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A new tool for quantifying the impacts of water sensitive urban design – the power of simplicity

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Abstract
We present a prototype for a new software tool which enables quantification of impacts of water sensitive urban design (WSUD) plans in a simplifying manner. The tool is designed to fill a gap between the needs of utility companies for assessing WSUD performance and available urban drainage simulation tools. Emphasis is put on reducing complexity in order to help drainage engineers communicate their priorities to other stakeholders. The tool outputs include two key indicators: The first is the amount of runoff held back in stormwater control measures on event basis, presented graphically against three distinct decision domains. The second is the percentage of runoff managed locally on an annual basis, presented graphically as a water budget. The tool concept was tested on several smaller case studies in Denmark, and we plan to have it ready for full-scale testing ultimo 2015.

Keywords
Water sensitive urban design, low impact development, sustainable urban drainage systems, planning, communication

BACKGROUND AND RELEVANCE

Water Sensitive Urban Design (WSUD) is an approach to urban stormwater management which takes into consideration a wider part of the urban water cycle, including e.g. harvesting of rainwater, evapotranspiration and groundwater recharge (Fletcher et al., 2014). Examples of stormwater control measures that embody the concept are green roofs, bioretention units and wet ponds. Planning for such measures requires a significantly higher degree of collaboration between drainage engineers and other stakeholders compared with underground drainage systems.

Tools developed to inform decisions regarding traditional drainage systems are not readily adaptable to consider WSUD; new tools are needed which encompass the wider range of potential impacts and facilitate interaction with non-water professionals, as e.g. discussed in Lerer et al. (2015). We developed a new tool to specifically address the needs of Danish utility companies in the early planning and design phase of WSUD for retrofitting in urban areas. The existing drainage system in these cases would often be combined sewers, and the drive for retrofitting would often be to reduce the frequency of combined sewer overflows and flooding, combined with an ambition to add value in terms of sustainability and liveability through multifunctional stormwater control measures.

RESULTS AND DISCUSSION

The tool concept is illustrated using a small example. Figure 1 below shows a residential area in central Copenhagen with a high degree of impermeable surfaces. In order to reduce the risk of surcharge from the combined sewers under intensive rain, the inhabitants are interested in managing stormwater using WSUD. Due to low hydraulic conductivity of the soil and a high groundwater table, infiltration to the groundwater is not desired; hence a system of lined bioretention units with drainage to the nearby lake is suggested for treating the road runoff, while the roof runoff is considered clean enough to be transported directly to the lake. Respecting the space requirements for parking and passage of large vehicles, a number of feasible bioretention units were sketched up, yielding a cumulative area of approx. 50 m2.

