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Using MOUSE LTS to analyze sewer mains in Greater Copenhagen

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Abstract

This study focuses on a 3 km critical stretch of a combined sewer system in Greater Copenhagen. The upstream area has approximately 150.000 inhabitants. The current sewer system consists of 3-6 pipes running in parallel with a poor gradient. The downstream water level is often high relative to the sewer system, leading to almost still standing water. The current sewer system leads to sedimentation in the sewers decreasing hydraulic performance and demanding much manpower. Further, the sewer system has many small and outdated combined sewer overflows without local treatment. The objective is to analyze the system and to suggest changes that will reduce the number of structures and at the same time reduce the need for maintenance. The flow scheme is rather complicated both in the current setup and in the proposed scenarios and demands analysis with a full hydrodynamic wave model in combination with historical rain series. The new long-term simulation add-on module to MOUSE, MOUSE LTS, is used in the study. The optimum scenario is one where some of the combined sewer overflows are closed and a reduction of the downstream water level in dry weather is ensured by means of pumping. The hydraulic conditions in the shift from dry to wet weather is rather complicated to analyze.

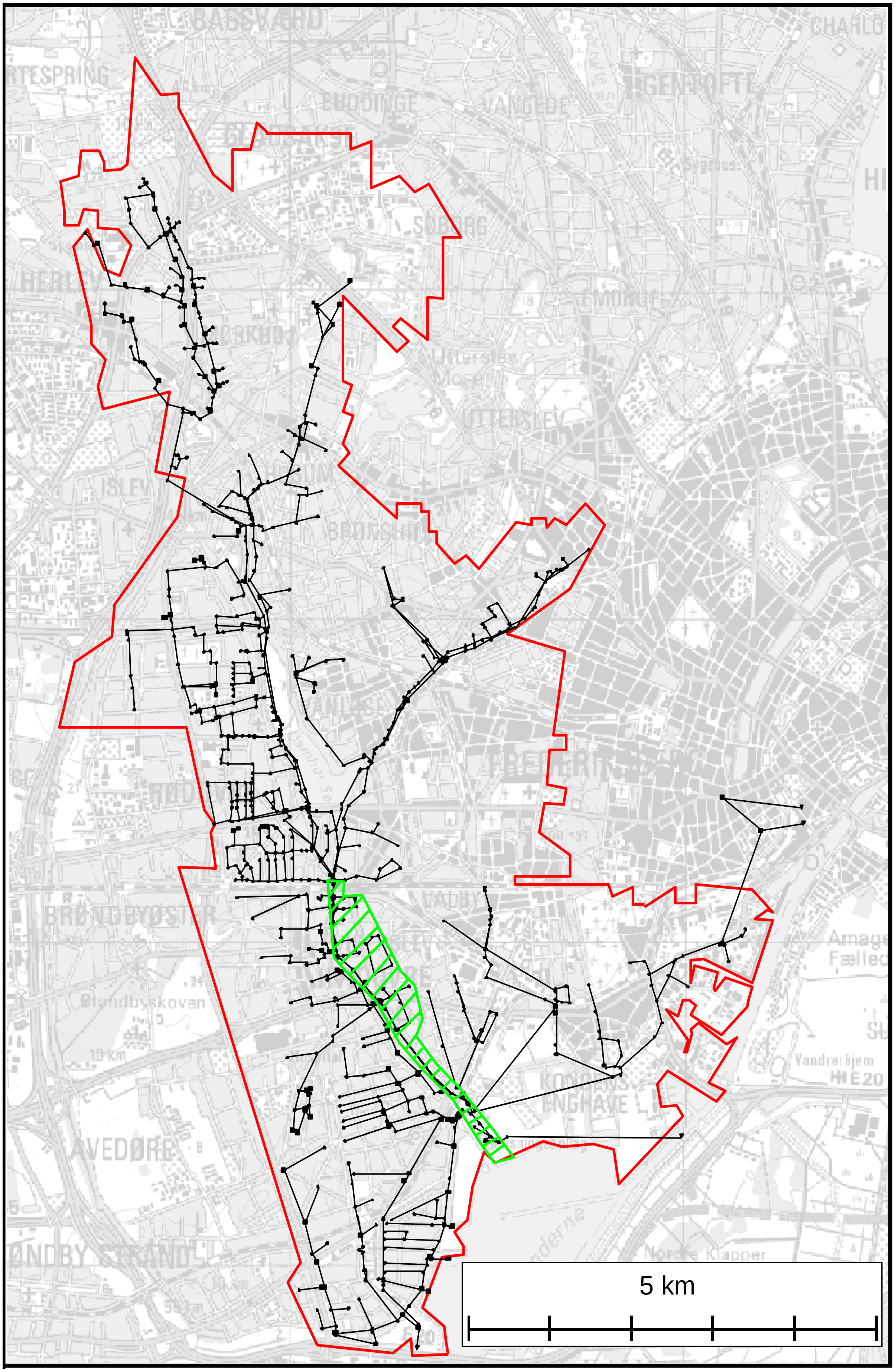
Introduction

The sewer mains from a large combined sewer catchment in the Greater Copenhagen region with 150.000 inhabitants lies with very low gradients (0,2 ‰) through park areas to the treatment plant. The sewer mains consist of 3-6 concrete pipes running in parallel. All the pipes have a diameter of 1,20 m. The flow in the sewer system is influenced by temporary high water levels as the downstream boundary condition. The last 3 km before the inlet to the treatment plant is influenced. This stretch has large problems with sedimentation in the pipes and requires much maintenance. The municipality has stressed the importance of improving the self-cleansing capabilities of the sewer system.

Inserting a wooden pig in the upstream manholes is the current solution to cleaning the pipes. The pig is shown in Figure 1. The pig moves through the sewer system by means of the water pressure built up behind it. This is a slow and complicated process, demanding much manpower. If the water level downstream could be kept at a low level continuously the velocity of the sewage in the pipes flow would be much higher leading to less sedimentation. This scenario would also enable installation of other maintenance systems. The scenario could be implemented by constructing a new pump shortly before the treatment plant in combination with a closure of the direct flow to the treatment plant. The major concern is the hydraulic performance during rain, where the direct flow pattern must be reinstalled by means of real time control to ensure that the maximum hydraulic performance of the sewer system is at least as good as under the present conditions.

Figure 1. Cleaning pig used for maintaining the parallel pipes.

