A case study for integrated modeling in urban drainage facilitating the interface approach

Etude de cas pour la modélisation intégrée du drainage urbain facilitant l'approche de l'interface

Roman Maier[1], Thomas Hofer[1], Günter Gruber[1] and Dirk Muschalla[1]

[1] Graz University of Technology, Institute of Urban Water Management and Landscape Water Engineering, Stremayrgasse 10/I, A-8010 Graz, Austria
(e-mail: roman.maier@tugraz.at, phone: +43 316873-6760)

RÉSUMÉ

Les dernières avancées en matière de recherche et de développement montrent une tendance en faveur des modèles intégrés simulant le cycle de l'assainissement urbain et offrent ainsi un aperçu complet de l'efficacité du système. Cependant, en ce qui concerne les modèles intégrés tenant compte de la qualité de l'eau, il n'existe que peu d'études de cas réelles. Nous avons mis au point un modèle pour le système d'assainissement urbain de la ville de Graz, en Autriche, contenant la formation du ruissellement, un système d'égout, des actionneurs et la station d'épuration (STEP) de la ville. Ce modèle intégré utilise une approche d'interface, qui relie des sous-modèles largement connus des divers sous-systèmes par des scripts automatisés. L'utilisation de cette méthode offre l'avantage d'un modèle compréhensible et plus facile à entretenir pour l'opérateur responsable de la gestion des égouts.
Jusqu'ici, le modèle a été utilisé pour évaluer l'impact d'un tunnel de stockage combiné nouvellement construit pour gérer les débordements des égouts (tunnel de stockage central – TSC) sur la station d'épuration existante et pour en tirer de meilleures pratiques de gestion (BMPs) pour l'exploitation intégrée du système en termes de réduction de la charge totale d'émissions vers le plan d'eau récepteur.

ABSTRACT

Late research and developments show a trend towards integrated models to simulate the urban drainage cycle to offer a complete picture of the system's performance. However, in regard to integrated models considering water quality, only few actual case studies exist. We developed such a model for the urban drainage system of Graz, Austria containing runoff generation, a sewer system, actuators and the wastewater treatment plant (WWTP) of the city. This integrated model uses an interface approach, which connects commonly known sub-models of the various subsystems by automated scripts. Following this methodology results in the advantage of an understandable and easier to maintain integrated model for the sewer operator.
So far the model has been used to evaluate the impact of a newly constructed combined sewer storage tunnel (central storage tunnel – CST) on the existing WWTP and to derive best management practices (BMPs) for the integrated operation of the system in regard to minimizing the total emission load to the receiving water.

KEYWORDS

Boundary relocation, integrated modeling, interface approach, total emission, urban drainage

1 INTRODUCTION

Ever since the introduction of the European Water Framework Directive in the year 2000 (European-Community, 2000) the simulation of the entire urban water cycle gets more and more important. With the currently available knowledge the development of models following an integrated approach to show the complete picture of the situation of the system, including runoff generation, the sewer system and WWTP as well as the state of the receiving water, is becoming a feasible solution for today's drainage challenges (Rauch et al., 2002; Butler and Schuetze, 2005; Muschalla et al., 2009; Benedetti et al., 2013). There are various ways to design such integrated models. So far two of these ways have manifested as the most commonly used ones: i) by using a supermodel approach which uses a large model that describes the most relevant processes within the integrated system and ii) by using an interface approach where different sub models of each subsystem are implemented separately and later connected with appropriate interfaces.

Both approaches aim to show the big picture of the complete system's situation. However both have several advantages and disadvantages. So the question of which one to use for a specific situation comes up. To know which approach suits the situation best however, it is necessary to define the desired output and the objective of the model. Super model approaches like the WEST package (Meirlaen, 2002; Vanhooren et al., 2003; Nopens, 2005) have the advantage that all parts of the model are in one modeling environment, share the same database and run in one simulation. Therefore, they offer the possibility to use parallelized computing to reduce calculation time. Contrary to that, the interface approach uses highly specialized models for each sub-model that offer the ideal tools to generate and maintain them. That however, makes it necessary to use interfaces and interface models, which makes the execution of an integrated model using this approach more complex.

The specifics of the differences aside, this paper focuses on a possible way to implement the interface approach on a case study situated in Graz, Austria. The following methodology was developed and applied.

