An Integrated RTC-Strategy for the Sewer System and WWTP in Helsingborg - II

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1. INTRODUCTION

In this paper the background and the necessary steps to be taken towards a more efficient use of the sewer system, including the treatment plant (WWTP), by means of real time control (RTC) is described.

The sewer system in Helsingborg has been rehabilitated in many ways in connection with the reconstruction of the WWTP Öresundsverket for a high degree of nitrogen and phosphorus removal. In that context a holistic view has been used in order to optimise the measures seen from the effects in the receiving waters. One of the steps has been the engagement as a pilot partner in a Technology Validation Project (TVP) under the EU Innovation Programme (1997-99). The aim is to develop an integrated modelling tool including hydrology, hydrodynamic and water quality aspects in the sewer network and treatment processes at the WWTP for operational control and to demonstrate the effect of alternative planning measures. The project is focused on modelling pollutant transport and the effect of introducing RTC of the sediment pattern in the sewer. MOUSE TRAP is used to simulate the transport in the sewers and STOAT for the description of the processes at the WWTP.

The performance of the sewer system for the present conditions will be evaluated with respect to the flow and the transport of dissolved substances to the WWTP. This evaluation comprises a continuous simulation of the load at the WWTP and simulations of design events by use of the MOUSE TRAP modules. In addition the sedimentation pattern in the sewer system is evaluated for the same scenarios. The selected control strategies will then be evaluated with respect to changes in sedimentation pattern. I.e. the new control 'strategies should not increase the sediment deposits in the sewer system to an unacceptable level.

2. BASIS FOR A RTC-STRATEGY

Figure 1 Overview of Helsingborg sewer system

The municipality of Helsingborg is located on the South West Coast of Sweden. The catchment area connected to the WWTP is approx. 50 km^2 and the WWTP, Öresundsverket, receives wastewater from about 205 000 PE. The sewer system is partly combined, with 330 ha impervious area con-

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nected to the sewers mainly in the central part of the city. The dominant parts of the combined sewer overflows (CSOs) are located within the main wastewater interceptor sewer along the coastline.

2. 1 The technical background of the project.

The technological basis of the project is the Technology Validation Project - the TVP project. The background for the project is that in most part of the world there is a fragmented planning and management of the sewer system, the wastewater treatment plant and the receiving waters. Further, there was a lack of methodology and technology available for the integrated planning and management and finally there is simply a lack of regulatory framework for "Integrated Thinking". Hence, the objective of the TVP project is to provide the tools for integrated modelling of the urban water cycle and to demonstrate the integrated technology, methods and regulatory framework in selected European cities.

The modelling tools for the integrated analyses are based on MOUSE for the sewer system, STOAT for the wastewater treatment plant and MIKE 11 for the rivers. The tool is build in two versions:

Sequential simulation:

- The models run in a sequence, i.e. one after the other,
- There is no feedback in terms of RTC between the modelling systems. I.e. "passive systems" & local RTC
- Data exchange is through the result files

Parallel (simultaneous) simulation:

- The models runs at the same time and exchange data with each other during the simulation,
- This provides the possibility for RTC (global) between the models
- The data exchange between the model takes place at the "time step level"

In figure 2 the data flow can be seen both for the sequential and the parallel simulation of the urban water cycle.

