Uncertainty based decision making for water quality failures caused by sewer overflows

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Motivation

- Combined sewer overflow (CSO) spills managed by the water utility companies need to comply with the local regulations.

- Utility companies usually face the risk of paying penalties or suffering reputational damage if they fail to comply.

- Urban drainage models are used to simulate CSO overflow quality so as to make appropriate decisions.

- Understanding the potential uncertainty in such models can lead to a better informed decision making.

Objectives

- Quantify the uncertainty in the simulation of water quality failures caused by Combined Sewer Overflows (CSO) using urban drainage models
- Evaluate the impact of the modelling uncertainty on the outcome of decision making process
- Explore methods to determine optimal solutions satisfying water quality performance criteria set by regulatory authorities

Problem definition

- to comply with emission standards for Ammonia concentration in the CSO discharges.

Failed event criterion: Ammonia Concentration in the Combined Sewer Overflow > 5 mg/L for 1 hour.

(based on Austrian guidelines on ammonia concentration in the receiving water body caused by CSO discharges)

Problem definition

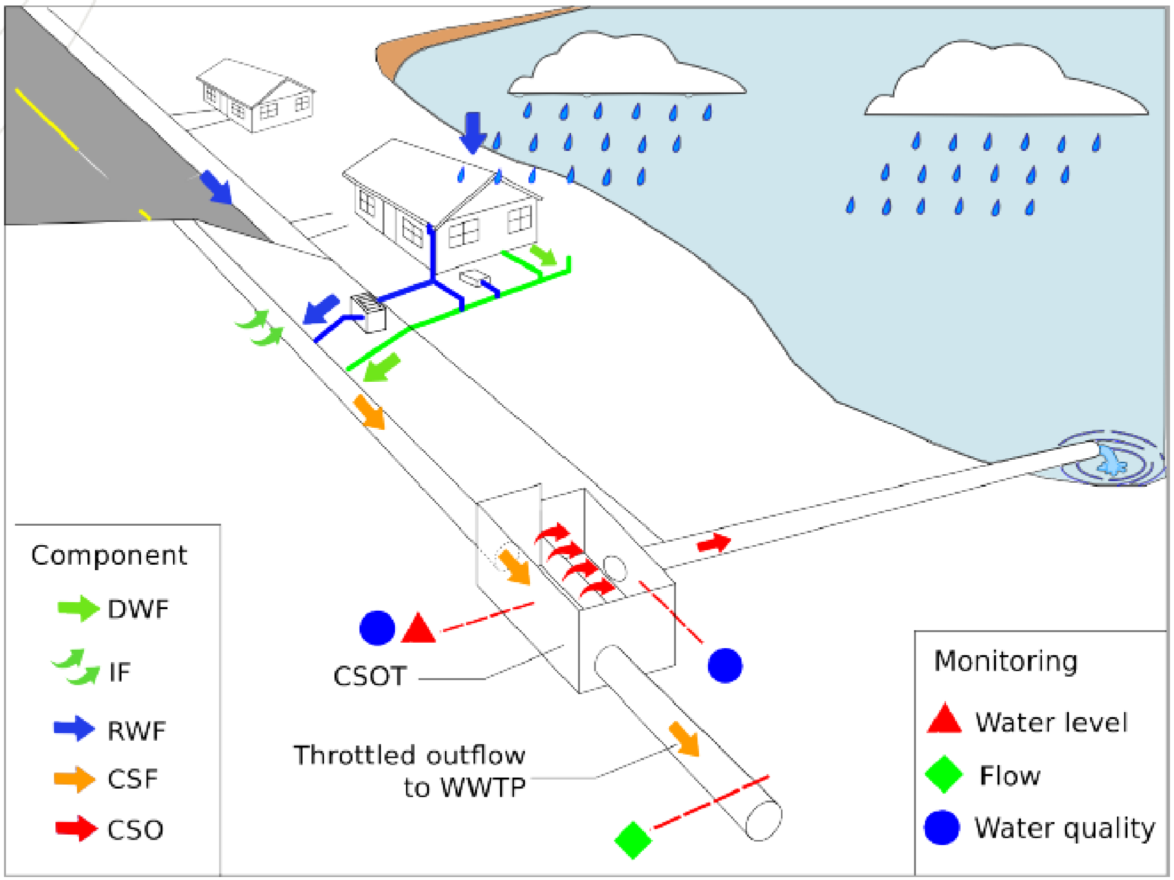
- Model: Calibrated urban drainage model to simulate combined wastewater flow quantity and quality
- Software/tool used : **EmiStatR** (R package to estimate combined wastewater emissions)
- Catchment: Haute-Sûre catchment in Luxembourg
- Model output: Ammonia concentration (mg/L) in the CSO spill
- Performance Criterion: Number of eligible failed events
- Decision variable: Storage volume at the CSO & Runoff coefficient of the catchment (as a proxy for Flow reduction from the catchments)