2 METHODOLOGY

Often, integrated models with the aim of optimizing operational processes show that only a small part of the system is influencing the end result, while the rest acts statically. Therefore, the interface approach seems more feasible in those particular cases, because the static parts can be simulated by a crude model, whereas the dynamic parts have to be implemented by a highly sophisticated model that can simulate the different control actions applied on the system.

After a thorough analysis of the system, follows the definition of sub-model boundaries based on the principle of boundary constrains and relocations (Vanrolleghem et al., 2005; Muschalla et al., 2009).

With this process done, coherent sub-models can be implemented and then calibrated separately. These sub-models need to be combined with an integrated model by using interfaces (or if needed interface models) according to the following three forms of integration:

- Semantical integration – achieving a shared understanding between all models
- Methodological integration – data produced by one model is a meaningful input to another model
- Technical integration – automating data exchange between models, making them jointly executable

The models for runoff generation and sewer system are using the same parameters, which rendered the semantic and the methodological integration unnecessary. Between the sewer system and the WWTP a fractionation model for the driving parameters of the WWTP, COD, TKN and P, had to be applied as a semantical and methodological integration.

For the technical integration, script-based model interfaces are used for sub-models with no feedback to the previous model. The script also controls the simulation, starts the sub-models sequentially and converts the data automatically between sub-models. Sub-models with bi-directional interaction are modelled with a direct connection or as one model environment allowing a parallel execution and the exchange of information for control purposes during runtime.

3 RESULTS

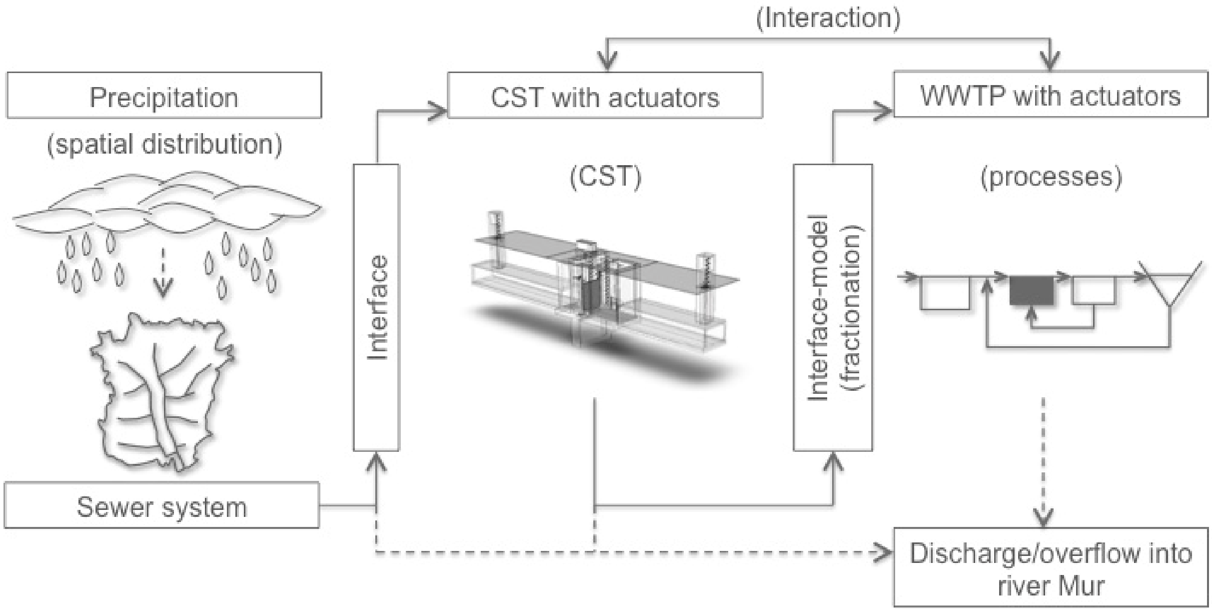

Figure 1: Schematic structure of the integrated simulation model including Interfaces and model emission pathways.

For the sub-model selection it is important to understand that the central storage tunnel (CST) is collecting the discharges from the former CSOs and allows the storage and routing of the combined sewage to the WWTP or the bypassing of it to the river Mur. The major part of the urban drainage system is hydraulically independent from the CST and the WWTP, allowing a maximal simplification of the city's sewer system as only flows and loads at the interfaces are of interest and no information exchange exists between the sewer system and the connected system of the CST and WWTP (see figure 1).

