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Research Paper

A distributed modelling approach to assess the use of Blue and Green Infrastructures to fulfil stormwater management requirements

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ABSTRACT

Blue and Green Infrastructures (B&GI) are nature-based solutions considered as particularly efficient to reduce the potential impact of new and existing developments with respect to stormwater issues. In order to assess their performance at some large scales compatible with urban projects, adapted distributed rainfall-runoff models are required. The latest advancements of the Multi-Hydro platform have made possible the representation of such B&GI. Applied in a virtual new urban development project located in the Paris region, Multi-Hydro has been used to simulate the impact of B&GI implementation, and their ability to fulfil regulation rules authorizing the connexion to the sewer network. The results show that a combination of several B&GI, if they are widely implemented, could represent an efficient tool to meet regulations at the parcel scale, as they can reduce runoff volume about 90%.

1. Introduction

Blue and Green Infrastructures (B&GI), including green roof, bioretention swale, porous pavement, harvesting tank, soakaway or pond for instance, can provide multiple benefits to urban areas affected by both climate change and urbanization effects: urban heat island reduction, biodiversity conservation, reduced buildings energy requirements,… Last but not least, they appear to be particularly efficient in stormwater management (Liao, Deng, & Tan, 2017). By detention, infiltration and evapotranspiration processes, they can be used to control urban runoff at the local scale.

The hydrological performance and benefit of B&GI have been shown in numerous studies conducted at small scales: Kamali, Delkash, and Tajrishy (2017) for porous pavement, Chapman and Horner (2010) for bioretention system, or Stovin, Vesuviano, and Kasmin (2012) for green roofs. Nevertheless, their performance and interaction at higher scales (urban project) are still uncertain and insufficiently quantified. Modelling tools are required to consider B&GI configuration and optimize their performance, as most of the existing models are focused on one or very few assets such as green roofs (Versini, Jouve, Ramier, Berthier, & de Gouvello, 2015). Few of them are technically able to combine dynamically several infrastructures, but usually in a semi-distributed approach that mixes different types of landcover (road, house, grass, park…), and implies some huge difficulties to adjust *a priori* the parameters without observed data. It is the case of the Storm Water Management Model, as shown in Lucas and Sample (2015) or Palla and Gnecco (2015) among others. To properly assess B&GI performance on a large set of spatial scales, a hydrologic model characterized by a high spatial resolution is also required. Such a structure is necessary to consider heterogeneous surfaces, and the associated dynamics due to the layout of impervious and pervious areas.

Based on these considerations, the main objective of this research note is to assess the performance of B&GI in stormwater management at the urban project scale. A distributed modelling approach has been chosen to especially study the respective performance of a B&GI set, and their evolution regarding storm event return periods.

2. Presentation of the case study: the “Echangeur” project

The virtual urban project called “Echangeur” has been designed by a group of students during a specialized master training devoted to the “Ecodesign of Sustainable Cities”. Supported by the Academic Chair on the Eco-design of building sets and infrastructure established by ParisTech and the Vinci group (see Kotelnikova, De Bartoli, Féraille, & Leurent, 2016 for a detailed presentation), the main activity of this course is to design a sustainable neighborhood materialized by a layout plan. Located in the eastern suburbs of Greater Paris (Champs-sur-Marne, France) and covering an area of 10.66 ha, the plan proposed by the students for the Echangeur project (Fig. 1) hosts accommodation for 5900 inhabitants and activities with the creation of 1150 jobs. This plan