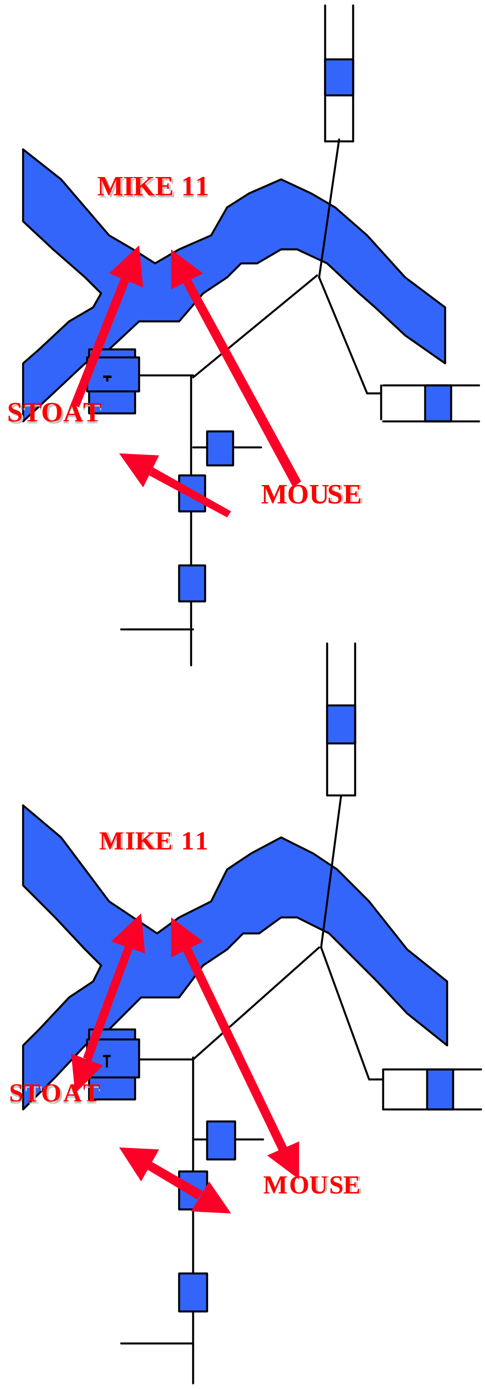


Figure 2. Top: The data flow in the sequential simulation tool. Bottom: the data flow in the "parallel" simulation tool.

2.1 The wastewater treatment plant

The WWTP Öresundsverket is designed to a high degree of nutrient removal. It was the first WWTP in Sweden designed and built for biological nitrogen removal. Enhanced biological phosphorus removal has been used in two of the four treatment trains for several years. As a final treatment the water is filtrated. At the plant a storage volume of 8000 m^3 is used for peak flow equalization. An additional volume of the same magnitude within the sewer system is possible to utilize as storage by regulation and control measures. The modelling of the WWTP is concentrated on describing the impact on the nutrient removal processes. The goal is to find the optimal way in the process to handle flow and quality variations in the incoming water.

2.2 Modelling of the sewer system: hydraulic processes and dissolved pollutants.

The description of the flow in the sewer system is based on the hydrological MOUSE NAM model and the hydrodynamic Mouse model. These models have previously been setup as a part of a sewerage master plan for the Helsingborg catchment. The aim of the master plan was to reduce the combined sewer overflows (CSO) volumes into the receiving waters, to minimise the risk of flooding and to improve the flow situation at the WWTP.

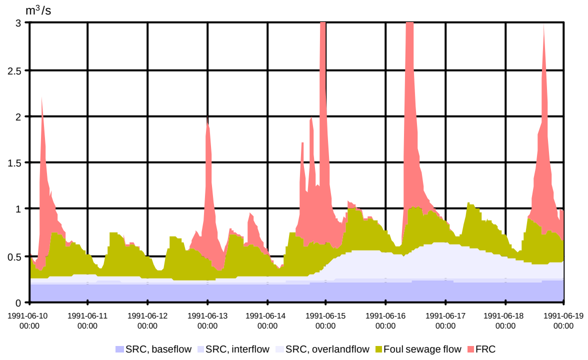


Figure 3 Distribution of flow components to the WWTP during the period 10/6-19/6 1991.

The master plan is implemented during the period 1994-99 and has by model calculations been estimated to result in a 60% reduction of CSO volumes from the sewer system. This is achieved by a combination of local drainage and rehabilitation measures, storage, regulations, optimised flow transport and separation of impervious area from the combined sewer.

The modelling of the transport of pollutants is carried out by use of the advection-dispersion model in MOUSE TRAP. A sampling programme for validation of the advection-dispersion model has been carried out. A tracer measurement programme has also been carried out to serve as a basis for simulations of the transport mechanisms in the sewer system (figure 4).