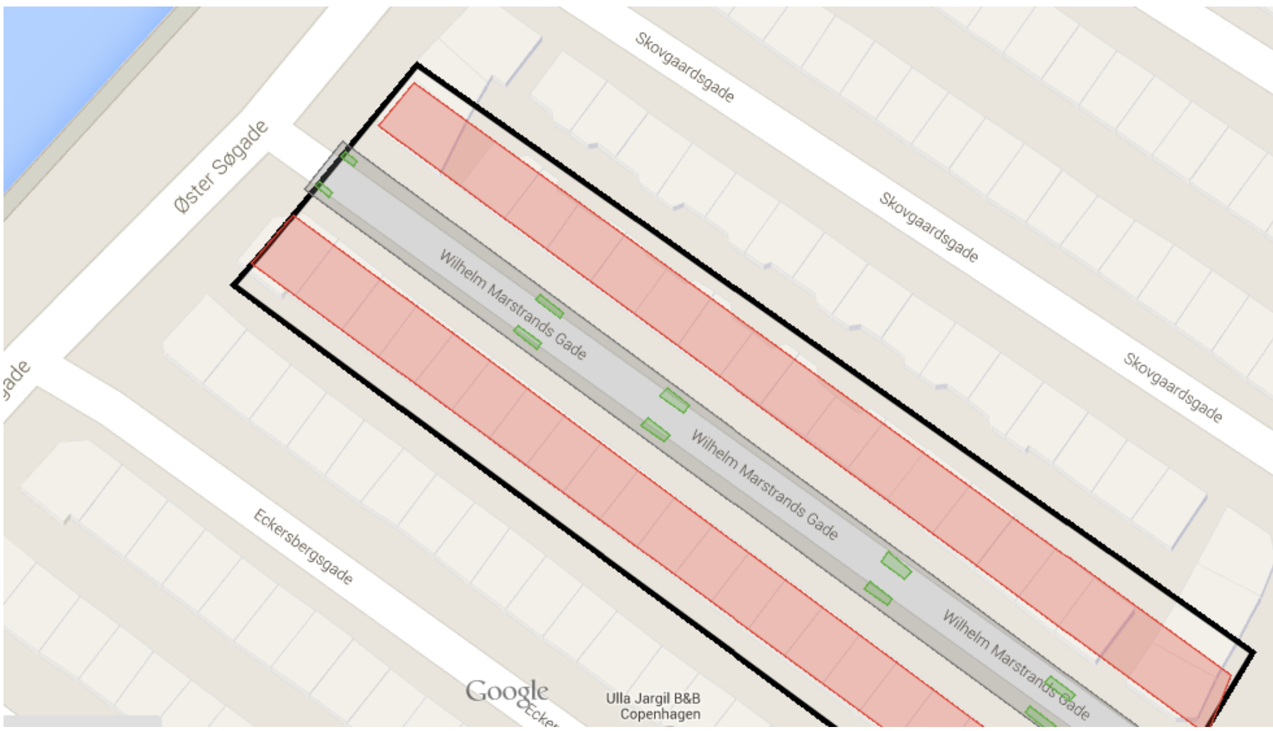

Figure 1: A WSUD plan for Wilhelm Marstrands Gade in Copenhagen, drawn in Google Maps. The black polygon represents the total catchment area, the red polygons are roof areas, the light grey polygon is the road area and the green polygons are bioretention units.

Assuming typical design values for bioretention units, their capacity was estimated to equate approx. 15 mm of rain on the road surface. The significance of this result is illustrated graphically by comparing with predefined rainfall domains, see Figure 2. These domains are based on the Three Points Approach (3PA), which has been shown to improve communication regarding the ability of different drainage solutions to meet expectations (Fratini et al., 2012). We adapted the original approach to a quantitative context by choosing a specific return period to define each domain, and associating a typical rainfall depth to each domain (based on statistical analysis of long term rainfall records, see Sørup et al., in prep.).

