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Methodology for a stormwater sensitive urban watershed design

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SUMMARY

In urban stormwater management, decentralized systems are nowadays worldwide experimented, including stormwater best management practices. However, a watershed-scale approach, relevant for urban hydrology, is almost always neglected when designing a stormwater management plan with best management practices. As a consequence, urban designers fail to convince public authorities of the actual hydrologic effectiveness of such an approach to urban watershed stormwater management. In this paper, we develop a design oriented methodology for studying the morphology of an urban watershed in terms of sustainable stormwater management. The methodology is a five-step method, firstly based on the cartographic analysis of many stormwater relevant indicators regarding the landscape, the urban fabric and the governance. The second step focuses on the identification of many territorial stakes and their corresponding strategies of a decentralized stormwater management. Based on the indicators, the stakes and the strategies, the third step defines many spatial typologies regarding the roadway system and the urban fabric system. The fourth step determines many stormwater management scenarios to be applied to both spatial typologies systems. The fifth step is the design of decentralized stormwater management projects integrating BMPs into each spatial typology. The methodology aims to advise urban designers and engineering offices in the right location and selection of BMPs without given them a hypothetical unique solution. Since every location and every watershed is different due to local guidelines and stakeholders, this paper provide a methodology for a stormwater sensitive urban watershed design that could be reproduced everywhere. As an example, the methodology is applied as a case study to an urban watershed in Belgium, confirming that the method is applicable to any urban watershed. This paper should be helpful for engineering and design offices in urban hydrology to define a sustainable and decentralized stormwater management plan and redaction of performance standards at the watershed scale. The method applied in this paper toggles the decentralized stormwater approach from a common experimental point of view to an oriented problem–solution point of view.

1. Introduction

In the Brussels-Capital Region in Belgium, as in many other European regions, the wide urbanization engaged in the twentieth century (Vanhuysse et al., 2006), is partly responsible for tremendous environmental damages due to soil sealing, such as the reduction of the urban biodiversity, the urban island effect or soil deterioration. Among these impacts, urbanization reduces the amount of undeveloped and natural lands and thus reduces the ability of urban areas to mitigate floods. Floods occur more frequently years after years leading to huge social and economic damages. Urban development combined with a changing climate may also cause alterations in the hydrologic regime resulting in more frequent extreme events, increasing peakflows, lowering baseflows and increasing stream erosion (Roesner et al., 2001). Although that the management of urban drainage is a critically important challenge for the future (Chocat et al., 2001), major traditional public works, such as combined sewer and stormwater reservoirs, have proven their limits to mitigate these increasing risks.

Since a few decades a new paradigm in urban stormwater management has emerged, shifting from a centralized and narrowly-oriented approach to a decentralized and multi-purposes approach (Marsalek and Chocat, 2002) fostering a sustainable design and decision process in stormwater management. While urban drainage was previously seen as a problem for which urban designers only planned to reduce rapidly run-off, the opportunities it presents are nowadays widely recognised (increased biodiversity, improved microclimate, etc.) (Ashley et al., 2013). A decentralized approach is highlighted by the incorporation of on-site low impact development techniques (LID) and best management practices (BMP). LID is intended to restore the natural conditions or to attenuate the impact of urban development and to maximize on-site stormwater control. As parts of LID, BMPs

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are small scale decentralised 'green techniques' used to prevent, control and treat stormwater. The objective of these stormwater management facilities at the scale of urban parcels or housing estates, such as swales, storage ponds, porous pavements or green roofs (Azzout et al., 1994), is to mimic to some extend the behaviour of the catchment before urbanization. Many guidelines and tools are nowadays available for the selection of stormwater best management practices. Selecting the appropriate BMPs for a development requires a fine appreciation of many decisive criteria. BMPs may be selected according to a wide range of criteria regarding the land use characteristics (Boucher, 2010; CIRIA, 2007; GVRD, 2012; LMCU, 2012; MDDEP, 2012; MEA, 1999; NCDWQ, 2007; Rodriguez et al., 2014; Romnée, 2015), the site characteristics (CIRIA, 2007; Marti et al., 2011; MDDEP, 2012; MSSC, 2008; NCDWQ, 2007), the catchment characteristics (CIRIA, 2007; MSSC, 2008; NYS, 2010), the quantity and quality performance requirements (CIRIA, 2007; MEA, 1999; LMCU, 2012; Marti et al., 2011; MSSC, 2008; NCDWQ, 2007; NYS, 2010; Rivard, 2005; UDFCD, 2010) and the amenity, environmental, community and participation requirements (CIRIA, 2007; Marti et al., 2011; MSSC, 2008; NCDWQ, 2007; NYS, 2010). All these local guidelines for the selection of BMPs perform mainly at the site scale without considerations and interactions with the watershed scale.

