Impacts of rainwater harvesting and greywater reuseon the entire water system – a general modelling methodology applied to a city in Israel

Impact de la récupération des eaux de pluie et de la réutilisation des eaux grises sur l’ensemble du système de gestion de l'eau - une méthodologie de modélisation générale appliquée à une ville en Israël

Schütze, M.*[1], Alex*, J., Snir, O. ** Friedler, E.**

*ifak e. V., Werner-Heisenberg-Str. 1, 39106 Magdeburg, Germany (manfred.schuetze@ifak.eu, jens.alex@ifak.eu)
**Dept. of Env., Wat. & Agr. Eng.; Faculty of Civil & Environmental Eng.; Technion – Israel Institute of Technology, Haifa 32000, Israel (ofersn@campus.technion.ac.il, eranf@technion.ac.il)

RÉSUMÉ

Depuis quelque temps déjà, la gestion et la récupération des eaux pluviales sont préconisées pour améliorer la gestion des eaux urbaines et faire face aux défis du changement climatique (pénurie d'eau et risque accru d'inondation en raison de précipitations moins fréquentes mais plus abondantes dans plusieurs régions du monde). Cependant, lorsque l'on regarde le système d’approvisionnement en eaux urbaines et de traitement des eaux usées dans son ensemble, peu de recherches ont été faites jusqu'à présent sur leurs impacts.
La présente contribution résume les travaux effectués sur un cadre général de simulation combinant des éléments de modélisation dynamique des systèmes, d'analyse des flux de matières et d'analyse du cycle de vie, qui permet à l'urbaniste et à l'ingénieur de modéliser, bien que de manière simplifiée, l'ensemble du cycle des eaux urbaines dans une application facile à utiliser. En outre, le cadre de modélisation permet d'évaluer l'effet combiné de différentes mesures du système d'eaux urbaines (p. ex. récupération des eaux de pluie, réutilisation des eaux grises, interaction de l'infiltration avec le bilan des eaux souterraines et la disponibilité en eau). Un modèle général est mis en place, qui peut ensuite être adapté au système de gestion de l'eau de la ville concernée, en tenant compte des conditions locales en vigueur. Cette contribution reprend le cadre général de modélisation mis en place pour un cas général (hypothétique), qui sera ensuite adapté à une étude de cas réel en Israël.

ABSTRACT

In order to improve urban water management under the challenges of climate change (increased water scarcity and increased flood risk due to less but more intense rainfall events in many parts of the world), stormwater management and rainwater harvesting have been advocated for some time. However, less research has been done to date as with regard to their impacts when considering the urban water supply and wastewater system as one entity.

The present contribution summarises work on a general simulation framework, combining elements of dynamic system modelling, material flow analysis and life cycle analysis, which allows the urban planner and the engineer to model, albeit in a simplified way, the entire urban water cycle in an easy-to-use application, Furthermore, the modelling framework allows to evaluate the combined effect of different measures in the urban water system (e.g. rainwater harvesting, greywater reuse, interaction of infiltration with groundwater balance and water availability). A general model is set up, which then can be adapted to the water system of the given city, considering the locally prevailing conditions.

This contribution resumes the overall modelling framework which is set up for a general (hypothetical) case, which then will be adapted to a real case study in Israel.

KEYWORDS

Greywater reuse, Life cycle Analysis, Material flow analysis, Modelling, rainwater harvesting

1 MOTIVATION

In order to improve urban water management under the challenges of climate change (increased water scarcity and increased flood risk due to less but more intense rainfall events in many parts of the world), stormwater management and rainwater harvesting have been advocated for some time. However, less research has been done to date as with regard to their impacts when considering the urban water supply and wastewater system as one entity. This is ever more important as the system under question involves several feedback loops. Such feedback loops (besides the obvious one of discharging treated wastewaters to receiving water bodies from which water is abstracted for drinking water purification) occur in particular when greywater is reused for (non-potable) water usages. Furthermore, often in research and application, only individual measures in subsystems of the urban water system are analysed, without always investigating their interactions with other measures or their effects on the entire water system. In order to bridge the gap, the German-Israeli CLUWAL project sets up a modelling framework for the entire water system and applies it for the analysis of several case studies.

