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## Applying the “WSUD potential”-tool in the framework of the Copenhagen Climate Adaptation and Cloudburst Management Plans

Application d'un outil "Potentiel des Techniques Alternatives" dans le cadre du plan d'adaptation climatique et de gestion des évènements pluvieux intenses de Copenhague

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### RÉSUMÉ

Les aménagements urbains alternatifs pour la gestion de l'eau (Water Sensitive Urban Design, WSUD) sont toujours dans la phase « opportunité » du processus de stabilisation en cours à Copenhague, Danemark. Ceci indique que des controverses existent encore autour de leur mise en œuvre et que le cadre législatif et réglementaire existant n'est pas complètement adapté à ces nouvelles technologies. En 2015, au Danemark, les propriétaires fonciers privés ont pu obtenir un financement pour mettre en place des mesures d'adaptation climatique, de la part des sociétés de gestion des eaux, et ce jusqu'à 100% des coûts de construction, entraînant une course aux candidatures pour ce type d'aide. Cette étude propose un compte-rendu rapide du cadre réglementaire pour l'adaptation climatique à Copenhague. Nous discutons ensuite l'interaction et l'adéquation de différents scénarios de gestion alternative avec ce cadre, dans une étude de cas. L'impact des différents scénarii est évalué par le biais de l'outil « WSUD potential », qui utilise l'approche « Trois Points ». Les résultats indiquent un schisme entre le Plan de Gestion des Pluies Intenses de la ville d'une part et son Plan d'Adaptation Climatique et objectifs de niveau de service, d'autre part. Ce schisme peut notamment entraîner un surdimensionnement du système de gestion des eaux pluviales.

### ABSTRACT

Water Sensitive Urban Design (WSUD) is still in the “Opportunity”-phase of its stabilization process in Copenhagen, Denmark, indicating that there are controversies surrounding its proper use and the regulatory framework is not completely adapted to the new technology. In 2015 private land owners in Denmark could get up to 100% of the construction costs of climate adaptation measures funded by the utility companies, which resulted in a race to apply for this co-funding plan. In this study we briefly review the climate adaptation framework in Copenhagen, and then discuss how well different scenarios of WSUD in a case study area interact with this framework. The impacts of the different scenarios are assessed using the “WSUD-potential” tool, which builds upon the Three Points Approach. The results indicate that there is a schism between the city's Cloudburst Management Plan on one side and its Climate Adaptation Plan and general service goal on the other side, which may result in over-sizing of the collective stormwater management system.

### KEYWORDS

Climate change adaptation, hydrological impact, planning tool, Three Point Approach, WSUD

## 1 INTRODUCTION

The objective of this study is to explore to what degree different implementations of Water Sensitive Urban Design (WSUD) in residential areas in Copenhagen impact the stormwater runoff from those areas, and how those impacts interact with the stormwater management planning goals set for the city. The impact assessment is done using the “WSUD-potential”-tool, which is briefly described in the Methods section. A brief review of the state of WSUD in Copenhagen and the relevant climate change adaptation planning framework is provided below.

### 1.1 Water Sensitive Urban Design in Copenhagen

As described by Fletcher et al. (2014), different regions have developed different terms for describing a suite of small, decentralized stormwater control measures, reflecting different scopes, principles, etc. In Denmark the term used is Lokal Afledning af Regnvand (LAR), which literally translates into Local Drainage of Rainwater. In English we choose to use the Australian term Water Sensitive Urban Design (WSUD), emphasizing the attention paid in Denmark to exploiting opportunities for “added benefits” to the urban fabric such as aesthetic and recreational values.

A comparative study conducted in 2012 (Madsen et al., in prep.) concluded that Denmark was just entering a third phase in the stabilization process of WSUD, Opportunity (whereas Melbourne had reached a fourth phase, Agreement). Our current observation is that Denmark is still in the phase of Opportunity, as there are still many actors involved in shaping the technologies and many conflicting views on their merits, e.g. whether they are useful measures against climate change impacts. Therefore it is still relevant to study WSUD cases and analyze how well they perform against different criteria, as we do here.