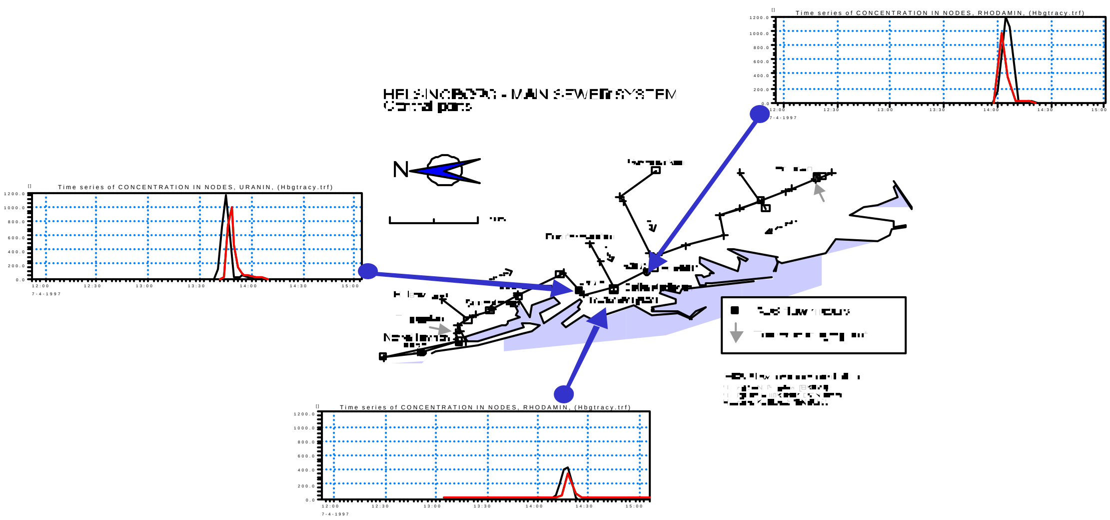


Figure 4 Tracer studies. Analysed pulse response (µg/l) compared to MOUSE TRAP simulation results.

From figure 4 it can be seen that the model is capable of transporting a conservative substance through the sewer system, and this provides the basis trust in the capability of the model in also transporting dissolved pollution with the right timing and peak concentration in the Helsingborg sewers.

In figure 5 examples are shown of wet weather sampling analyses compared to preliminary MOUSE TRAP calculation results. From this figure is can be seen that a good agreement is achieved for Ammonia both upstream of the WWTP and at the WWTP. Further, it can be seen that there is a good correlation between simulated and measured phosphorous at the WWTP, however the simulated values have a tendency of being too small. Finally, the comparison between the simulated COD and the measured COD at the WWTP shows that the simulated COD concentration at the beginning of the rain event is too low. This may be due to the fact that at the present stage only the dissolved COD is simulated and the COD measured at the WWTP also originates from COD attached to particles. These particles may either originate from the surface where they are washed off in the beginning of the rain or they may originate from sediment deposits in the sewers. These deposits are then eroded as part of the first flush during rain. Hence, the simulation of COD may be improved by adding a sediment source for pollution the present model of the Helsingborg sewer system.