This leads to a solution where rainfall information from the city's precipitation measurement network serves as an input for a grey-box rainfall-runoff model (KOSIM 7, (itwh, 2010)) on city scale including the main sewers to the WWTP, the main storage facilities and all existing combined sewer overflows (CSOs) to the receiving water body. A detailed hydrodynamic rainfall-runoff model (SWMM5, (U.S. EPA, 2008)) is used to represent the Central Storage Tunnel (CST) for hydraulics and water quality including actuators for control purposes. A detailed dynamic WWTP model was developed using the activated sludge model ASM3-BioP (Rieger *et al.*, 2001) within the SIMBA# simulation platform (SIMBA, 2014) to analyse the impact of sewer control measures on the treatment performance.

These models were all calibrated and validated separately with monitoring data gathered throughout extensive measurement campaigns in the past. Later the whole integrated model was validated by using monitoring data from the WWTP.

The calibrated and validated integrated model was applied to different rainfall events and emptying scenarios of the CST to evaluate the impact on the treatment performance of the WWTP. The final evaluation considered the total emissions to the river Mur including the effluent of the WWTP, the emergency CSOs of the CST, and the CSO tank located adjacent to the WWTP. The results were used to derive management strategies for the integrated waste water system with the aim to minimize the overall emission loads.

4 CONCLUSION & OUTLOOK

An integrated simulation model (sewer system and WWTP) was developed to evaluate the impact of different rainfall events and emptying scenarios of a recently installed central storage tunnel (CST) on the treatment performance of the WWTP Graz (Austria) and subsequently on the total emission load. To reduce model complexity and to increase simulation speed, a grey box model was used to represent the sewer system on city scale and boundary relocation was done for each sub-model. Model linkage and integration was implemented using script-based interfaces and bi-directional connections where needed. This allowed the calibration of each sub-model separately based on data sets for dry weather and wet weather conditions, respectively to consider the different complexities for both sets of conditions. The integrated model was used to simulate various combinations of rain events, emptying scenarios of the CST, and control strategies for the CST and the WWTP. The simulation results will be used to derive BMP for the integrated operation of the CST and WWTP.

Future development of the model and further research will go towards implementing the bidirectional interface model between WWTP and CST as well as an extensive measurement campaign to continue to improve that same interface model.

LIST OF REFERENCES

Benedetti, L., Langeveld, J., Comeau, A., Corominas, L., Daigger, G., Martin, C., Mikkelsen, P. S., Vezzaro, L., Weijers, S., and Vanrolleghem, P. A. (2013) Modelling and monitoring of integrated urban wastewater systems: review on status and perspectives. Water Science and Technology, **68**(6), 1203–1215.

Butler, D. and Schuetze, M. (2005) Integrating simulation models with a view to optimal control of urban wastewater systems. Environmental Modelling & Software, **20**(4), 415–426.

European-Community (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities, **43**(L327), 1– 71.

Meirlaen, J. (2002) Immission based real-time control of the integrated urban wastewater system Immissiegebaseerde real-time controle van het geïntegreerd stedelijk afvalwatersysteem. [online] http://buck.ugent.be/fulltxt/RUG01/000/731/483/RUG01-000731483_2010_0001_AC.pdf (Accessed December 9, 2015).

Muschalla, D., Schuetze, M., Schroeder, K., Bach, M., Blumensaat, F., Gruber, G., Klepiszewski, K., Pabst, M., Pressl, A., Schindler, N., Solvi, A. M., and Wiese, J. (2009) The HSG procedure for modelling integrated urban wastewater systems. Water Science and Technology, **60**(8), 2065–2075.

Nopens, I. (2005) Modelling the activated sludge flocculation process: a population balance approach. PhDThesis, Ghent University, Belgium. [online] http://lib.ugent.be/fulltxt/RUG01/000/894/656/RUG01-000894656_2010_0001_AC.pdf (Accessed December 9, 2015).

Rauch, W., Bertrand-Krajewski, J. L., Krebs, P., Mark, O., Schilling, W., Schuetze, M., and Vanrolleghem, P. A. (2002) Deterministic modelling of integrated urban drainage systems. Water Science and Technology, **45**(3), 81–94.

Vanhooren, H., Meirlaen, J., Amerlinck, Y., Claeys, F., Vangheluwe, H., and Vanrolleghem, P. (2003) WEST: modelling biological wastewater treatment. Journal of Hydroinformatics, **5**, 27–50.

Vanrolleghem, P. A., Benedetti, L., and Meirlaen, J. (2005) Modelling and real-time control of the integrated urban wastewater system. Environmental Modelling & Software, **20**(4), 427–442.