EmiStat R Model:

Physical processes modelled:

- Dry Weather Flow (DWF) : Wastewater input from the households contributing to Combined sewage flow
- Pollution of Dry Weather Flow: Ammonia load in DWF
- Rain Weather Flow (RWF) : Rainfall runoff from the impervious catchment surfaces contributing to Combined sewage flow
- Pollution of RWF : Ammonia load contribution from the catchment surfaces
- Combined sewage flow : DWF + RWF
- Combined sewage flow pollution : Ammonia load from DWF and RWF
- CSO volume and pollution : Flow volume diverted to the receiving water body (lake) and the ammonia (NH4) concentration in this overflow.

EmiStat R Model:



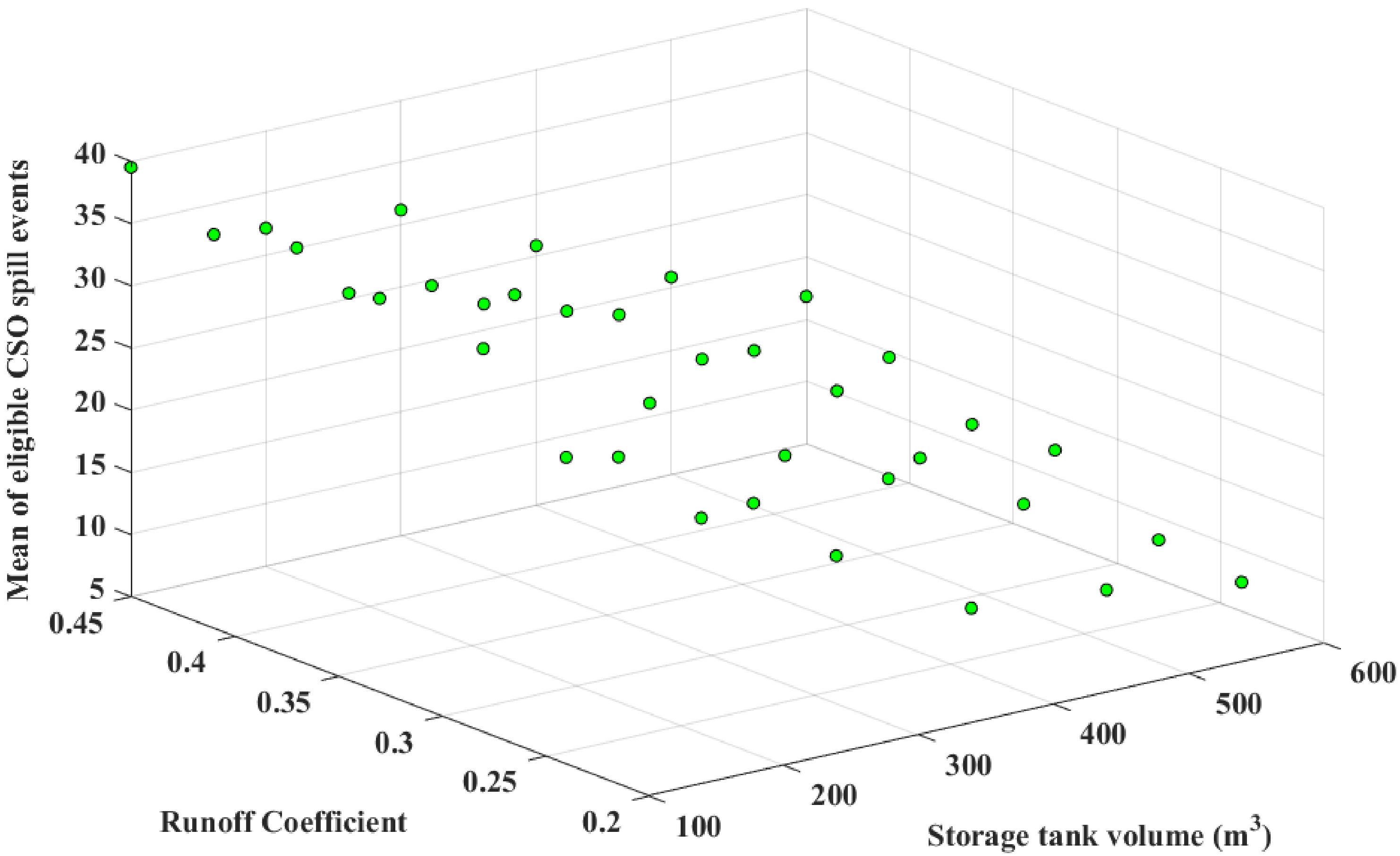
1) Dry Weather Flow (DWF) including Infiltration Flow (IF); 2) Pollution of DWF; 3) Rain Weather Flow (RWF); 4) Pollution of RWF; 5) Combined Sewer Flow (CSF) and pollution; and 6) Combined Sewer Overflow (CSO) and pollution.