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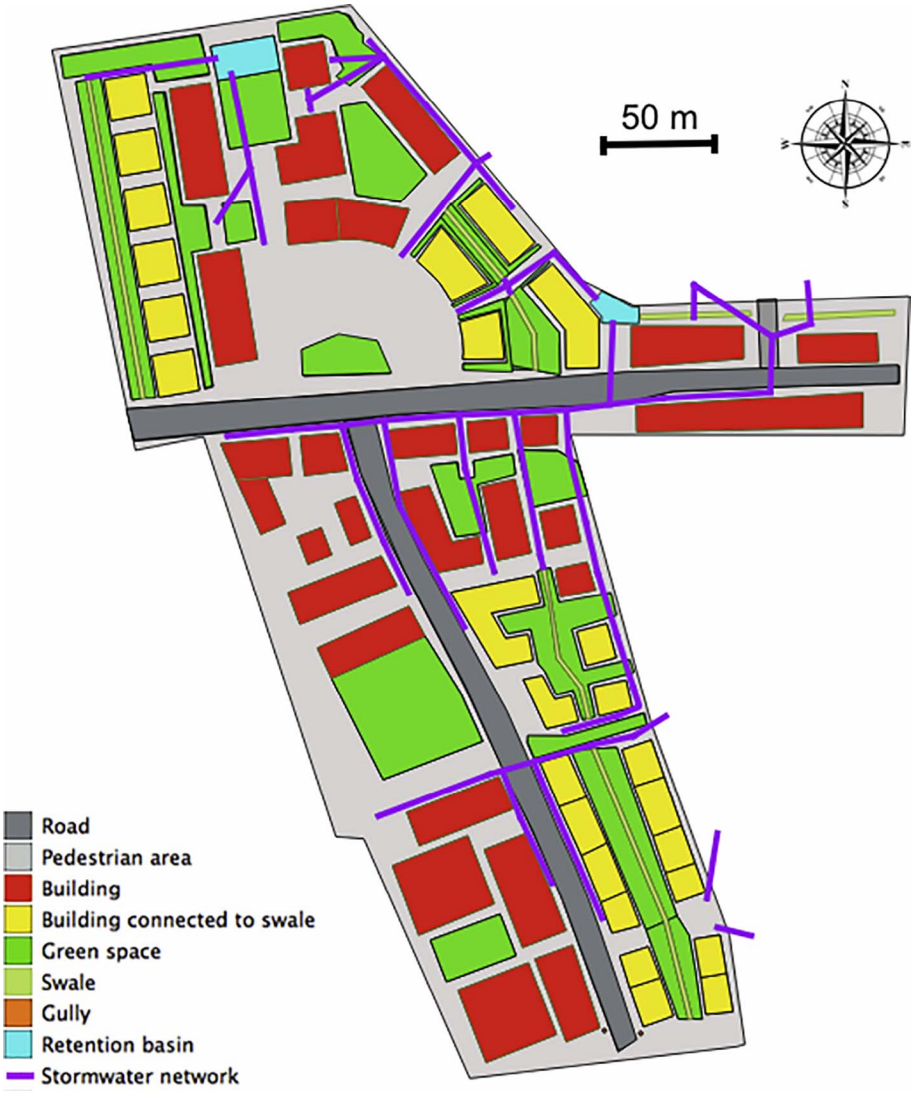

Fig. 1. Layout of the Echangeur catchment differentiating the different land use classes.

must also fulfill stormwater management requirements concerning the connection to the stormwater network. Here the discharge at the parcel outlet has to be lower than a reference threshold of 10 l/s/ha for a rainy event characterized by a 20-years return period. In the Paris region, this corresponds to a 30-minute rainfall event characterized by a 58 mm/h intensity.

Due to a lack of space, the construction of a large storage unit has not been considered. Several Blue and Green Infrastructures have been planned to fulfil this stormwater regulation rule: (i) Green spaces (grass, forest and vegetable gardens), (ii) green roofs, (iii) green swales (swaled drainage course with sloped sides and filled with vegetation and riprap), (iv) small retention basins, (v) porous pavement.

3. Materials and method

3.1. The Multi-Hydro model

The Multi-Hydro distributed rainfall-runoff model represents a well-adapted tool to assess hydrological impacts at the urban scale (Giangola-Murzyn, 2014; Ichiba et al., 2017). For each time step, Multi-Hydro provides overland water depth (flooding) and infiltration maps, but also discharge values for each pipe and junction of the stormwater network. Multi-Hydro is currently being developed at the Ecole des Ponts ParisTech, https://hmco.enpc.fr/portfolio-archive/multi-hydro/ to take into account the wide complexity of urban environments. The latest advancements have made possible the representation of several "resilience infrastructures" such as basins, barriers, and green roof (see Versini, Gires, Tchiguirinskaia, & Schertzer, 2016 for details). Based on these previous works, Multi-Hydro has been adapted to reproduce the hydrological behaviour of the mentioned B&GI planned in the Echangeur project.

Multi-Hydro has been implemented on this case study to simulate its hydrological response with a resolution of 5 m in space and 5 min in time. Based on the layout plan, the input data required by the model (map of topography, landuse and stormwater network) were produced by using adapted GIS tools.

3.2. Land use scenarios

In order to study the relative contribution of each implemented B&GI, different land use scenarios have been established: (0) there is no blue or green infrastructure, but only impervious surfaces such as roads, buildings and pavements, (1) Green spaces are implemented, (2) Every building roof is covered with an extensive green roof, (3) Green swales are implemented, (4) Impervious pavements are replaced with porous ones on the pedestrian area, (5) Most of the stormwater network outfalls are connected to two small retention basins, (6) All of the B&GI mentioned above are implemented.