Development and implementation of a large-scale Real Time Control system: the Rotterdam case study

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Highlights

- Design of rule based RTC using sewer and WWTP models
- RTC performance evaluation system
- Balancing CSO emissions to urban canals, CSO emissions to a large river and WWTP performance

Introduction

The city of Rotterdam (630000 inhabitants) is located in the western part of the Netherlands and is the second largest city in the Netherlands while it's harbour is the 4th largest of the world. The municipality of Rotterdam is very ambitious to develop towards a climate adaptive, circular city and invests heavily in blue-green solutions, such as green roofs, urban agriculture, floating parks and water squares. As the transition to blue-green and climate proof systems will take decades, Rotterdam is also investing in RTC to optimise the performance of the existing wastewater infrastructure, comprising 964 pumping stations, 3043 km sewers pipes and 515 Combined Sewer Overflow (CSO) structures. The first application of Real Time Control (RTC) in Rotterdam dates back to the early 2000s, when a RTC system called CAS (Centrale Automatische Sturing – central automatic control) was implemented (van Leeuwen, 2003). The CAS system had the objective to minimise CSO emissions to urban canals while not exceeding the annual thresholds for CSO emissions to the river system (Geerse and Lobbrecht, 2002). Due to several practical issues, the CAS system was rapidly taken 'out of service' and the control was switched back to manual control by system operators. In 2018, preparations started to develop CAS2.0, a new RTC system benefitting from the strong development of the sewer monitoring network in Rotterdam as well as research developments in the field of RTC. This abstract describes the use of sewer and WWTP models to develop control rules and an evaluation system to evaluate performance of the wastewater system and the CAS2.0 RTC system.

Methodology

Model development

The sewer model, see figure 1, is developed using InfoWorks software as a linear reservoir model, where each (sub)catchment has been schematised as a singular linear reservoir. Model inputs are dry weather flow of households and industry, extraneous water based on monitoring data and rainfall from local rain gauges. Model updates are made automatically by connecting the model to the asset management system. The model is validated against monitoring data at pumping stations and at CSOs.
The WWTP model for the two biggest WWTPs, WWTP Dokhaven and WWTP Kralingseveer, has been developed using the ASM3+ bio P model (Rieger et al., 2001) using SIMBA software. The WWTP model is validated against monitoring data of WWTP effluent.

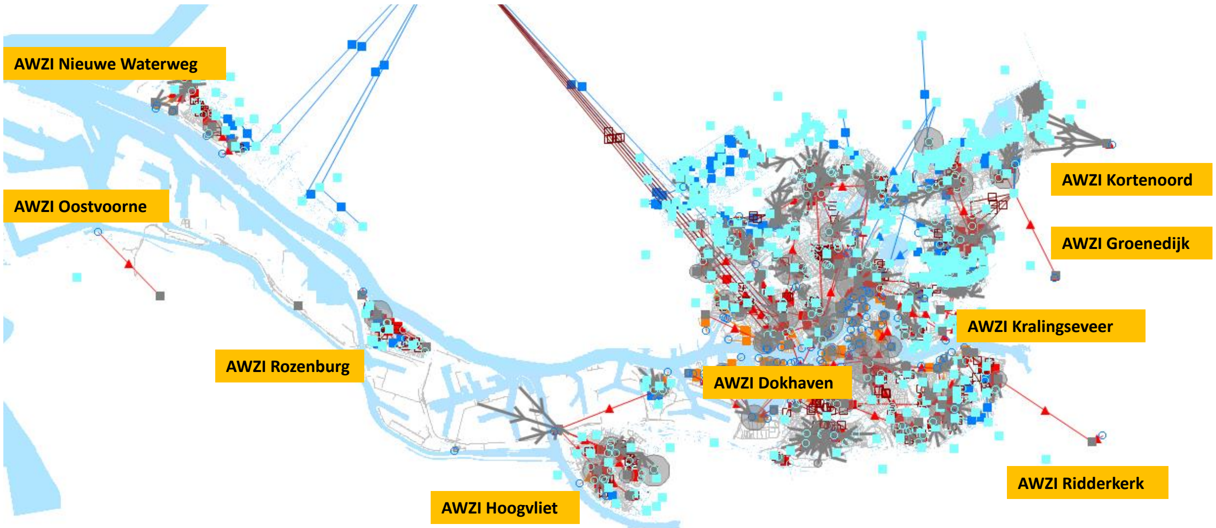

Figure 1. Sewer model of Rotterdam sewer system. The yellow blocks indicate the location of the downstream WWTPs.

RTC strategy & RTC rule development

The RTC strategy has been developed iteratively. At first, an indicative 'span of control' for the RTC system has been defined by assessing the range in performance that can possibly be achieved by the sewer system and subsequently assessing the potential impacts on receiving water bodies downstream CSOs and downstream WWTP's. This first step was a combination of expert judgement, monitoring data analyses and modelling using above mentioned models. Second, the RTC objectives have been defined and prioritised, with the prioritisation being condition dependent: during dry weather and small storm events, priority will be given to optimise WWTP performance, while during heavy storms prevention of urban flooding will get priority. Thirdly, a RTC strategy has been developed which balances the (conflicting) objectives. Fourthly, a sensitivity analysis has been performed to select sewer subcatchments that should be part of the RTC system and to identify subcatchments where RTC will not result in an improvement, e.g., due to their small contribution or due to a lack of control potential. Finally, RTC scenarios and heuristic RTC rules have been developed and tested using the sewer model.

