Using an integrated model to support long term strategies in wastewater collection and treatment

Un modèle intégré pour l'implémentation de stratégies à long terme pour la gestion et le traitement des eaux usées et pluviales

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RÉSUMÉ

Depuis 2013, VCS Denmark, société des eaux de la commune d'Odense, a initié une approche pionnière pour la planification intégrée de la gestion des eaux urbaines de la ville d'Odense au Danemark. Au centre de cette approche, un modèle rapide, dynamique et intégré prédit les changements de qualité des eaux des rivières en fonction du comportement du réseau pluvial (dont les rivières elles-mêmes, milieux récepteurs), du réseau d'assainissement et des stations d'épurations. Le modèle intégré permet de représenter la nature interconnectée de ces éléments dans un système global : par exemple, l'impact du réseau d'assainissement sur les stations d'épurations. VCS Denmark utilise cette approche de modélisation pour développer un plan intégré à long-terme afin d'assurer des écosystèmes durables et de bonne qualité sur les 80 kilomètres de rivières du domaine communal. Le modèle intégré est utilisé pour l'analyse coûts/bénéfices de solutions « grises » et « vertes » (y compris contrôle en temps réel) sur l'ensemble de leur cycle de vie, pour comprendre l'influence du changement climatique et de la croissance urbaine, etc.

ABSTRACT

The paper describes how VCS Denmark is pioneering new technologies in integrated wastewater planning in Odense, Denmark. Central to the approach is a fast-simulating dynamic integrated model that predicts river water quality changes in response to dynamics in the river basin, stormwater network, wastewater collection network and wastewater treatment facilities. The interconnected nature of this system is represented, e.g. the impact of the wastewater collection system on the wastewater treatment facilities is modelled. The utility is using this modelling approach to develop a long-term integrated plan that helps secure sustainable ecosystems in an 80 km network of rivers. The model is being used to evaluate the different whole life costs and benefits of grey and green type solutions (including real-time control), to understand influences of climate change and of growth.

KEYWORDS

Integrated modelling, planning, simplified sewer model, water quality, wet weather

1 OBJECTIVES

VCS Denmark is the water utility for Odense, Denmark's third city. The urban wastewater system is complex and characterised by 124 combined sewer overflows (CSOs), 60 significant stormwater outfalls and three WRRFs. All have a polluting impact upon the Odense River and its tributary streams. Figure 1 is a schematic of the system as represented in DHI WEST software.

VCS Denmark is developing a long-term investment strategy for the whole wastewater system (collection and treatment components) which:

- protects watercourses from wet weather pollution to achieve and maintain Good Ecological Status (GES) under the European Union's Water Framework Directive (WFD);
- uses whole life cost accounting methods to strike the right balance capital and operating expenditure (including the consumption and generation of energy);
- accounts for co-benefits (for example, the wider benefits of green stormwater infrastructure (GSI) or the reduction of sewer flooding);
- anticipates and is adaptive to climate change;
- recognises the uncertainty that is inherent when planning in this type of system; and
- has the agreement and participation of the Regulator and other stakeholders.

2 STATUS

The project, technically supported by CH2M, has been running for 24 months (in November 2015) and model development is substantially complete and was reported in a paper at WEFTEC15 (Gill et al, 2015).

The 2016 paper will illustrate how the model is being used to generate system wide metrics in support of long-term investment decisions, especially the multi-criteria comparison of strategy alternatives. For example, whether to provide distributed collection system storage, green stormwater infrastructure, real time control, a new CSO tunnel or increased WRRF treatment capacity – or some combination of all these.

3 METHODOLOGY

An integrated model of the system (collection, treatment and receiving water) is constructed in WEST, a treatment process simulator with features that enable to model the collection and receiving water systems with simplified hydraulics and detailed quality processes. This modelling platform delivers the advantages of integration and speed which enables the rapid assessment (over long continuous simulations) of different wastewater strategies representing all key dynamics, including the impact of wet weather flows on the WRRF and the impact of CSO, stormwater and WRRF discharges on receiving water chemistry. Different wastewater strategies are tested by taking a baseline integrated model representing the current system (Figure 1) and altering elements to represent alternatives. The concepts and benefits of integrated modelling are reviewed by Benedetti et al. (2013).

Through 2016 a network of 16 river quality monitoring stations (Figure 2) in Odense will be collecting data for river model calibration and validation. This final, and most important, aspect of model validation will be reported in the paper. A validated water quality model will support comparisons between modelled water quality and Urban Pollution Management (FWR, 2013) fundamental intermittent standards to indicate whether Good Ecological Status is achieved over the long term.

The collection system is represented as a 'tanks in series' model with each CSO discharging from a single catchment within the network. The simplified model input parameters are derived from a validated MIKE-URBAN collection system model. The WEST model is then validated against the MIKE-URBAN model results, checking that the CSO spill volumes and frequencies are consistent. The simulations in WEST are for a five-year period with a 60-second rainfall input time step. Sewer flow quality is generated for dry weather by using average loads and daily profiles, and in wet weather by accumulation/wash-off for particulates (COD, TSS) and fixed event concentrations for solubles (NH_4, PO_4). Routing of pollutants in the sewer includes sedimentation and resuspention of particulates. The pollution model is validated against observed sewer flow quality at the WRRFs and CSOs.