The stretch also has a number of small structures with emissions to the receiving waters. They are outdated and reconstruction is in many cases needed to ensure better performance in terms of reducing emissions of pollutants. The study of the sewer system must also answer if it is possible to reduce the number of structures, i.e. to construct less and larger and more modern structures. The hydraulics of the runoff from the catchment is rather complicated with several pumps, basins, storage pipes and some real time control measures to minimize the combined sewer overflows to a small stream.


5 km
BAGSVÆRD
BUDDINGE
VANGEDE
GENTOFTE
HERLEV
ISLEV
Utterslev
Mose
UTTERSLEV
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Brøndbyskoven
AVEDØRE
KONGENS
ENGHAVE
Amager
Fælled
Vandrerhjem
Nordre Klapper

An important feature of this project is that the hydraulics of the sewer system is changed dramatically because the downstream boundary conditions currently give rise to high water levels in the sewer mains while the preferred future scenario completely remove this unwanted boundary condition. This implies that it is rather difficult to identify one particular design return period. Design storms such as CDS-storms are not considered to give an adequate computational accuracy because the water levels are in the level of surcharging, the catchment contain real time control measures and the spatial variation of rainfall over the catchment is significant. Therefore historical rain series are used. Ranking of the individual historical rain events change when the sewer system is changed and thus many events must be calculated to study the effects of both the current status and each possible scenario. MOUSE LTS has proved to be an important tool in performing this task.

The long term simulation module MOUSE LTS

The traditional approach is to compute and use results related to a specific (design) return period. Both hydraulic functioning and discharge of combined sewage to receiving waters is related to a prescribed return period. Traditionally the effect of the prescribed return period is calculated by selecting a suitable design storm. This imply, that the return period of that specific storm represent the return period of the effect in the sewer system both in the status and the future sewer system. For some time it has been known, that this is not the case. Indeed, in some instances a design storm with a prescribed return period may have effects in the sewer system that has a substantially different return period. In other words, it is more important to compute the return period for flooding of basements directly rather than considering how often rain events occur with certain characteristics that may or may not be relevant for the specific detrimental effect. For small and simple systems design storm are rather accurate, but for large catchments with complicated runoff schemes, volumes, real time control and complicated boundary conditions from outlets the difference between results obtained by means of design storms and historical rain series often differ quite substantially. This is the reason for the development of MOUSE LTS.

MOUSE LTS is an add-on module to MOUSE2000 and uses as rain input one or more long historical rain series with a known observation period. Output data is organized with respect to the computed return periods directly for each manhole. Examples of the output data are maximum discharge, maximum water level and volumes of combined sewer overflows. Figure 2 show examples of output from MOUSE LTS.