Figure 1 illustrates the scope of the water system to be considered in this work.

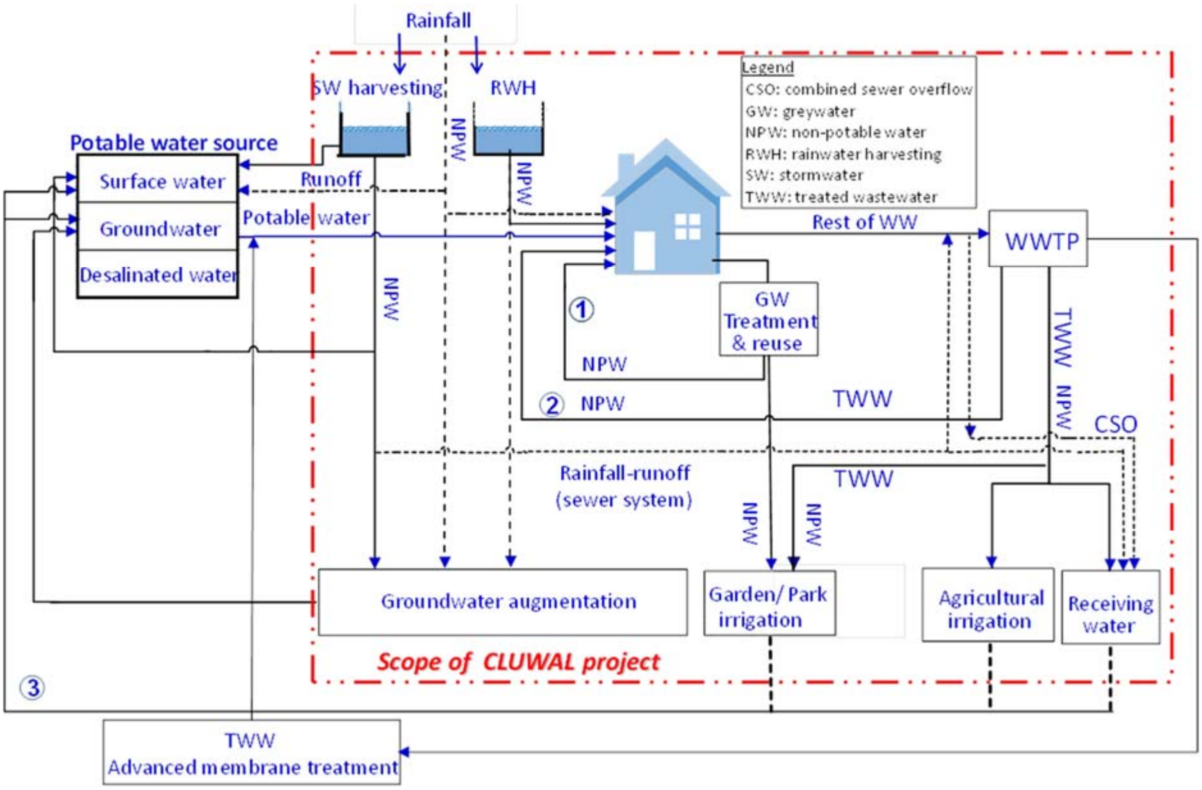

Figure 1: The urban water system as considered in the CLUWAL project

2 MODELLING THE URBAN WATER SYSTEM IN ITS ENTIRETY

So far, a considerable amount of modelling activities has been carried out for urban water management. For the present task, an Integrated Urban Water System model (as classified by Bach *et al.* 2014) is sought. However, in order to be able to adapt the complexity of the modelling approaches chosen for the individual subsystems (whilst maintaining their consistency), the modelling framework should allow for simpler as well as for more complex (e.g. detailed dynamic) modelling approaches to be chosen. Furthermore, balancing between availability and demand forms an important requirement for modelling studies such as those outlined above.