Uncertainty propagation

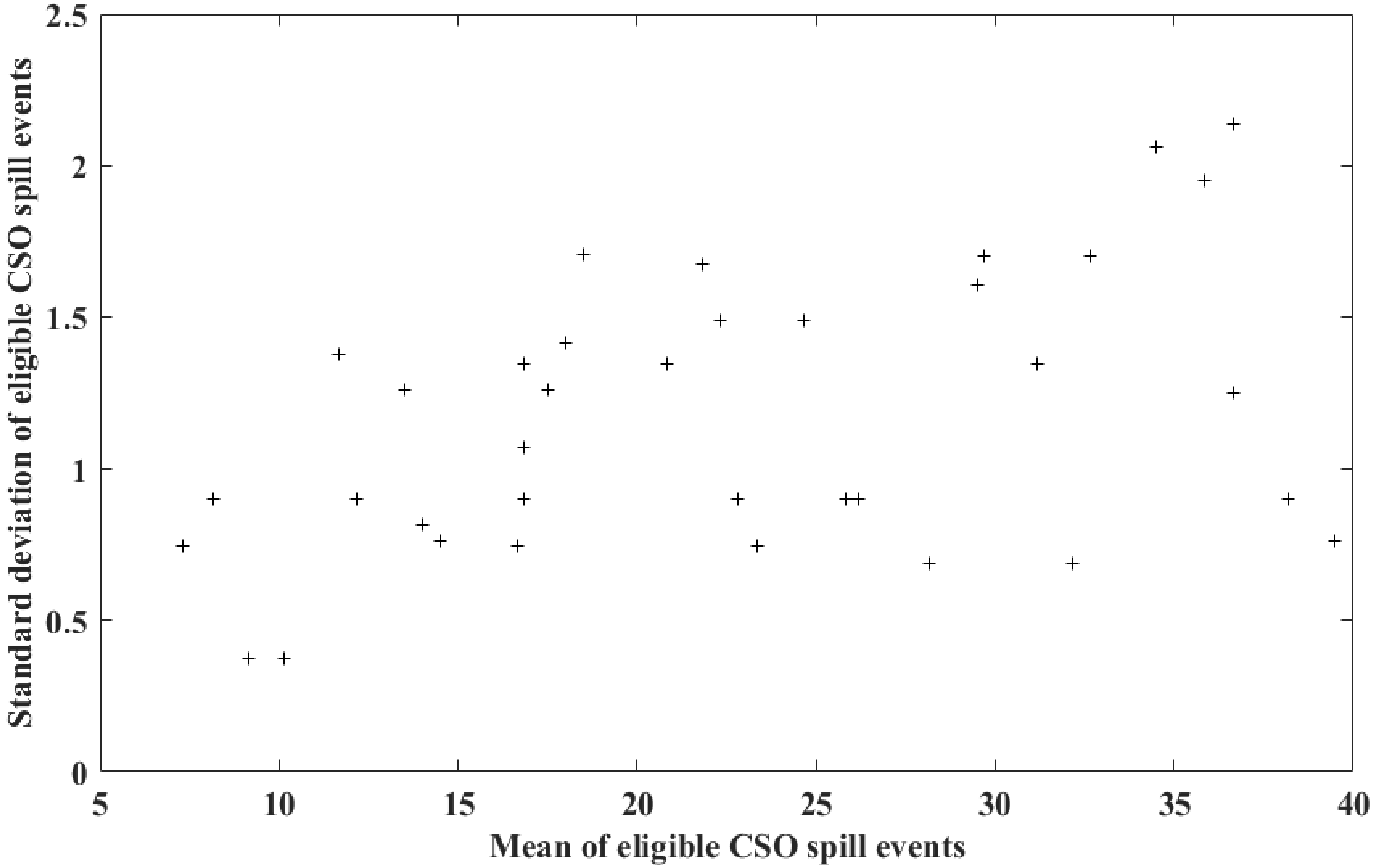
- Monte Carlo simulations used to propagate uncertainty in model inputs and parameters.
- 1-year rainfall precipitation data for the year 2010 was used for these simulations. Variability in rainfall precipitation was represented using a Multivariate autoregressive model developed by Torres-Matallana et al. (2017)
- Storage tank volume: 100 m^3 to 600 m^3
- Runoff coefficient: 0.24 to 0.45
- Monte Carlo simulations were repeated by changing storage tank volume and the runoff coefficient
- For every combination of Storage tank volume and Runoff coefficient, 1500 Monte Carlo simulations were performed resulting into 1500 time series of NH4 concentration in the CSO spill

- For each time series of NH4 concentration, number of eligible CSO spill events were calculated by applying the failure criterion. This resulted into a distribution of eligible CSO spill events in the simulated year for each pair of storage tank volume and runoff coefficient