Cities have widely forgotten the natural geography on which they are built and stormwater drainage plans are mainly determined by local scale conditions. However, in this geographical territory, the water does not care about the parcel division of the city and still flows from upstream to downstream and accumulates at the outlet leading to some floods (Rivard, 2005). The concept of watershed indicates a specific relation between the natural geographical substrate, the water, the built environment and the population. The watershed is therefore considered as the territorial unit of reference for urban hydrology (Musy and Higy, 2009). A watershed-scale approach, relevant for urban hydrology, is almost always neglected when designing a stormwater management plan with best management practices (Roy et al., 2008). As a consequence, urban designers fail to convince public authorities of the actual hydrologic effectiveness of such an approach to urban watershed stormwater management. This consequence is reinforced by the fact that until now, this decentralized approach is mainly considered by architects and local authorities only for their environmental opportunities and almost never thought and designed as a problem/solution-oriented urban drainage system.

Acknowledging that every location and every watershed is different due to local guidelines and stakeholders, it is important to provide urban designers and stakeholders a methodology for a stormwater sensitive urban watershed design that could be reproduced everywhere. This methodology emphasises the distribution of best management practices as effective stormwater management facilities throughout the urban watershed. In this article, we provide such a methodology developed in five steps. The methodology is then applied to an urban watershed located in the Brussels Region, in Belgium.

The methodology developed and experimented in this paper should sustain the redaction of performance standards allowing urban designers and engineer consultants to adequately select stormwater management techniques, especially in Belgium where these standards are recognised as a critical impediment to BMPs.

2. Methodology for a stormwater sensitive urban watershed design

The watershed is the spatial unit of reference for hydrology. It is defined as the territorial extent drained by a river and bounded by a watershed line. An urban watershed is a landscape shaped by water, which was urbanized by urban fabrics according to territorial development agreements granted by the society. The urban watershed, considered as a territorial unit, therefore puts three items together and it cannot be considered without the interaction of these elements: the landscape, the urban fabric and the territorial development agreements (conventions) (see Fig. 1).

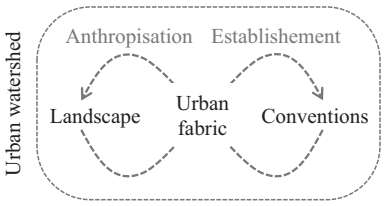

Fig. 1. Definition of an urban watershed – an urban watershed is a landscape shaped by water, which was urbanized by urban fabrics according to planning rules of the territorial development granted by the society.

The landscape consists of the physical substrate and geomorphology, as well as natural spaces prior to human action on the territories. It is the set of physical characteristics always already present, constraining and allowing the establishment of the human. The urban fabric is the common denominator between the public space, the collective space and the private parcels of land. The urban fabric is made by the system of blocks and parcels, the system of roads and nodes and the buildings system (Allain, 2004; Borie and Denieul, 1984; Merlin and Choay, 1988; Panerai et al., 1999). The conventions are the set of rules and mechanisms, recognised by the society, enabling the landscape to be anthropized for the establishment of the human society. This is the set of processes and territorial development rules of the urban fabric of the watershed.

In order to reduce stormwater floods risks and to sustain a sustainable stormwater management in an urban watershed, the configuration of the watershed has to be studied and adapted. Indeed, the storm effects on the urban area depend on the morphology of the watershed and on human activities within the watershed. Here, a five-step methodology, summarised in Fig. 2, highlights a process to study the morphology of an urban watershed focusing on a stormwater sensitive design. The first three steps, namely the analysis of stormwater management indicators, the identification of territorial stakes and strategies and the definition of spatial typologies, realise the morphological study of an urban watershed in terms of sustainable stormwater management. The last two steps, namely the proposition of scenarios of decentralized management and the design of decentralized management projects, realise a desirable and effective evolution of the urban watershed exploiting existing and future potential. This five-step method was applied to the Molenbeek watershed located in the Brussels-Capital region in Belgium. The Molenbeek watershed has an area of 13.5 km^2 and covers 8% of the the Brussels region.

2.1. Indicators analysis

The research of decentralized solutions for the stormwater management in an urban watershed requires a fine analysis of the three components: the landscape, the urban fabric and the conventions (urban planning regulations). The analysis is based on the identification and valuation of many indicators representative of the landscape, the urban fabric and the convention, and relevant for the stormwater management. By relevant, the author means the indicator is an element that should be took into consideration when designing an urban stormwater management project. The indicators highlight some physical components of the urban watershed promoting the design of a decentralized management of stormwater. Others indicators, such as historic, sociocultural or