Therefore, the present work builds on earlier results as those presented by Ramírez *et al.* (2015) and Schütze *et al.* (2018), yet adding additional modules which had not yet been considered by these authors in sufficient detail. For many locations in the world, which are characterised by seasonal rainfall patterns and resulting water scarcity in dry periods, issues of rainwater harvesting, greywater reuse and interactions with the groundwater aquifers (serving as a water source) are of high significance. Hence, additional modules have been set up, integrating the modelling approach by Muklada *et al.* (2016) for rainwater harvesting modelling and by Rojas (2018) for simplified groundwater modelling. Furthermore, a general purposes module library for managing demand and availability of resources has been set up, allowing time-discrete and time-continuous propagation of demands. Hence, a comprehensive library of modelling modules has been set up (cf. Figure 2). As a development environment, the simulation system Simba#water (Version 3) (ifak, 2018) has been used.

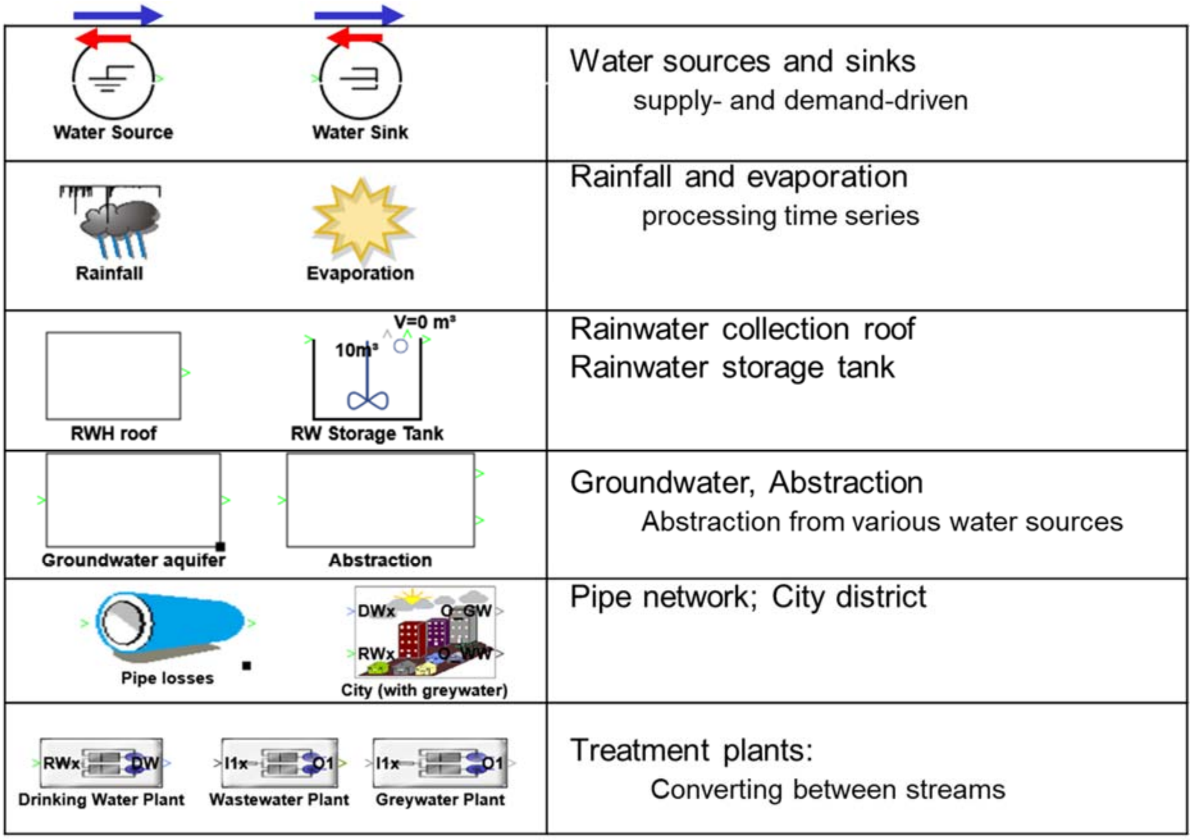

Figure 2: Modelling modules for general water system modelling (present state)

These blocks also have been extended to include parameters and routines to calculate demand on capital and operational costs and resources (e.g. for construction and for operation), thus assisting in the calculation of economic and environmental criteria over the lifetime of the water system as is required in a Life Cycle Analysis.