### 1.2 Climate change adaptation in the urban drainage sector in Copenhagen

Projected climate changes over Denmark show an expected increase in magnitude and frequency of larger rainfall events (Arnbjerg-Nielsen, 2012). The Water Pollution Committee of the Danish Society of Engineers recommends using a climate change factor of 1.3 when sizing new stormwater management systems in order to account for the expected increase in storm intensities (Arnbjerg-Nielsen, 2008). This seems to have influenced the main guideline concerning stormwater management in the climate adaptation plan that the city of Copenhagen adopted in 2011 (City of Copenhagen, 2011): it states that the expected increase in precipitation intensity in the 10-year storm event must be counteracted by disconnecting 30% of the impermeable areas of the city from the sewage network. The disconnections should preferably be made using WSUD.

The same year, however, an unusually large storm hit Copenhagen, with local intensities higher than 200 years return period, causing damages estimated at more than 800 mio. Euros (Arnbjerg-Nielsen et al., 2015). This resulted in the adoption of a cloudburst management plan in 2012 (City of Copenhagen, 2012), which adds a new service goal on top of the 10-year service goal: flooding depth must not exceed 10 cm more often than every 100 years. This shall be achieved by securing flow paths for stormwater through the city and out to the harbor, preferably on terrain where possible.

## 2 MATERIALS AND METHODS

### 2.1 The “WSUD-potential” tool

The “WSUD-potential” tool was developed with the aim of supporting the initial planning phases of new WSUD projects in existing urban areas (Lerer et al., 2015). The tool builds upon the Three Point Approach (Fratini et al., 2012) and a later quantification hereof (Sørup et al., n.d.). The tool uses a simplified approach to quantify the hydrological impacts of a given WSUD layout, using only three inputs: the impermeable area to be managed, the area dedicated to different types of WSUDs (such as permeable paving, raingardens and detention ponds), and the hydraulic conductivity of the soil. The impacts are calculated using a mix of simplifying assumptions and tabulated results from simulations using the LID module in SWMM (Rossman, 2010), similarly to Henrichs et al. (2016). The impacts are illustrated using two key indicators, which are presented graphically to the user: the return period of overflow from the system (and the corresponding rainfall depth), and the change in annual water balance (compared to the point of departure).

### 2.2 The cases study area

The case study area was chosen among approximately 25 homeowners associations that entrusted

Klimavej.dk with handling their applications for co-funding of climate adaptation measures in 2015. The Danish government set a cap on the level of funding that Danish utility companies are allowed to support climate adaptation measures on private property with: in 2015 it was 100%, dropping to 75% in 2016. This resulted in a race to apply for co-funding during the latter part of 2015, and Klimavej.dk assisted many associations who saw an opportunity for upgrading their common roads using WSUD.

Of those cases we here present one example: Gåsebæk Vejlaug. Gåsebækvej is an arterial road in a residential area in the western part of Copenhagen. *Bæk* in Danish means creek, which hints that probably at some time in history the road was running parallel to a small water course (which is no longer visible today). Not surprisingly, this road plays a crucial role in the concretization of the cloudburst management plan for the surrounding catchment: it is projected to act as a “cloudburst road”, i.e. that the road profile will be shaped so that in case of an extreme storm event it can transport excess stormwater from the entire catchment towards the harbor, and in this way prevent flooding in the catchment (at the cost of being out of function for traffic purposes for a short while).

The members of the local homeowner’s association share responsibility for 2,840 m<sup>2</sup> of road area and 3,145 m<sup>2</sup> of sidewalk area. In addition, the extent of driveways is estimated at 290 m<sup>2</sup>, and the extent of roof area that inclines towards the road is estimated at 4,130 m<sup>2</sup>. In total, a local WSUD should be able to manage stormwater from up to 10,405 m<sup>2</sup> of impermeable area. The preferred WSUD-technology is raingardens formed as bump-outs, since these would allow for retention, evapotranspiration, treatment and infiltration of stormwater, while adding benefits of greenery and traffic regulation. The soil in the area is classified as boulder clay and is hence expected to have a hydraulic conductivity of about 10<sup>-6</sup> m/s.

### 3 RESULTS AND DISCUSSION

The consultants at Klimavej.dk assessed that an application for co-funding had very little chances of success if it could not demonstrate that the WSUD-plan suggested could manage rainfall up to at least a 5-years return period, based on the existing regulatory framework. Using the “WSUD-potential”-tool they assessed that assigning about 700 m<sup>2</sup> of the impermeable areas to bio-retention units (i.e. raingardens upgraded with underground storage and drainage) could reach this goal; Figure 1 below shows the outputs from the tool for this scenario.

