Probabilistic Assessment of the Performance of Combined Sewer Systems
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Summary

This publication is a Dutch summary of the PhD thesis *Probabilistic Assessment of the Performance of Combined Sewer Systems* by Dr. H. Korving. It especially examines the possibilities of practical implementation of risk-based asset management. Finally, the results are critically reviewed by several experts in urban drainage.

Too optimistic impression
Usually, serviceability of a sewer system is assessed on the basis of model results because of insufficiency of measurements. Serviceability is defined as “The ability of an asset to deliver a specific service to customers”. The services offered by a sewer system consist of protection of public health and prevention of flooding provided that the quality of the environment is safeguarded. Hydraulic performance is assessed on the basis of calculations (e.g. combined sewer overflows (CSOs) and flooding) that support interventions reducing environmental and economic damage. Visual inspections (e.g. closed circuit television (CCTV) data) in combination with predictions of remaining service life determine whether rehabilitation is necessary.
However, this approach has several shortcomings. Firstly, uncertainties in knowledge of system structure, system dimensions and determinative processes are ignored. Secondly, natural variability of rainfall is not considered. Thirdly, system performance is often described with imperfect models assuming that assets are not liable to failure, such as blockage of conduits due to ingress of soil or root intrusion, subsidence of conduits and technical failure of pumps. Finally, it assumes that deficiencies can be (visually) detected and quantified. All this leads to a too optimistic impression of sewer performance.

Risk analysis
The research *Probabilistic Assessment of the Performance of Combined Sewer Systems* had the objective to provide a methodology for the assessment of serviceability of sewer systems accounting for uncertainty and risk. It determines the serviceability of a sewer system with respect to environmental impacts and is based on predicted system performance. Several uncertainties are accounted for, including database errors, rainfall variability, parameter uncertainty after calibration and failure of assets. For that purpose, several techniques from uncertainty and risk analysis have been applied to the assessment of the hydraulic performance and structural condition of sewers. For example, risk analysis enables decision-making on either improving repair and maintenance of sewage pumps or enlarging in-sewer storage capacity in order to reduce CSOs.

Database errors and rainfall variability
The data set applied in a hydrodynamic model is never entirely perfect. Errors in the database of a sewer system affect calculation results of hydrodynamic models. Within a sewer database, several data types are distinguished, including geometry of sewer system, hydraulic parameters, runoff parameters, catchment area and structure of sewer system. In addition, rainfall input uncertainties are one of the most important sources of uncertainty. Uncertainties regarding rainfall consist of natural variability in the rainfall process, measurement errors and uncertainties resulting from simplification of the real spatial variability of the rainfall.
Errors in sewer databases and rainfall variability considerably affect calculated sewer performance. The former results in larger average CSO volumes, whereas the latter has the largest impact on the variation of CSO volumes. The observed variation increases with increasing return periods. However, variation due to rainfall variability partly results from the limitations of the rainfall generator, which underestimates the volume of frequent storm events with a duration longer than 2 hours.

Model calibration
Model calibration may considerably influence calculation results. Calibration is the process in which model structure and parameters are adapted in such a manner that the model reproduces measured behaviour as well as possible. Calibrating a model reveals discrepancies between model and observed reality. It enables the quantification of systematic errors, which may stem from incomplete process descriptions in the model, errors in the database of the sewer system and measurement errors.
Event-based calibration of a sewer model does not result in more reliable model predictions because the calibrated parameters have low portability. However, the advantage is that database errors can be removed during calibration, which harmonises model predictions and 'reality'. Variation of calculated CSO volumes due to differences in calibrated parameter sets based on different storm events is dominant. This variation increases with increasing return periods. It is also clear that, for sloping catchments, a simplified model overestimates CSO volumes. As a result, using a series of separate reservoirs may improve predictions.

Failure of sewage pumps
Sewage pumping stations and pressure mains are critical components of sewer systems, especially in flat countries like The Netherlands. Their performance is directly responsible for affecting the serviceability of a sewer system. Availability and reliability of sewage pumps have been modelled with various descriptions of the failure process using available field data.
The failure rate of a pump can increase due to ageing or decrease due to renewal or refurbishment. Furthermore, failures of sewage pumps tend to be clustered. The analysis of failures of sewage pumps should account for the chronological order of events.
The number of failures is relatively large compared to pumps in drinking water, polders and wastewater treatment plants. It varies strongly and is independent of the specific function of a pump. The average duration of failures is also highly variable and depends on the repair policy. The serviceability of a sewer system is significantly affected by pump failures. Average yearly CSO volumes increase more than 15%. Therefore, improved maintenance of sewage pumps will improve sewer performance.

Final conclusion
In conclusion, risk-based assessment of sewer performance will result in more effective investments with respect to sewer maintenance and rehabilitation. Risk-based assessment accounts for unavailability of assets and uncertainty of driving forces, system knowledge and impacts. Therefore, field data on the performance of sewer systems are required in order to check model results. In addition, new serviceability standards for sewer systems should account for impacts of uncertainties.