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Reconstruction of the complete sanitation network at Greater Paris scale

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Highlights

- The oriented graph of the Greater Paris whole sanitation system has been rebuilt automatically
- The tool produces data for hydro-microclimatic modelling with TEB-Hydro model
- The tool allows to analyse potential urbanisation impacts of complex sanitation systems

Introduction

The growing urbanisation of these last decades impacts the urban water cycle by limiting infiltration and evapotranspiration and increasing surface runoff (Fletcher et al, 2013). More intense and more frequent floods are observed in dense urban areas. This urbanisation is expected to still grow the next decades (United Nations, 2018).

The EU Water Framework Directive (2000/60/CE) leads the municipalities to limit combined sewer outflows to the natural hydrographic network. Municipalities seek to limit urban floods that can be responsible for casualties or at least damages to property. Sustainable Urban Drainage Systems (SUDS) are a solution by allowing the urban water cycle to move closer to a natural water cycle (Zölch et al., 2017) which implies to better take into account hydrological processes (*i.e.* soil-water interactions). Furthermore, many SUDS may improve not only the water management but also the thermal comfort (evapotranspiration, shading) (Livesley et al., 2016; Gunawardena et al., 2017). Numerous hydrological models are able to represent different SUDS impacts on the hydrological functioning of urban catchments (Rodriguez et al, 2005; Rossman and Huber, 2016; Locatelli et al, 2017) but very few resolve with a same detail level both water and energy budgets, even more at the city scale. Stavropoulos et al. (2018) have then developed a urban hydro-microclimate model (TEB-Hydro) able to evaluate, for both water management and thermal comfort issues, climate change adaptation strategies. The model runs at spatial scales ranging from the neighbourhood to the city. TEB-Hydro has been evaluated on two urban catchments (respective areas of 5ha and 30ha) in Northwestern France. For larger catchments, the water transfer in the sanitation network, or in the river network has to be taken into account. Unfortunately, the sanitation network is rarely available in urban data banks as an oriented graph.

This study, financed by PIREN-Seine program (2015-2019), aims at the definition of a hydrological modelling framework with TEB-Hydro for Greater Paris territory (Paris City and the surrounding departments) by the reconstruction of the whole hydrographic network.

Methodology

The tool for the reconstruction of a complete and simplified hydrographic network : TOHR

TOHR (TOol for the Hydrographic network Reconstruction) has been developed to provide to TEB-Hydro model the outlets for each mesh of the grid with the distance to each outlet and the distance between 2 outlets. Combined and separate systems are taken into account and possibly connected to each other and to the rivers, by combined sewer overflows. TOHR is based on the same regular mesh grid as TEB-Hydro, allowing the simplification of the network. The network reconstruction is made up 4 stages. First, the network

nodes are selected among the manholes from the combined network. The one with the smaller altitude is selected for each grid mesh. For the meshes where no combined manhole exists, the same process is performed for the stormwater system and the waste water system. Second, the lifting stations and the CSOs (hereafter named specific devices) are connected to the node belonging to the same grid mesh. Third, the edges of the oriented graph are oriented lines that connect two nodes, with the larger slope. The connection is possible between two nodes from a combined system, from a combined system and a wastewater network and vice-versa. The slope has to be positive (except for the lifting stations) and the edge length cannot exceed 3 times the grid resolution. Each node can have several upstream connections but only one downstream connection. Waste water and combined nodes are connected simultaneously with the main objective to get closer to the treatment plant. The specific devices that do not enable a connection are removed. Stormwater nodes are connected, with a same process, in order to reach the closer river. The last step is the projection of the graph to the grid. If a mesh has no combined or stormwater node, the D8 algorithm is applied, to connect it to another mesh. Once the outlets have been chosen by the user, they are associated to each grid mesh and the distance to each of them as well.

The study case: Paris and its suburb

The studied area (more than 700 km²) covers the city of Paris, the Hauts-de-Seine, the Seine-Saint-Denis and the Val de Marne departments (Figure 1). The climate is continental, with a light oceanic influence. The climatic mean maximal temperature (1981-2010) is between 7°C and 25°C (Météo-France website). The climatic total rainfalls are more than 630 mm, almost equally distributed all over the year.

These four departments share a same sanitation system that transfers storm and waste waters to different sewage treatment plants localised upstream and downstream the Seine river and downstream the Marne river. SIAAP (Greater Paris sanitation authority) manages this interdepartmental sanitation system, that extends beyond to the departments for a few municipalities. Thus, this administrative organisation of the sanitation system makes difficult to study only one part of this territory. The waste and storm waters collect is made locally by a sanitation network managed by the municipalities, while the departmental sanitation network transfers from the municipal network to the interdepartmental network. Due to the large number of stakeholders and the density of each network, it has been decided to rebuild the network only from the 4 departments and the SIAAP databases. Given the role of each network manager, it has been decided to rebuild first the interdepartmental network and secondly, each department network connected to the reconstructed interdepartmental network. Thus, the interdepartmental network cannot flow to the department network.