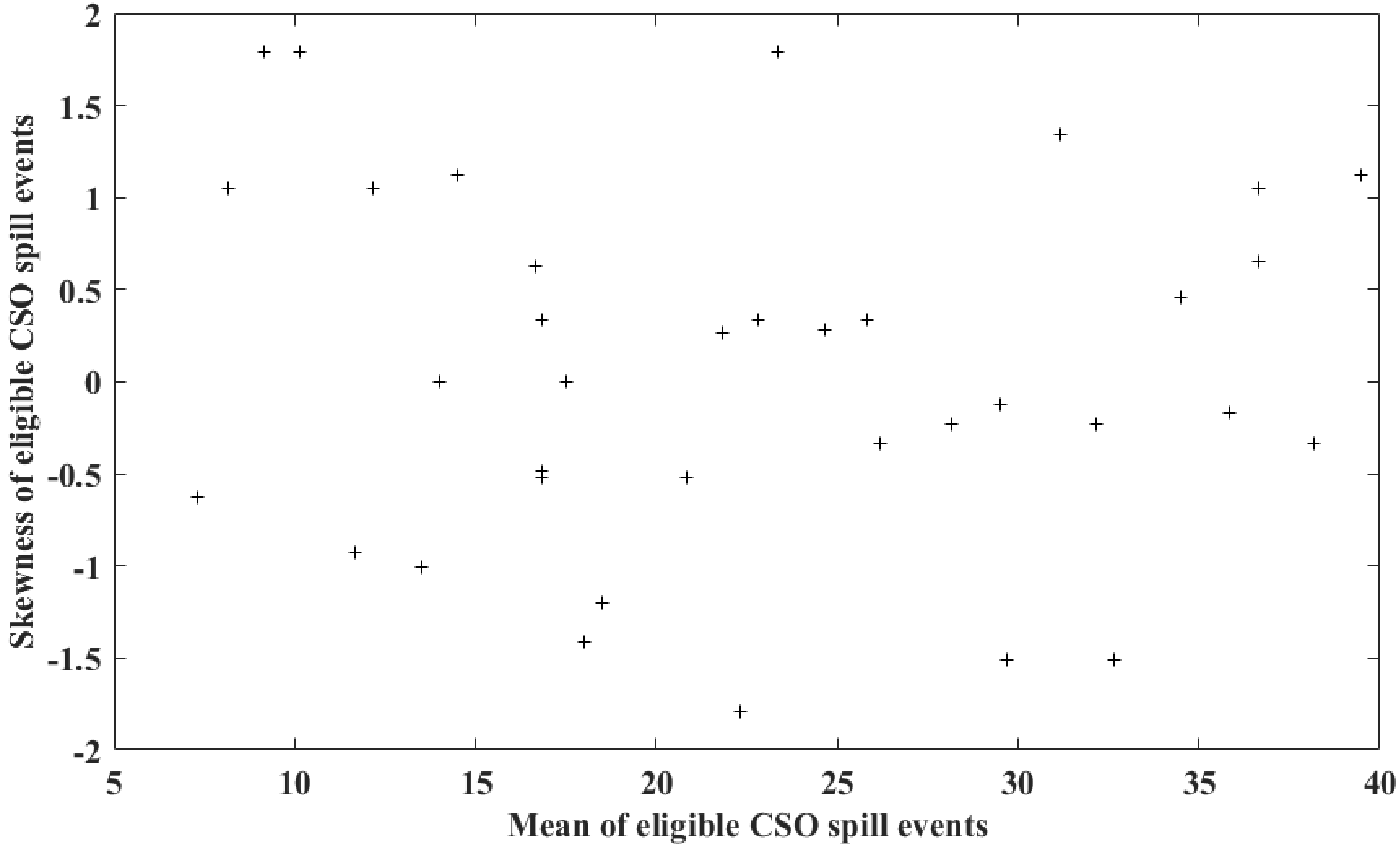
Uncertainty propagation



Mean vs Standard deviation



Mean vs Skewness



Failure probability

Eligible CSO spill events

