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Storm Water and Wastewater Management for Improving Water Quality

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Abstract: Climate change and urbanization will increase the frequency and magnitude of urban flooding and water quality problems in many regions of the world. In coastal and delta areas like The Netherlands and the Philippines, where urbanization is often high, there has been an increase in the adoption of sustainable urban drainage systems (SUDS). SUDS are installed around the world with the expectation to reduce urban flooding and reduce the pollution impact on receiving waters. Most cities in Asia are starting to implement SUDS as their strategy to make their cities sustainable and resilient. The combination of SUDS with appropriate wastewater treatment and management systems have the potential to be multifunctional in alleviating flood run-off, improving water quality, alleviating heat stress and as a source for reusing the stormwater and wastewater. Since the earliest SUDS are implemented in Europe decades ago it is advised to use the lessons learnt in this process. International knowledge exchange is promoted in projects as IWASTO where several organisations from the Philippines and The Netherlands join forces on a specific region as the Pateros river in Manila with the aim to minimise the pollution impact on this receiving water. The first findings of this project related to storm water and wastewater management are presented in this paper. In this stage of the project high level support models that map the challenges in the city (such as flooding and heatstress) are valuable tools for implementing cost effective sustainable drainage for improving water quality.

Keywords: storm water quality, waste water management, sustainable urban drainage systems

Introduction

Urbanisation usually leads to degradation of the urban dense area by e.g. soil sealing, air water and soil pollution with the result that humans are exposed to floodings, contaminants and loss of biodiversity. Some of the biggest challenges are to bring down city temperatures, fight water shortages, protect homes and businesses from damage by flooding and increase biodiversity within small budgets and timeframe. For example in the Philippines the entire Cebu province is now under state of calamity due to drought (CNN, 2016) and Philippine temperature hits dangerous levels (Philippine Star, 2016).

Given the worldwide increase in urbanization, and the impact of urban stormwater and wastewater on both humans and aquatic ecosystems, the management of urban drainage is a critically important challenge [Fletcher et al., 2013]. Urbanization increases the variety and quantities of pollutants found in downstream receiving waters [Hatt et al., 2004].

Figure 1 examples of problems in the Urban areas: degradation of waterways (Pateros river, Manila) and heatstress (right).

The implementation of SUDS in an integrated strategy can reduce urban surface water flooding as well as reduce the impacts of urban stormwater pollution discharges on receiving waters. Surface water drainage systems that have been developed in line with the ideals of sustainable development are collectively referred to as Sustainable Drainage Systems (SUDS). Appropriately designed, constructed and maintained SUDS are more sustainable than conventional drainage methods because they can mitigate many of the adverse effects of urban stormwater runoff on the environment [Woods-Ballard et al., 2015]. They can achieve this through:

* reducing runoff rates, and reducing the risk of downstream flooding,

* reducing the additional runoff volumes and runoff frequencies that tend to be increased as a result of urbanisation, and which can exacerbate flood risk and damage receiving water quality,

* encouraging natural groundwater recharge (where appropriate) to minimise the impacts on aquifers and river baseflows in the receiving catchment,

* reducing pollutant concentrations in stormwater, and protecting the quality of the receiving water body,

* acting as a buffer for accidental spills by preventing direct discharge of high concentrations of contaminants to the receiving water body,

* reducing the volume of surface water runoff discharging to combined sewer systems, and reducing discharges of polluted water to watercourses via Combined Sewer Overflow (CSO) spills,

* contributing to the enhanced amenity and aesthetic value of developed areas,

* providing habitats for wildlife in urban areas and opportunities for biodiversity enhancement.

From experiences in Europe and the USA it can be derived that the efficiency of SUDS depends highly on the dimensions of the facility and on its implementation in the field [Wilson et al., 2004]. Acquiring the following information on storm water quality is required to understand their treatment performance:

- Stormwater quality levels, which determine the need for stormwater treatment techniques based on the removal of solids.
- Behavior of pollutants, which pollutants are bound to which particles sizes and how much is dissolved.
- Particle size distribution, which gives an indication on what particles are likely to be removed by sedimentation and filtration

Multiple research has been done on stormwater characteristics and new testing methods for certain sustainable urban drainage systems (Boogaard, 2015). The Method of international knowledge exchange on this subject is regarded in the IWASTO project.