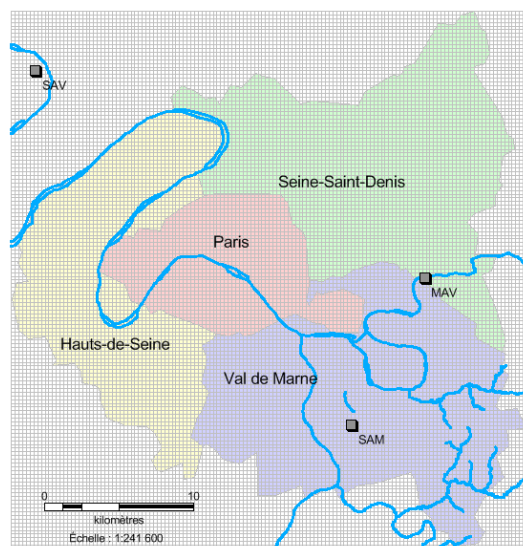


Figure 1 Greater Paris study area with the four departments (colored), the river network (blue), the treatment plants (grey squares) and the TEB-Hydro grid (grey).

Results and discussion

Once the functioning of the sanitation system at the different scales has been understood, thanks to meetings with operational manager teams, the reading of annual operational reports and the data GIS pre-treatment, TOHR has been run on the study area. The rebuilt hydrographic network is drawn on Figure 2. The visual

comparison with the real network is globally satisfying (not shown here). Except for the Seine-Saint-Denis department because of a not complete river network (Canal de l'Ourcq). As a result, some north to south stormwater connections (western part of the department) should be east to west connections. In Paris area, the northwestern part is not well reconstructed. The comparison of the reconstructed and real drained areas highlights some strong differences. Nevertheless, the main flows directions to the different treatment plants and the rivers are well reproduced. In addition to allow the simulation of water flows in urban environment, the rebuilt network helps to analyse the impacts of urbanisation on receiving environment. For example, the drained areas of the stormwater outlets will be presented.

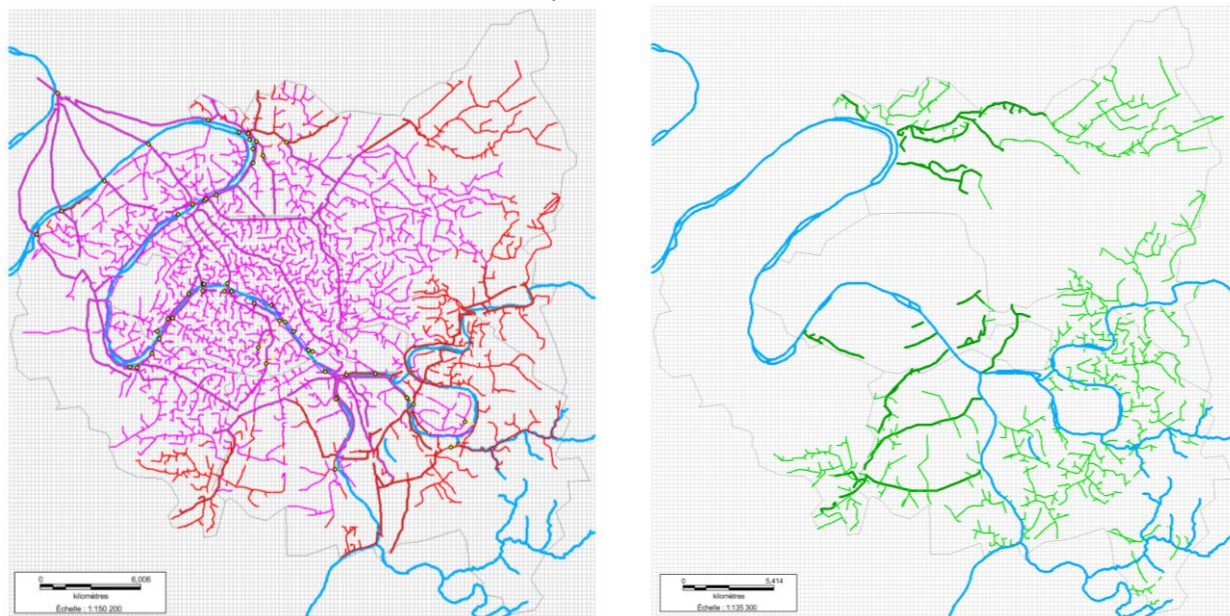


Figure 2 Rebuilt combined (pink) and waste water (red) networks (left) and stormwater (green) network (right) of Greater Paris. The interdepartmental network is larger, the CSO are in yellow and the river network in blue. TEB-Hydro grid and the departments limits are in grey.

Conclusions and future work

The whole sanitation network connected to the natural hydrographic network has been reconstructed at Greater Paris scale. The evaluation from different approaches shows good skills for the tool. Such reconstruction allows a global and synthetic view of the functioning of the sanitary system but also it highlights the potential urbanisation impacts on receiving environment. The use of the produced data for hydrological modelling is presented in a second paper. The method will be applied in other cities.

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