Data-Driven Extraneous Water Quantification

H. D. Macedo, Ph.D.[1*], J. Højberg, M.Sc.[2], J. M. Jensen, M.Sc.[3], U. S. Thomsen, Ph.D.[4]

[1]*DIGIT, Aarhus University, 8200 Aarhus N, Denmark*
[2]*Solteq Utility Consulting, 8230 Abyhøj, Denmark*
[3]*Frontmatec Control Systems, 7800 Skive, Denmark*
[1]*WATEC, Aarhus University, 8200 Aarhus N, Denmark*
**Corresponding author email: hdm@ece.au.dk*

Highlights

- We developed a platform to identify and quantify the share of extraneous water for wastewater systems with complex networks of pumping stations.
- Our method does not require in-field operations or visual inspections.
- The platform has been experimentally applied in several projects.

Introduction

Water that enters a sewer network from precipitation/groundwater, Inflow/Infiltration (I/I), also known as extraneous water, increases the network flows and reduces the efficiency of wastewater collection and treatment operations. The increase in the sewage volume leads to environmental issues and is a substantial cost to operators everywhere in the world. According to (Rödel, 2016), extraneous water amounts to a quarter of all the wastewater treated in Germany, and the U.S. expect to spend $165 billion in a period of 20 years because of the excess water increases.

The burden of extraneous water is more pronounced in relatively flat topography regions like Denmark, where most wastewater systems rely on pumps and energy to move sewage. According to a white paper[1] from the Danish Environmental Protection Agency, I/I adds approximately 150-200 million cubic meters a year to the national wastewater volume figure. The added volume corresponds to a 500 million DKK ($79 million) expense and increased CO2 emissions. Therefore, the operators of modern wastewater treatment systems aim to minimize the amounts of I/I with interventions in the network (coating cracked pipes, diversion of storm water,…), but because upgrades to the sewage network are expensive, careful trade-off studies and benefit estimations are required.

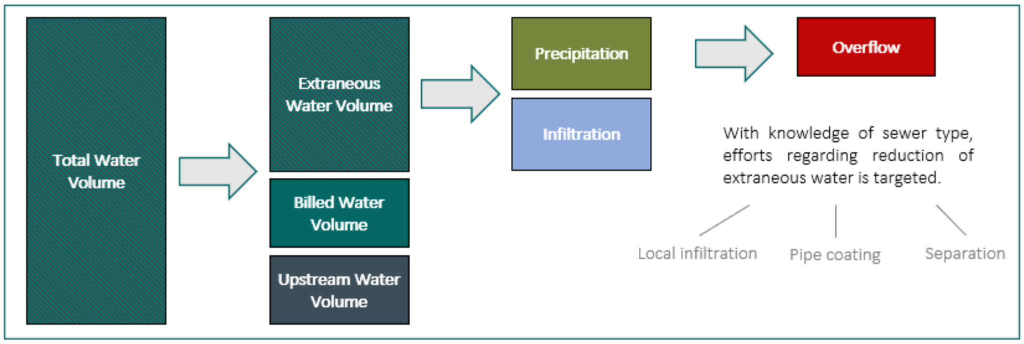
The benefits of mitigation interventions depend on the identification of the extreme cases in the network, which traditionally requires visual/in-field inspections usually providing a local picture restricted to part of the network. Our data-driven alternative provides, instead, a global picture estimate of the I/I broken down in each of the stations in a sewage network. The approach avoids costly in-field operations or visual inspections, yet our model and predictions depend on knowledge of the sewer network topology, weather data and sewage flow data extracted from the pumping stations' Supervisory Control And Data Acquisition (SCADA) system, which are commonly available in modern facilities. The platform has been experimentally proven efficient in several studies and wastewater networks in Denmark. Our approach belongs to the recent data-based approaches like the work in (Lund, 2021), where the authors assert the feasibility of using smart meter data in anomaly detection, though subject to uncertainties. The application of data-driven approaches to extraneous water detection is recent, and there is potential for innovations and new technology developments.

[1] Bedre viden om uvedkommende vand (https://tinyurl.com/2y58r8kn)

Methodology

The wastewater quantification is based on a stepwise approach to flow data available from the SCADA systems of both the water supply network and the wastewater pumping stations. In the first step, we compute the difference between the total wastewater flowing through the system and the amount of water supplied to the region (billed water). Then we divide the non-billed water amount into an estimate of Inflow/Infiltration using a weather model. We depict the different steps in Figure 1 and provide more details in the following paragraphs.

Figure 1: Method overview



Data Collection In all our applications we were able to obtain flow data from the SCADA system operator with the required values and time resolution. In addition to pump flow data, our method requires that the network structure of pumping stations is known and adequate, meaning that the stations and their relationship must form a tree structure where the root node is the destination of the water, typically a wastewater treatment plant. This flow-directional relationship reflects that for each station there can be found upstream stations from which each station has an influx of water. The total sum of this flowing water is thus calculated as the total flow of the upstream station's flow.