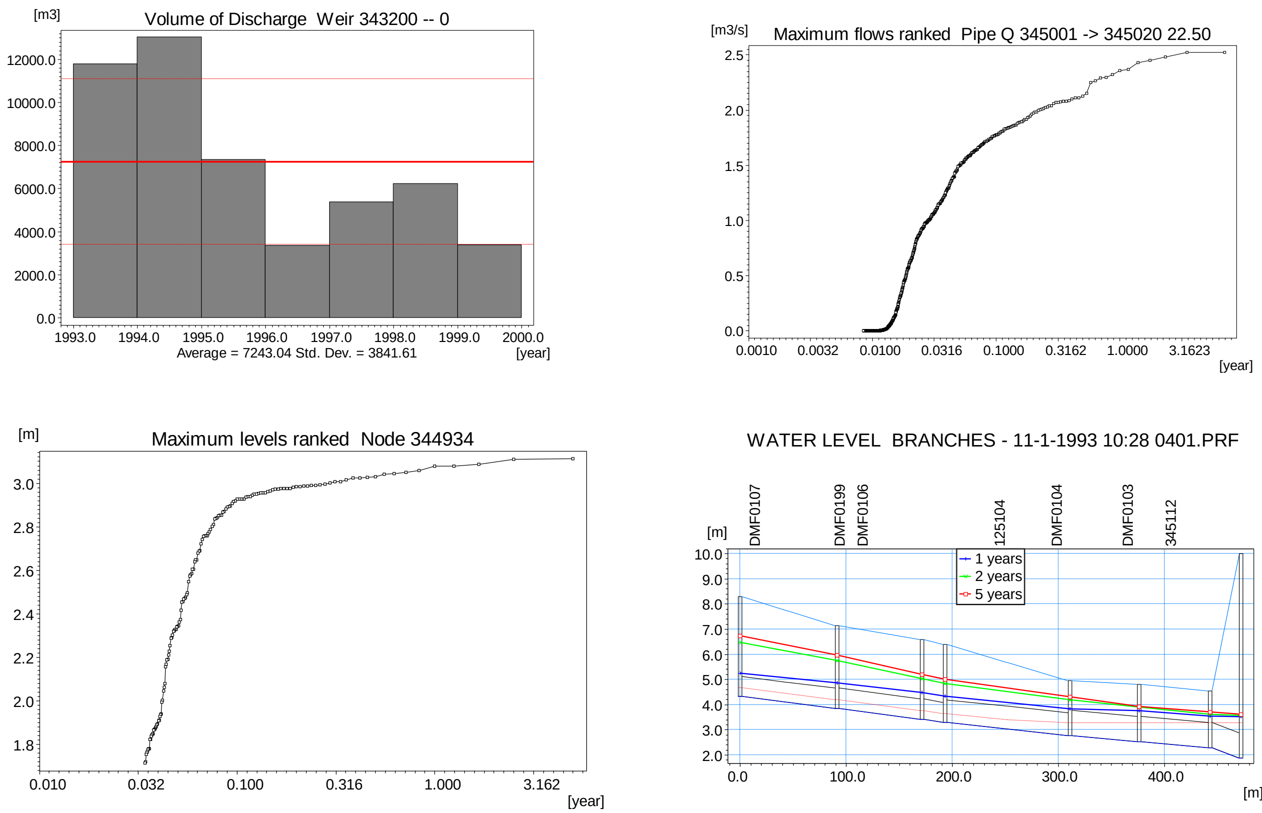

Figure 2. Examples of possible outputs from MOUSE LTS

Modeling the sewer mains of Greater Copenhagen

The add-on module MOUSE LTS is ideal to use in the study of the sewer mains of Greater Copenhagen. Thus such a model is constructed. The final model is rather large, with a total of 1200 nodes, 170 weirs, and 25 pumping stations. Further real time control of three gates is implemented in a large storage pipe to control the storage and thus reduce the discharges to the receiving waters. The model covers an area of 3700 ha. and the longest runoff stretch is 14 km.

The flow in the sewer mains studied varies between 0.1 and 5 m3/s. Historical rain series from five rain gauges is used in the calculations.

With the MOUSE 2000 release it became possible to include dry weather profiles. In a critical point an electromagnetic flow gauge has been installed for 10 years, enabling modeling of both a diurnal and annual variations in the dry weather flow. The infiltration is thus assumed to be constant within each month. The profiles are shown on Figure 3.

