attributable to systematic measurement error (Figure 3c). However, for other sites (such as shown in Figure 3b) there is not an immediately obvious explanation, and these results highlight the need for further work to determine the cause and any implications on how flood warnings are generated in this area.

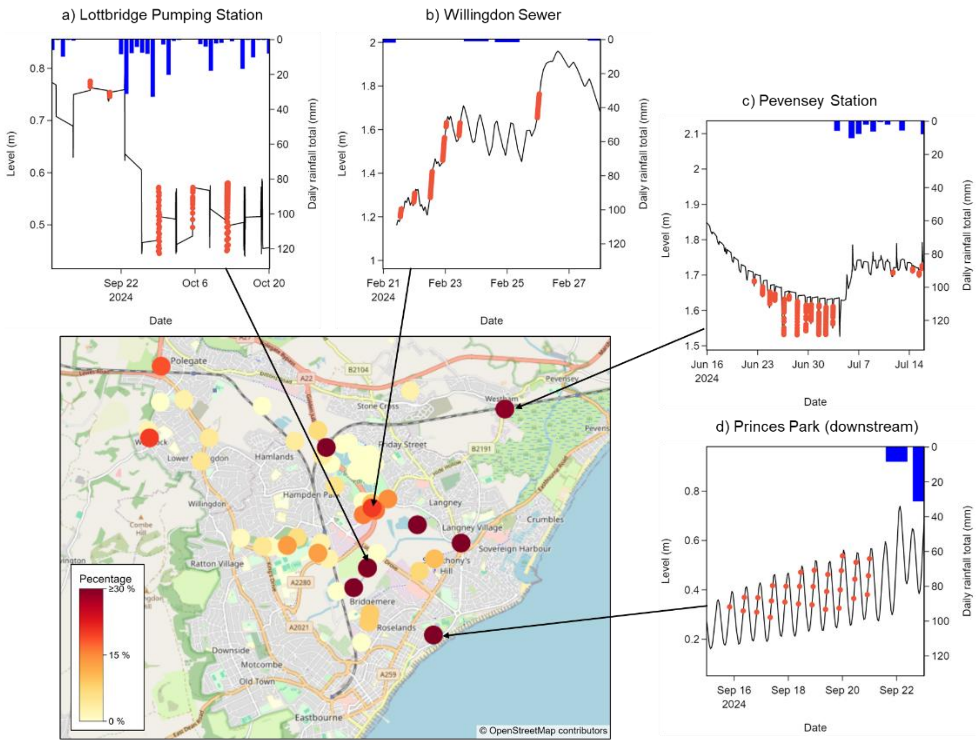

Figure 3. Map showing percentage of rapidly rising water levels at each fluvial gauge location that occurred with no recorded rain in the preceding 24 hours, with example level data shown for four locations where at least 20% of measurements corresponding to rapidly rising levels do not relate to rainfall in the previous 24 hours.

Opportunities and future work

The case study catchment does not yet address the enhanced control and operational aspects of smart stormwater management; however, the technologies implemented to date provide the knowledge and capability do so, and options for real time control of water levels are currently being explored. Furthermore, the example insights presented use only a small fraction of the data available, and there is wide scope for further knowledge building (for example, using sewer level data).

Acknowledgement

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