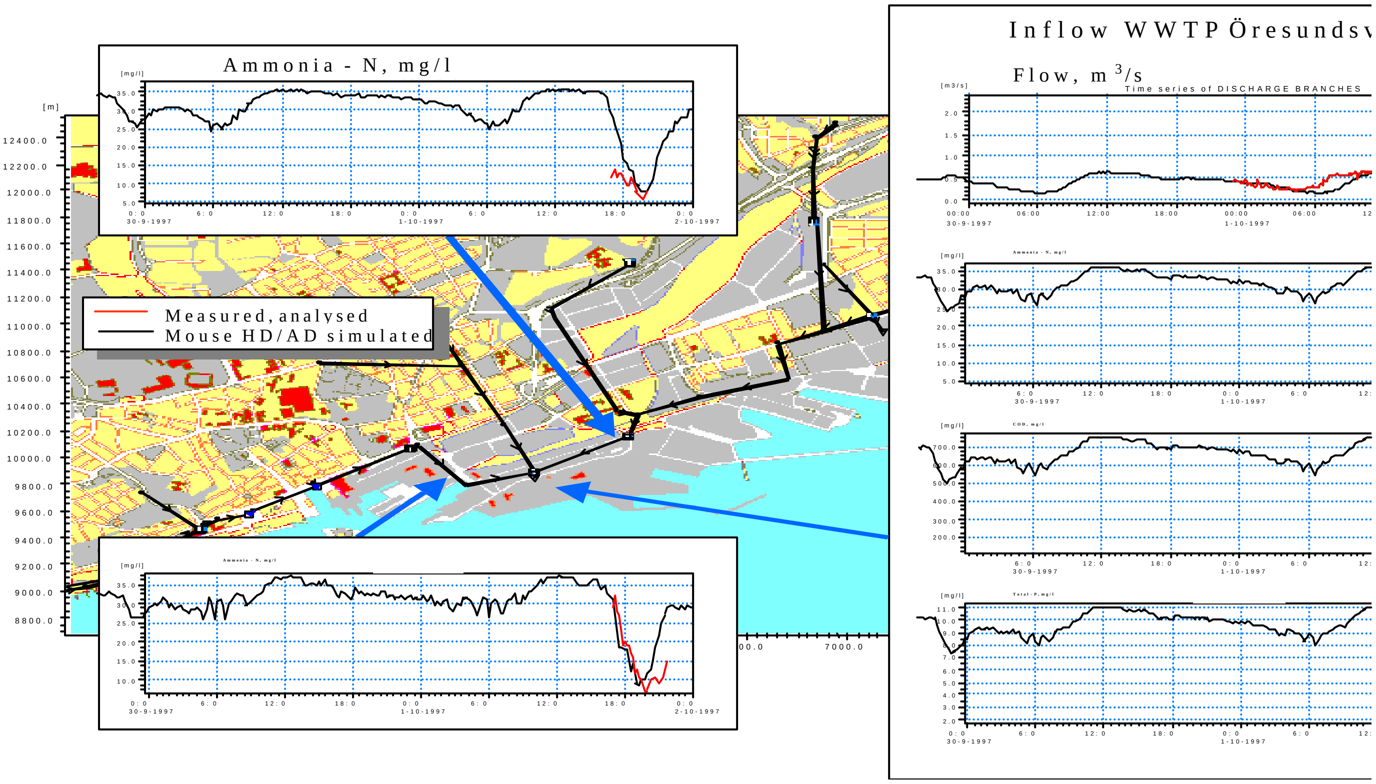


Figure 5 Wet weather sampling. Examples of measured flow and wastewater analyses compared to preliminary MOUSE HD/AD simulation results.

2.3 Modelling of the sewer system: sediments and RTC.

The purpose of the sediment transport modelling is to investigate the effect of the real time control strategies that will be proposed for the sewer system. In other words, the proposed real time control strategies should not create flow pattern, which will give increased

deposition at critical locations in the sewer system, as sediment deposits reduce the hydraulic capacity of sewer systems.

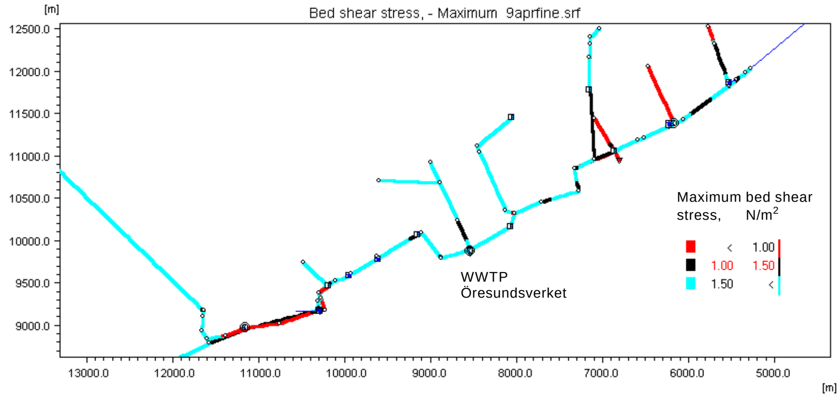


Figure 6 Example of MOUSE TRAP ST simulation results. Maximum sediment bed shear stress during dry weather conditions.