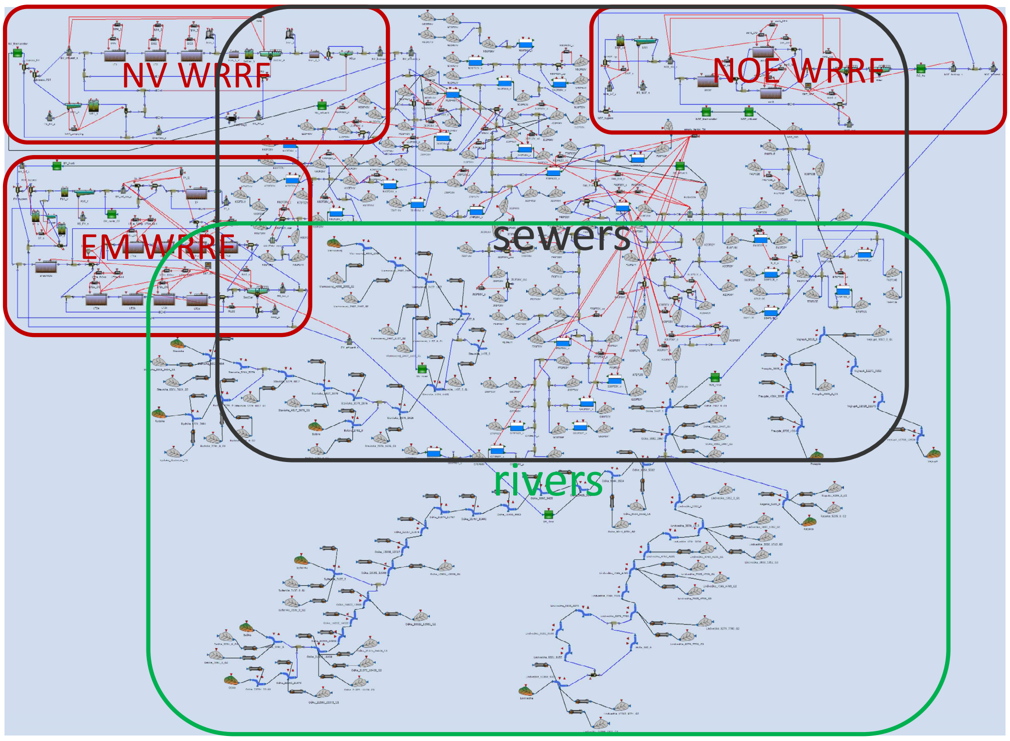


Figure 1 – System layout in WEST

Figure 2 – River water quality on-line monitoring station prototype

Three WRRFs are in the system: one existing model translated in WEST from BioWin and two developed for this project. Plants are modelled including all units of the wastewater treatment line, from primary settling to activated sludge to secondary settling, including all controllers for aeration, recycles, etc. Activated sludge model No. 2d (ASM2d) was used for bio-chemical processes. Figure 3 illustrates an example of the modelled influent and effluent from one of the WRRFs.