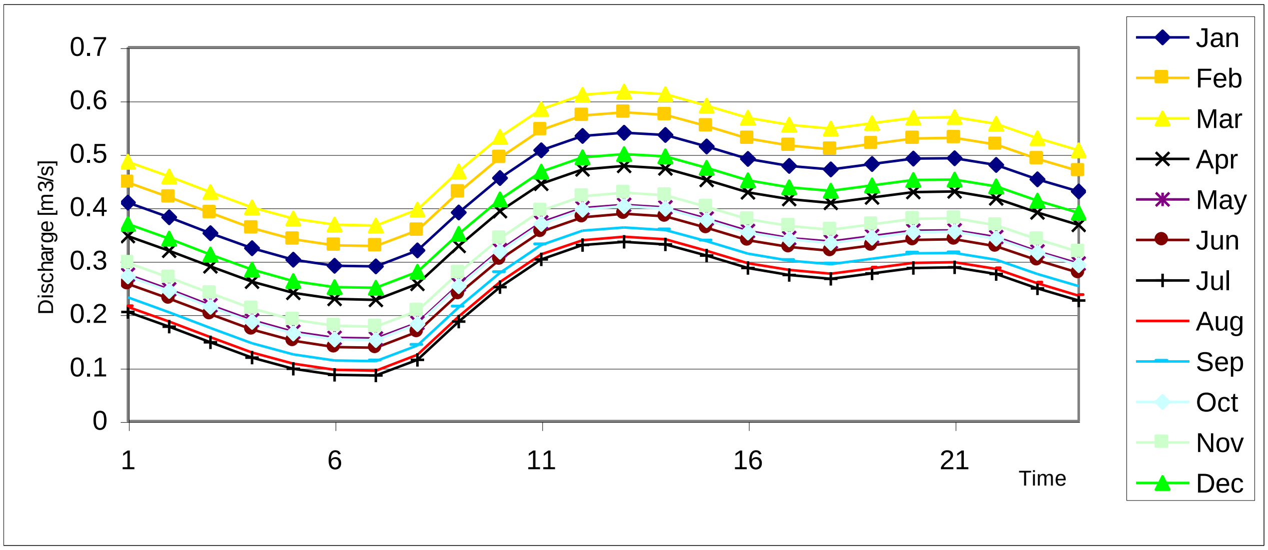

Figure 3. Plot of the diurnal and annual variation of the dry weather flow.

The MOUSE LTS module is used to make two computations:

- Computation based on the current situation
- Scenario with all the proposed structural changes.
  After some preliminary studies four weirs are closed, connections between the parallel pipes are established and the water level in the downstream boundary condition is lowered for flows less than 1.5 m^3/s.

Both calculations are based on five rain gauges. An observation period of seven years is used in the calculations out of the total observation period of 22 years.

Results

The computations enable comparisons between current and future water levels in critical manholes for a range of return periods, see Figure 4. From the Figure it may be concluded that the water level is somewhat higher for small return periods but smaller for return periods above 0.2 years. The water level in the critical situations is therefore lower in the future scenario. The calculated discharges from the current and future system are almost identical.

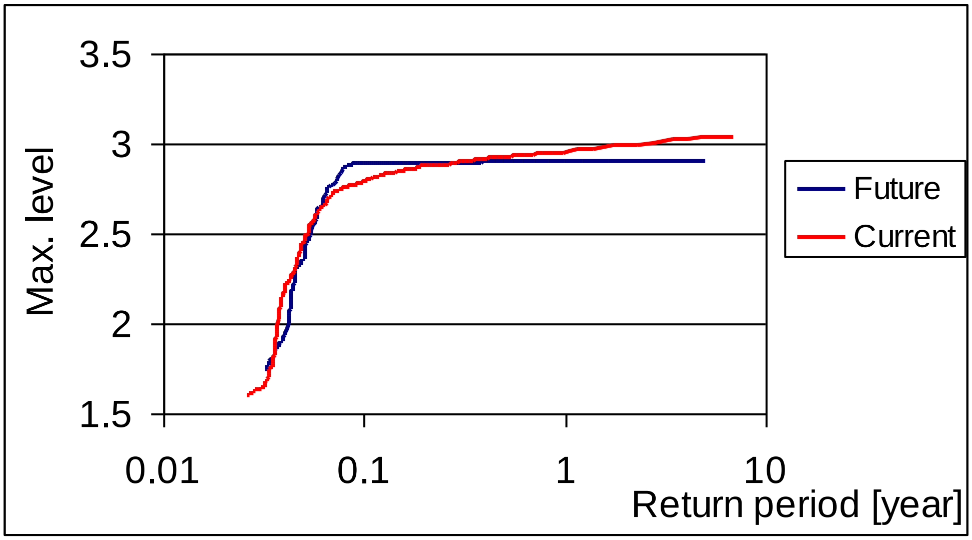

Figure 4. Water levels at manhole 344934 as a function of return period

Conclusions

In projects where it is necessary to use historical rain series MOUSE LTS is an important tool. The computations are heavy and time-consuming, but achieving the same kind of results without the new add-on module would be virtually impossible.

References

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