In turn, this may cause flooding and consequently increase the volume and the frequency of the combined sewer overflows. Based on the results from the sediment transport model, critical sites in the sewer system will be identified (figure 6). However, these simulations may point out locations where sediment deposits may exist, but they may not have significant influence on the flow and the CSOs. This could e.g. be the case for a pipe with a negative slope (slope in the opposite direction of the flow), where local sediment deposits may develop, but these may reach a steady state where they don't influence the flow and the CSO. In order to evaluate the effect of eventual local sediment deposits the morphological modelling is carried out.

2.4 Modelling of RTC the sewer system.

At present, the work on the project in focused on the formulation of the RTC strategies and the objectives of these. Below a list of the objectives is given:

- Available resources (volumes) are used as much as possible
- The increased risk for flooding must compensated for by movable weirs
- Full treatment at the treatment plant as far as possible
- Part of in-line storage used for that purpose
- When certain storage levels are exceeded incomplete treatment is preferred (via treatment plant storage overflow) compared to CSO discharge.
- Additional in-line storage volume is used to avoid CSO
- CSO discharge by pumping is preferred
- At higher (emergency) levels in the sewer system, CSO volumes are discharged over fixed weirs and by lowering the movable weirs.

In figure 7 the most important components within Helsingborg RTC strategy are shown and in figure 8 a simulation with one of the newly proposed RTC strategies are shown. The reduction in CSO of the rain event in figure 8 is 40 %.

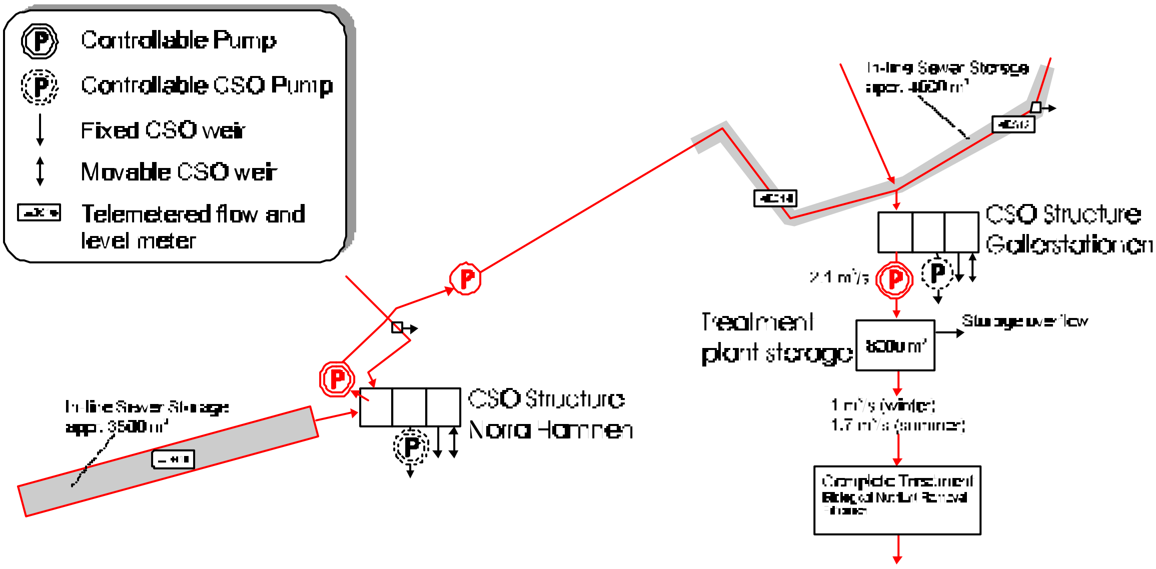
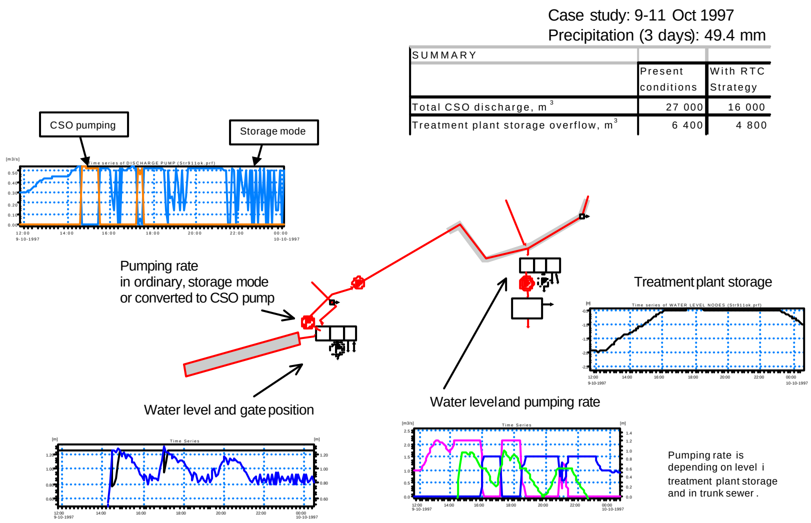