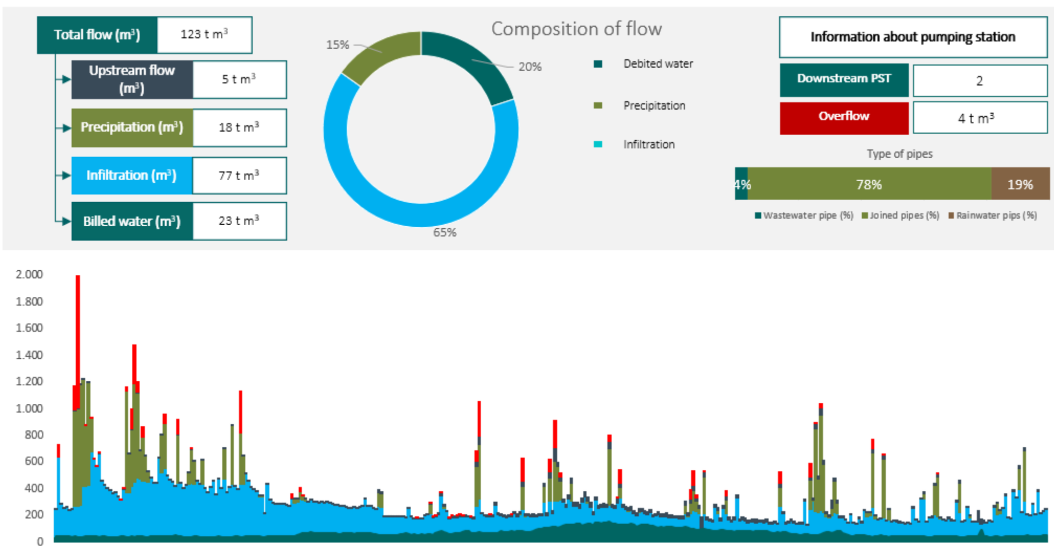
Total Extraneous Water Besides channelling the water received from other stations, the upstream water volume, each station receives the sewage originating from the billed water delivered to nearby houses and industries. The calculation of billed water is defined by a simple sum of the registered water supply consumptions. A model of the relation between water supplied/billed water and average wastewater collected at a single substation is inferred in the period where flows from other stations are zero, and a station's amount of extraneous water is computed as a subtraction of the upstream volume and the billed water to the total water volume pumped to the downstream stations.

Inflow/Infiltration Separation We input the daily amount of precipitation to our model and label each station with a token (wet) when inflow is expected or (dry) otherwise. The labelling is decided on a threshold for daily precipitation weather readings. A reading of 2 mm or below leads to labelling station as dry. A station labelled as wet on a given day is always labelled wet on the following day to reflect the fact that direct precipitation may take some time to find its way from where it falls to the station. As with instruments measuring flow, precipitation instruments are typically not present at each pumping station. In such cases, we approximate values with the measurements from neighbouring stations. By removing all flow data on wet days and by filling the resulting gaps with linear interpolated data it is possible to estimate how the daily flow would look like if it had no impact from precipitation.

Results and discussion

The general pattern emerging from the different locations where we deployed our platform shows that a significant amount of the sewage flows is due to extraneous water, which can be broken down into approximately 20 % from precipitation/inflow, 60 % from water infiltrating into the pipes, and 20 % billed water (sanitary sewer). The fact that most of the water comes from infiltration matches the known wear and tear problem affecting the pipe networks. In Figure 2, we provide a typical dashboard available on our platform. The data comes from one of our default case studies, pumping station P237. The dashboard consists of yearly key measurements at the top and a graph visualizing flows throughout the year at the bottom. In the horizontal axis, each column provides the flow breakdowns for each day beginning on the 1st of January. The station has a total flow of 123 t. m3 and 80 % of the unique water flow is extraneous water. The figure shows most of the infiltration occurs during winter, which is expected given that the groundwater level in Denmark peaks in that season. Extraneous water from precipitation comes in short periods of a few days depending on the rainfall.

Figure 2: Breakdown of the analysis in one of the sites (P237)



Conclusions and future work

Our results confirm that it is possible to quantify and break down the amounts of extraneous water by exploring flow data obtained from pumping stations readings. A data-driven approach provides a global estimate of the extraneous water for the whole network, and it does not require extra equipment in pump intensive sewer network systems. We envisage the application of our method in other regions where a network of pumping stations follows a tree topology and flow data can be extracted from the SCADA system. In addition, we expect our models to easily scale to a digital twin setting (Pedersen, 2021), where utility managers are equipped with a live snapshot of the current amount of extraneous water in the system at all times and can use the model to perform what-if analysis before interventions.

References

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