Using these modules, as a proof of concept, as a first step a benchmark model of urban water modelling defined in the literature (Chauvet *et al.*, 2016), has been set up and proven to be fit for use. As a simple demonstrational example of a model covering the entire water system, a model corresponding to the water system defined in Figure 1 has been set up (Figure 3). This example model illustrates the use of rainwater (collected in rainwater harvesting tanks), use of greywater and abstraction of groundwater and of river water as potential water sources for an urban agglomeration. The example shown here illustrates, for a town of 1,000 inhabitants, with a per-capita water consumption of 120 l/d the related water fluxes. Drinking water and non-potable water are distinguished by colour codes, and use of non-potable water is considered and shown as separate fluxes in the model. The example assumes, by means of example, that the greywater treatment capacity is limited to 30 m^3/d. Furthermore, managerial decisions are considered in simulation and visualising the water fluxes in the urban water system (this example assumes that water demand is met, in a certain order of priority: rainwater tanks, greywater reuse, groundwater abstraction and, finally, river water abstraction). As each of the modules also allows cost definitions (CAPEX and OPEX) as well as resource consumption and emissions (e.g. of greenhouse gases), the effect of various strategies of water management can be simulated and compared easily.

Each of the subsystems can be modelled in a level of detail as appropriate for the given case study, For example, the high-resolution stochastic model for rainwater harvesting as set up by Snir et al. (submitted) is currently being integrated into the general modelling framework shown here.

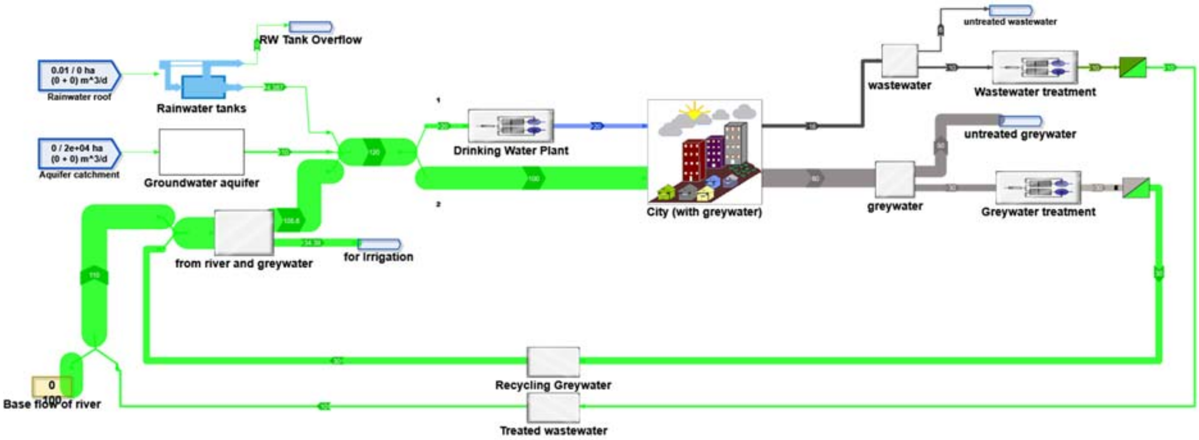

Figure 3: Model implementation of Figure 1 with water fluxes shown as Sankey diagram (Unit: [m^3/d])

The conference contribution elaborates on the general modelling principles, characterised by a combination of system modelling, material flux analysis and Life Cycle Assessment, whilst also allowing detailed dynamic modelling to be integrated (cf. Robleto, in press). This is done on a general model, also considering the catchment runoff – infiltration – groundwater interface. Subsequently, the application of the modelling methodology on a case study in Israel will be presented in detail.

3 CONCLUSIONS

A general modelling framework for urban water systems has been set up. It represents an Integrated Urban Water System Model and allows to integrate various levels of detail of component models. Particular emphasis is laid on balancing availability and demand of water resources. The framework allows managerial decisions to be simulation, visualised and analysed not only in terms of resource fluxes, but also by costs and emission criteria. It is currently applied for various case studies in Israel and throughout the world.

ACKNOWLEDGEMENT

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