Figure 7 RTC components in Helsingborg main sewer system.



SUMMARY	Present conditions	With RTC Strategy
Total CSO discharge, m³	27 000	16 000
Treatment plant storage overflow, m³	6 400	4 800

Figure 8 Example of a RTC simulation in Helsingborg main sewer system. The reduction in CSO was 40% for this event.

3. SUMMARY

The present paper describes an application of integrated modelling tools as a part of the TVP project for the municipality of Helsingborg. At present, a MOUSE TRAP model and a STOAT model have been build for the system and they are in the process of being calibrated and validated.

Tracer measurements have been carried out and these are be used to validate the capability of the MOUSE AD to transport conservative dissolved pollutants in the Helsingborg sewer system. Further, preliminary simulations of Ammonia, Phosphorous and COD have been carried out. The simulation of Ammonia as a conservative pollutant gives very good results. The simulation of Phosphorous is good but the simulated values are always below the measurement, hence there may be scope for improvements. The simulation of COD is not satisfactory yet. This may be due to the fact that at present only dissolved COD is simulated and sediments may contribute the total COD load. Hence, the water quality model has to be extended in the near future.

One of the goals of the project is to investigate the applicability of real time control strategies in the sewer network. At present the RTC strategies are developed and they show the potential for reducing the CSO in the order of 40 % for selected rain events. When the RTC strategies based on the hydrodynamic conditions have been evaluated to a satisfactory level with respect to flooding, the RTC strategies may be extended to be based on water quality parameters in the sewers and at the WWTP. Such RTC based on the WQ parameters may improve the overall performance of the systems.

Finally, the effect of the real time control strategies will be evaluated with respect to the effect on the change in sedimentation pattern. The effect of additional sediment deposits will be evaluated before the implementation of the real time control strategies in the Helsingborg sewer system. This modelling of the sediment deposition pattern for the existing sewer system has been initiated and a methodology for the analysis has been established. This methodology takes both the flow and the dynamical sediment movement into account. So far these analyses indicate that sediment deposits may already exist for the present flow conditions without RTC. However, more information concerning the sediment properties and further analyses are needed before precise statements can be made on the present sediment conditions in the Helsingborg sewer system.

4. REFERENCES

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DISCUSSION

Question George Heywood Tynemarch

What are the run times for the model ?

Answer

The sewer model is considerably simplified to make it run faster, I am not sure about the Stoat run times. Generally the integrated model runs about 10 times faster than real time.

Question Adrian Saul Sheffield University

You put dye in the sewers, did this give good results and agreement ?

Answer

Yes it was good we saw no need to try and improve on it further.

Question Martin Osborne Reid Crowther

How much time and cost was associated with the DWF dye tracing ? What about doing it in wet weather ?

Answer

The local municipality staff did the dye tracing , I believe it was quite cheap. It was only done in dry weather and only needs to be done at 2 or 3 pipes. We did not do it in wet weather because the amonia predictions gave a good correlation in wet weather.