RTC Performance Indicators

The evaluation of RTC performance is developed based on the method of van Daal et al.,(2017).

Results and discussion

The RTC system in Rotterdam has to meet the following objectives (with *in italics* the connected strategy and the stage when the strategy is active, see figure 2):

- Enhance WWTP performance by 'flattening' the DWF diurnal curve. *DWF peak reduction is achieved by maximising the total inflow of the WWTP to a predefined $Q_{DWF,max}$ and temporarily storing any additional DWF wastewater volume in the sewer districts discharging directly to the WWTP*. DWF peak reduction is applied in stage I
- Enhance WWTP performance at the onset of storm events. *Pumping capacity is increased slowly from DWF setpoints to WWF setpoints by using an intermediate 50% WWF setpoint at 50% filling degree of the in-sewer storage*. Incremental step wise increase in pumping capacity is applied in stage II, III and IV.
- Minimise CSO discharges to urban canals. *Active use of 'pumped CSOs', large pumps that discharge directly to the river, switch off pumping stations located in parts of the harbour at the*

outside of river and sea dikes, switch of pumps off storm sewer systems and, the most traditional RTC action: balancing available pumping capacity over the sewer catchments to minimise overall emission. Full focus on CSO emission reduction is central in stage V, VI, and VII.
- Minimise emission of pumped CSO's and pumping stations outside the dikes. *This control strategy uses weather predictions to identify the moment to switch off the pumped CSOs and switch on the pumping stations outside the dikes*. The return after a large event is controlled by stage VIII. The return to DWF after a small event is controlled by stage IX, X, and XI

The actual loading rate of the combined sewer systems determines which of the objectives gets priority. The actual loading rate is derived from the water level sensors in the sewer catchments. These levels can be used, as the performance of the combined sewer systems of Rotterdam is dominated by the, in an international context, relatively large storage volumes of on average 9 mm or 90 m^3/ha. Figure 2 gives an example of measured system dynamics, with an indication on the stage of the RTC system being based on the measured water level in the sewer system. In the fully developed RTC system, downstream catchments will determine the control stage of the upstream catchments.

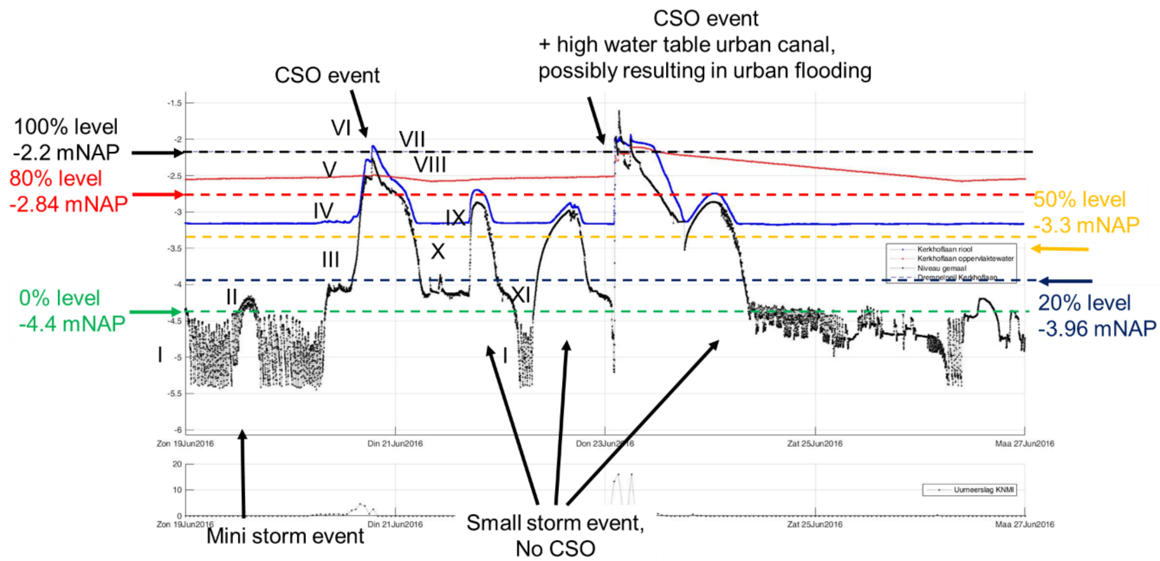

Figure 2. Typical events (DWF, mini storm event, small storm event and very large storm events) and filling degree thresholds determining the stage of the RTC system. NAP indicates mean sea level. Horizontal coloured lines indicates the water levels that determine the stage of the sewer system. The stage determines the RTC-objective which gets priority.

Conclusions and future work

This abstract only shows a small part of the RTC development. The developed heuristic RTC rules will be implemented shortly. Once the system is stable, model-based RTC will be developed as an add-on to the heuristic control rules.

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