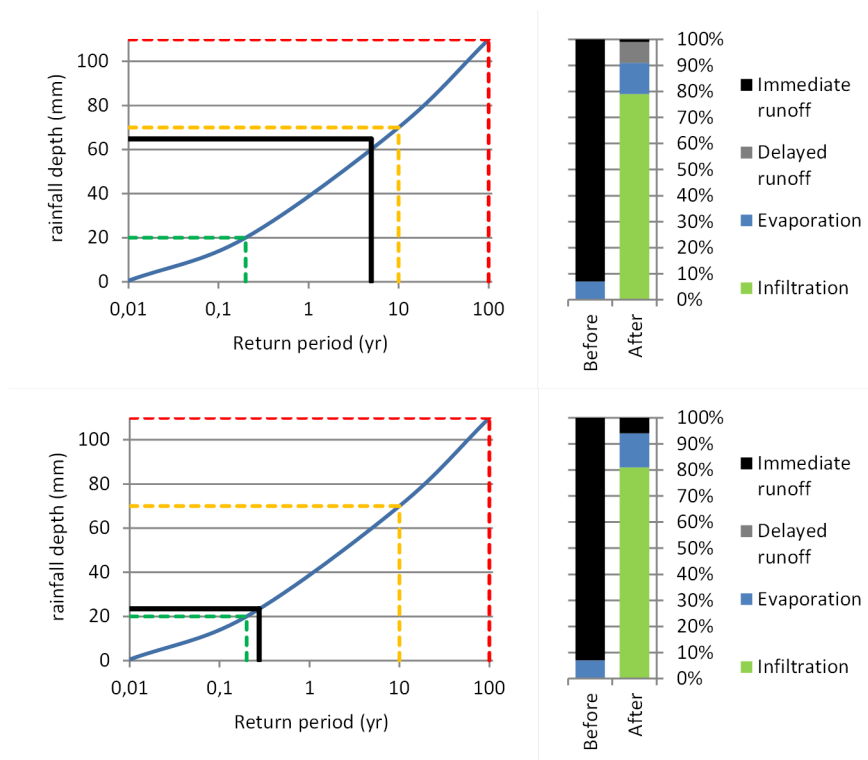


Figure 1: Impact assessment for two scenarios of WSUD implementation in Gåsebæk Vejlaug. Left panels show return period of overflow while right panels show annual water balance before and after WSUD implementation.

Top figures show the impacts of plan 1: repurposing 700 m<sup>2</sup> of the road area to bio-retention units with underground soakaways with drainage. The lower figures show the impact of plan 2: repurposing the same amount of area for simple raingardens.

However, the requirement for managing a 5-year storm can be contested, given the plans of establishing a transport corridor through this area to the harbor. Obviously, stormwater cannot be discharged directly through this corridor on a daily basis since this would pose a major pollution issue. Yet if pollution is the main concern, a lower threshold than a 5-year storm would probably be sufficient.

The lower part of Figure 1 shows the impact of an alternative WSUD plan, which converts all the bio-retention units into simple raingardens. The results show that these are assessed to overflow about 3 times per year, yet still managing about 95% of the annual rainfall locally (around 82% would infiltrate to the groundwater and 13% would evaporate). The 5% that overflows could be directed to the cloudburst transport corridor, since it can be expected to have a rather low pollution concentration (due to the effects of first flush and dilution during larger rains).

The advantages of the alternative WSUD plan is that it would be significantly cheaper to construct and maintain, while still managing a considerable proportion of the annual rainfall, and making good use of the cloudburst transport solution. The cloudburst infrastructure represents a major future investment which is currently projected to be in use only rarely (every 5-10 years), hence it would increase its resource efficiency if it could be exploited more often.

## 4 CONCLUSION

This study demonstrates the application of the tool “WSUD-potential” in the pertinent planning framework in Copenhagen, Denmark. The tool is very fast and simple to use and hence it allows exploring different scenarios at an early stage of the planning process, such as the application for co-funding of climate adaptation measures as in the case we described here. The scenarios we explored in this case indicate a schism in the planning framework: on the one hand, the cloudburst management plan sets a visionary goal of protecting the city from flooding under a 100-year storm through a network of transport corridors. On the other hand, the climate adaptation plan focuses on local WSUD solutions which must manage water up to a 5-10 years storm event, in alignment with the current service goal for the city. It seems that keeping both goals at the same time may result in over-sizing of the collective system and hence a waste of resources.

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