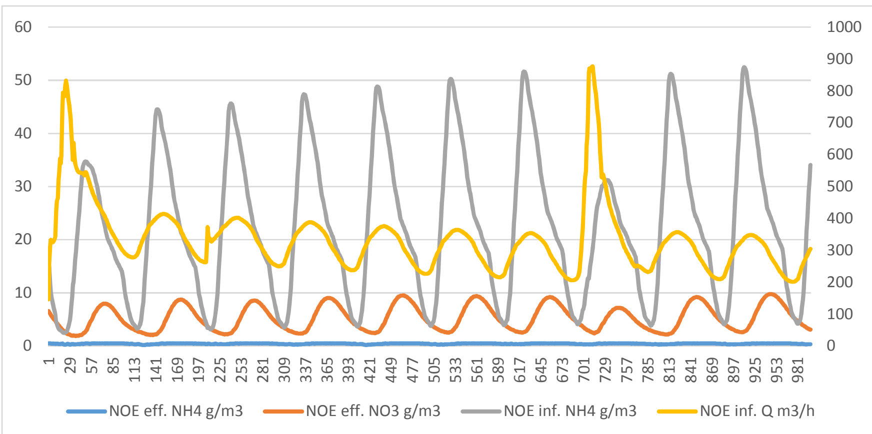
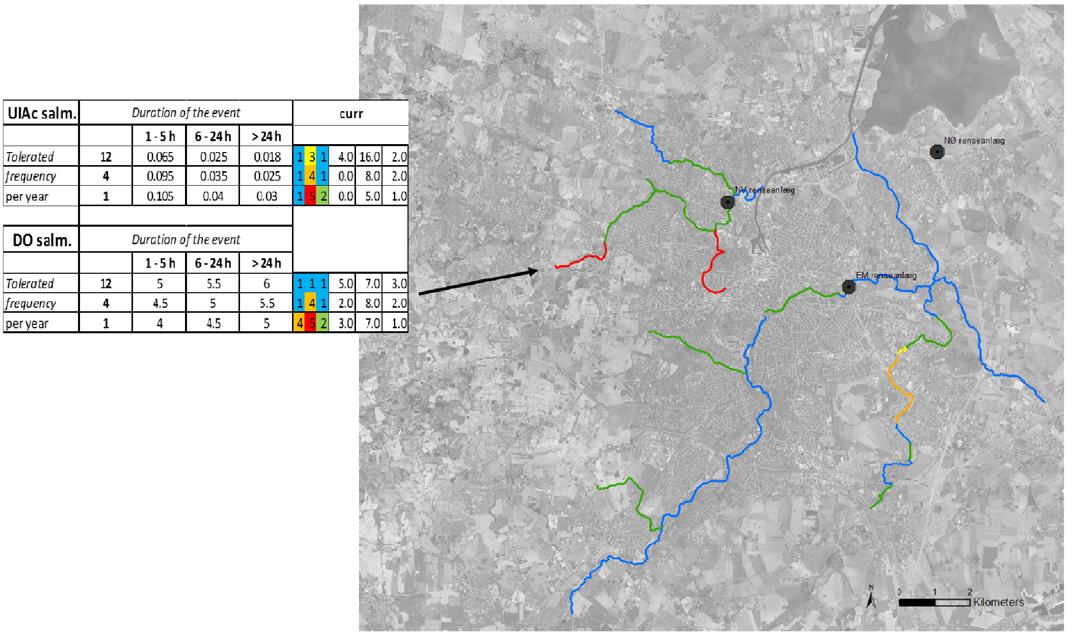


Figure 3 – Modelled Influent/Effluent at one of the WRRFs

The model is configured to enable operating costs to be calculated for the sewer (pumping) and for the WRRFs including pumping, aeration, chemicals and sludge treatment. This is useful to test the impact of different collection system management strategies on the operating costs of the WRRFs.

An 80 km network of rivers is modelled, receiving flow and pollutants from stormwater outfalls, CSOs and the WWRFs. The model is simplified by representing channel section as tanks with a regular gradient and trapezoidal shape; this is sufficient to model flows reliably, which is validated against gauged data at two locations. The water quality model includes processes for DO (consumption by 5 types of BOD and reaeration), for nitrification and algae activity. Assessment of Water Framework Directive (WFD) standards is undertaken by using the United Kingdom develop Urban Pollution Management (UPM) Fundamental Intermittent Standards (FIS) (FWR 2013). These are threshold, duration, frequency standards for dissolved oxygen and unionised ammonia that are designed to test the long term (> 1 year) wet weather water quality impact of urban wastewater systems (Figure 4).



UIAc salm.	Duration of the event				curr					
		1 - 5 h	6 - 24 h	> 24 h						
Tolerated	12	0.065	0.025	0.018	1	3	1	4.0	16.0	2.0
frequency	4	0.095	0.035	0.025	1	4	1	0.0	8.0	2.0
per year	1	0.105	0.04	0.03	1	5	2	0.0	5.0	1.0

DO salm.	Duration of the event									
		1 - 5 h	6 - 24 h	> 24 h						
Tolerated	12	5	5.5	6	1	1	1	5.0	7.0	3.0
frequency	4	4.5	5	5.5	1	4	1	2.0	8.0	2.0
per year	1	4	4.5	5	4	5	2	3.0	7.0	1.0

Figure 4 – Example of scenario results in Odense showing impacts on rivers through UPM analysis, here for dissolved oxygen (from blue = best water quality to red = worst water quality)

4 FINDINGS AND SIGNIFICANCE

The integrated modelling approach has been successfully implemented and further validation of the model is ongoing using data from a continuous water quality monitoring programme. This will provide greater confidence in the model predictions and its use as a decision making tool.

Meanwhile, a number of scenarios are being developed and tested to consider the costs and benefits of different wastewater strategies. This work is being carried out in collaboration with the Regulator. Scenarios being tested include the use of distributed network storage (grey infrastructure) to limit spill frequency and volume at each CSO (default management approach currently planned). The program is disruptive and expensive and early modelling outputs indicate a resulting deterioration in river water quality because of impaired wastewater treatment. Alternative scenarios are considering various configurations of stormwater green infrastructure and conventional 'grey' elements. The integrated modelling tool enables the rapid and robust evaluation of different strategies including the impact on WRRF and collection system operating costs. The sensitivity of each strategy to climate change is also tested.

The benefits of adopting integrated modelling techniques are established. They provide fresh insight into system dynamics and support all stakeholders (utility and regulator) formulate a long-term strategy which meets the needs of the environment at the lowest cost.

LIST OF REFERENCES

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