- Ammonia Concentration in the Combined Sewer Overflow > 5 mg/L for 1 hour

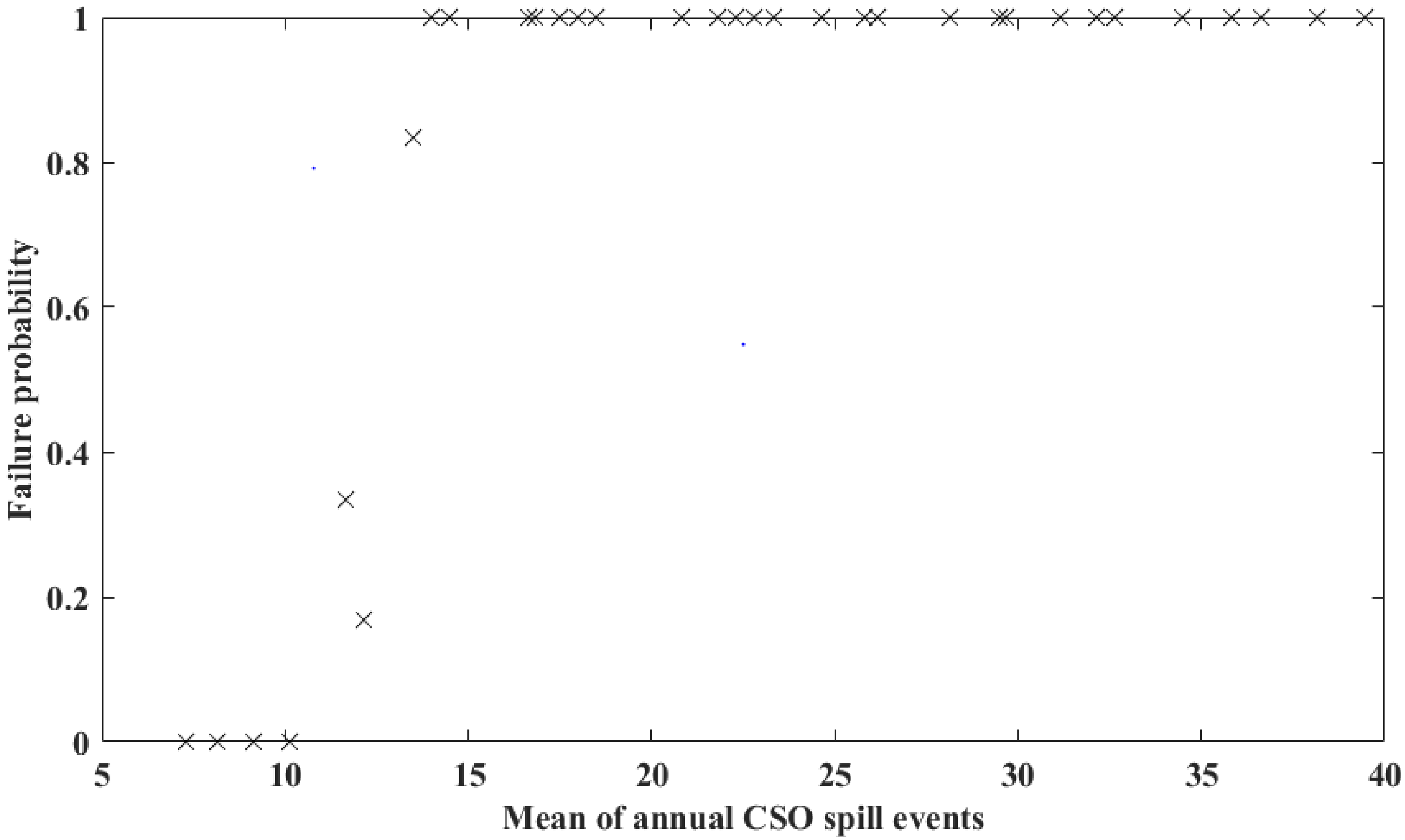
Assuming a return period of 1 month for such events, the CSO would fail