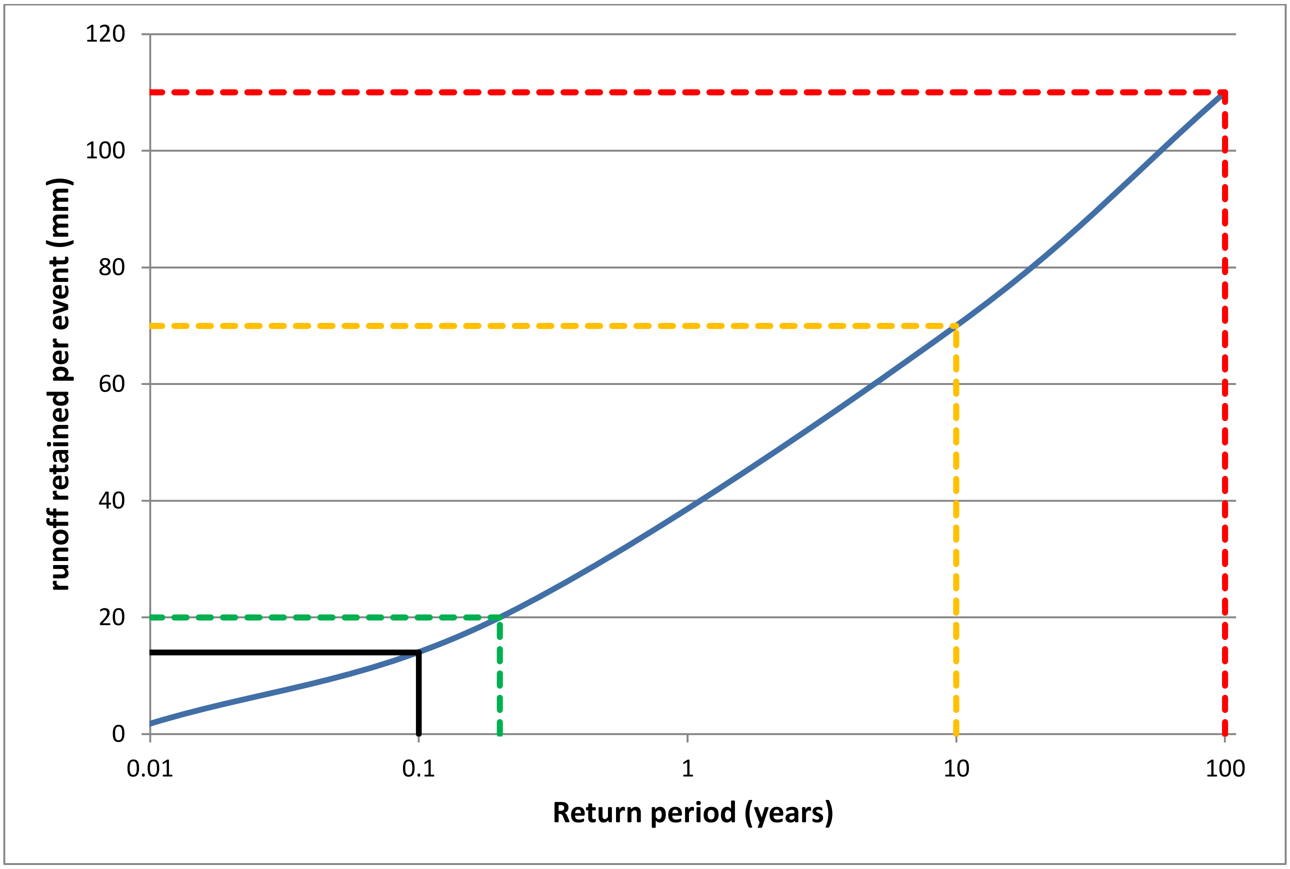

Figure 2: The amount of runoff managed in the bioretention units per event, expressed in mm of runoff from the supplying catchment (the road), and displayed against characteristic rainfall events for the domains of the 3PA: everyday domain (dashed green line), design domain (dashed yellow line) and extreme domain (dashed red line).

On this background 15 mm do not seem significant, which suggests that this design does not offer sufficient protection from flooding on its own, and should be supplemented with some measure to transport excess water away. However, 15 mm of rain corresponds to a return period of approx. 0.1 years, and as can be seen from Figure 3, this means that the cumulative volume of rainfall events of this magnitude or smaller represents almost 75% of the annual rainfall. In other words, a substantial fraction of the annual runoff from the road will be filtered and attenuated in the bioretention units. This key result is illustrated as a water budget, see Figure 4.

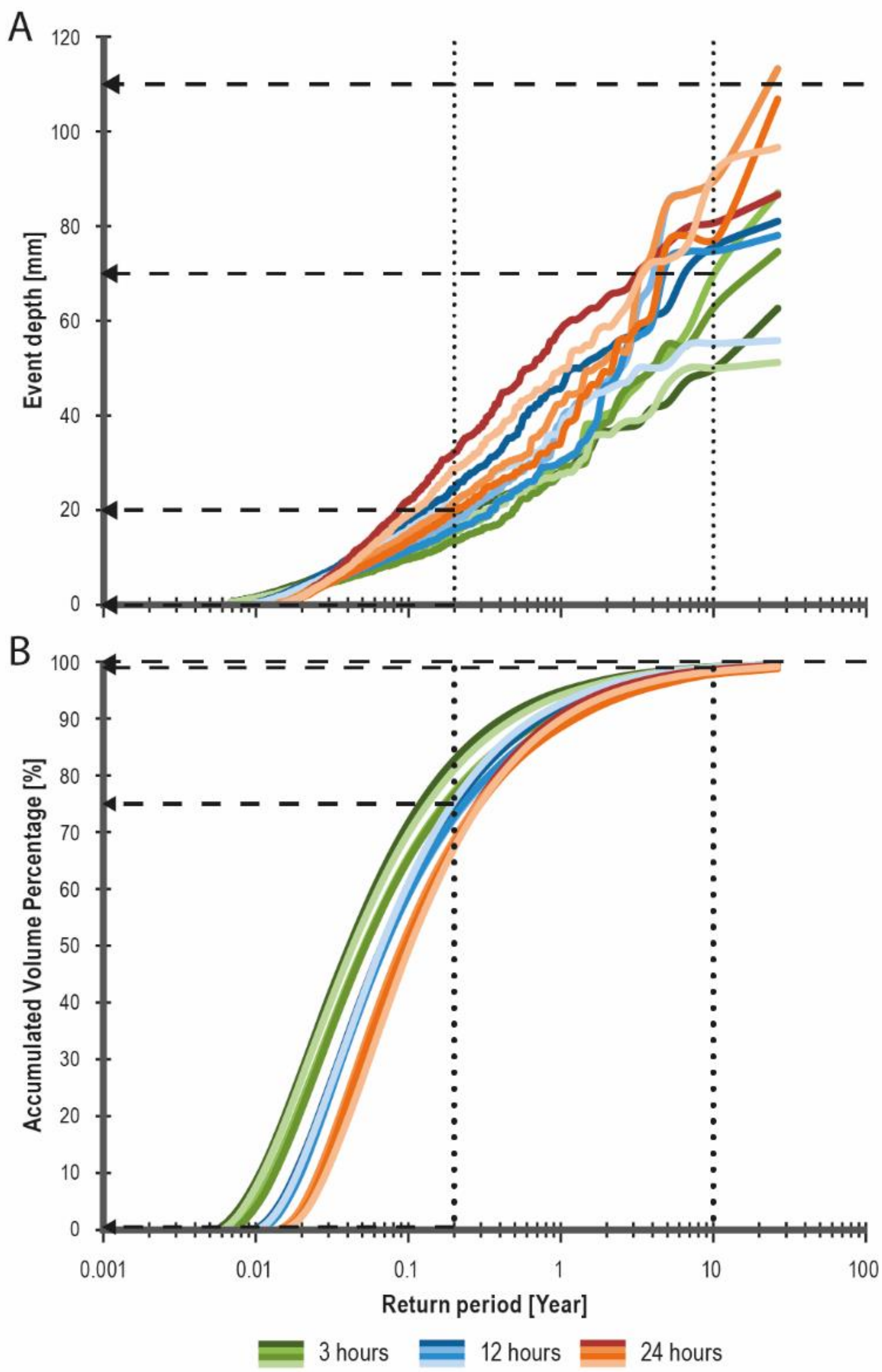

Figure 3: Usage of precipitation data to quantify the 3PA. Three different event definitions were included (3, 12 and 24 hour extremes), each calculated for four different rainfall series (from different parts of Denmark), resulting in 12 curves in total. The dotted vertical lines at return periods of 0.2 years and 10 years represent Point A and B of the 3PA. A: Event depths ranked according to return period and marking of which event depths that constitutes the different points in the 3PA. B: Volumetric percentages of total rainfall that falls within the domains of the 3PA.

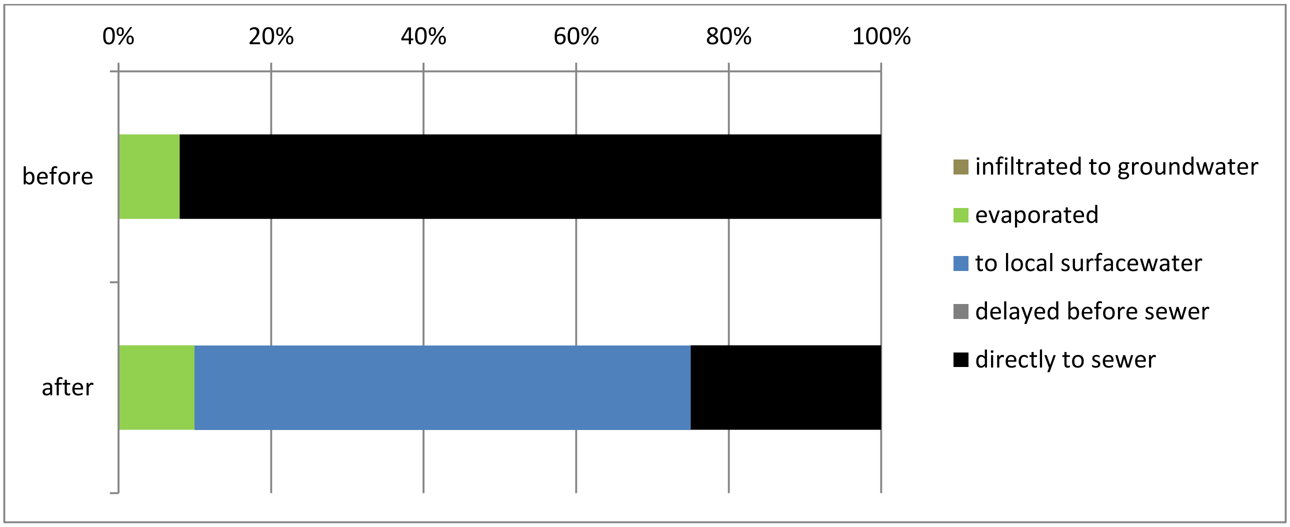

Figure 4: Annual water budget for the road surface before and after installation of bioretention units.

We have devised simple methods for assessing these two indicators for three types of stormwater control measures commonly used in WSUD planning including conversion of impermeable surfaces to permeable surfaces, bioretention units and detention units. We are investigating the feasibility of implementing them in a map-based online interactive tool that will allow easy access to a diversity of users. The results can be used to evaluate the potential a given urban area has for WSUD retrofitting; in promising cases, more accurate models should be used to refine the results.

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