- If the number of eligible CSO spill events in a year > 12

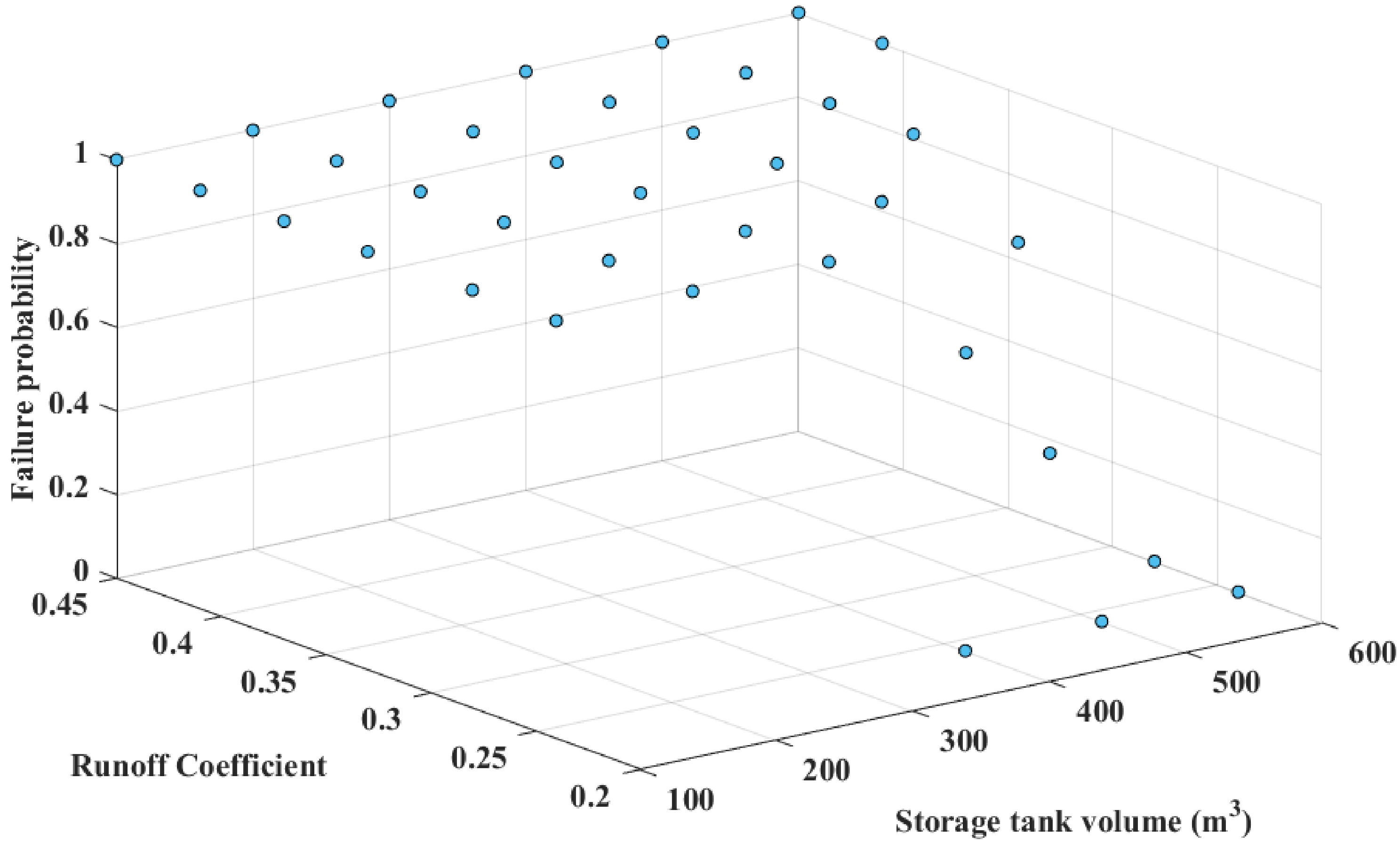
Failure probability can be expressed as,

the probability that the number of eligible CSO spill events in a year > 12

Failure probability



Failure probability



Conclusion & continuing work

- How strict are the failure criteria?
- Failure probability does not capture the behaviour of the tails of the distributions
- Is failure probability a sufficient measure of risk
- What is the preference for the skewed distributions? Should they be preferred over symmetrical distributions.
- The choice of threshold on ammonia concentration and duration was found to have significant effect on the distribution of the eligible CSO spill events. Low threshold values (e.g. 0.175mg/L for NH4 in the UK) result into similar number of failures for all the model simulations.

Thank you!