MATERIAL AND METHODS

IWASTO

IWASTO, which means to correct and to prevent is a collaborative project of the Rotary Club of Makati Pasong Tamo, Department of Interior and Local Government, several Dutch (applied) universities and companies. The goal of IWASTO is to rehabilitate and sustain the integrity of the decaying and heavily polluted Pateros River for the sake of ecological balance, disease and flood prevention in the barangay areas that are most affected during natural and man-made calamities The Pateros River traverses 11 barangays and affects the lives of around two million people - the local residents of the barangays of Pateros, Taguig, Pasig and Makati and their respective business districts that line the banks of the Pateros River (fig 3).

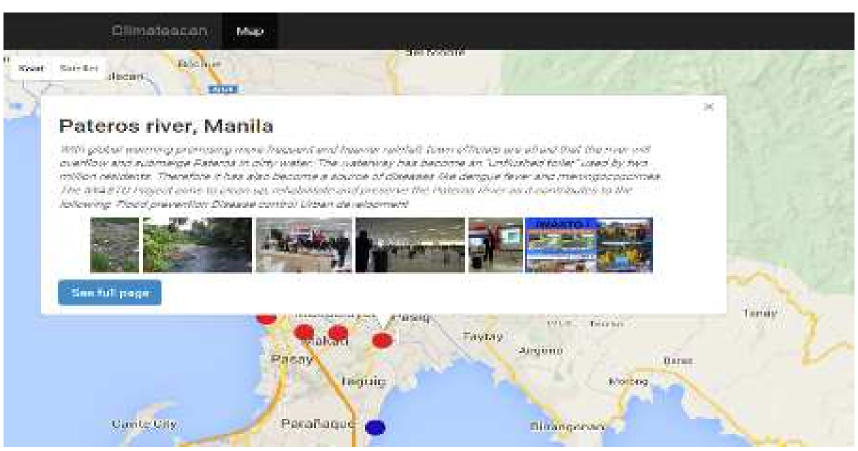

Figure 2 Pateros river Manila on the international knowledge exchange platform: www.climatescan.nl (Tipping, 2015)

The first IWASTO actions that are planned:

- Determination of situation and ambitions
- Cleaning up emissions
- Improving the drainage system
- Education: public awareness (waste management, circular economy)
- Implementing innovating nature based solutions
- Monitoring
- Evaluation & governance

The multiannual programme “IWASTO” aims at bringing together Philippine and Dutch expertise in the fields of spatial planning, urbanization, mobility, spatial economics, civil engineering, water management, social science and other fields, to develop a sustainable vision for Manila and other cities. A ‘meet in the middle strategy’ is used which is a unique combination of a ‘bottom up’ and ‘top down approach’. Mapping of the challenges such as floodings and heatstress of the entire metro Manila will be mapped in high level support systems. From the mapping stage locations are prioritized and detailed solutions are designed to face the multiple challenges, such as innovating wastewater treatment and sustainable urban drainage systems on streetlevel.

Mapping heatstess and floodings

High level support tools are set up as flood maps that show inundated points in the center that are known to flood during heavy stormwater events. Photos and videos are gathered by researchers to verify these points and are mapped on www.climatescan.nl. Measures as sustainable urban drainage systems (SUDS) are planned to minimize these floods. The pathways of the water from the higher centre to the lower parts around will be used as waterways and with reprofiling of some urban spaces these roads will be a cost effective drainage system itself by discharging to the surface water and to stop flooding of houses (Figure 3b). Thermal stress can be mapped in the same way to identify priority locations for adaptation of flooding and heatstress.

When more detailed models are needed models as ENVI-met can be used (example for Tainan figure 3a) and measurements are taken to validate the model. The first validation processes confirm that the ENVI-met model can be usefully applied in the urban climate estimation throughout Europe and Asia and other parts of the world. New maps will be made to prioritize challenges on mobility and air quality (Boogaard, 2015).

Tainan Groningen

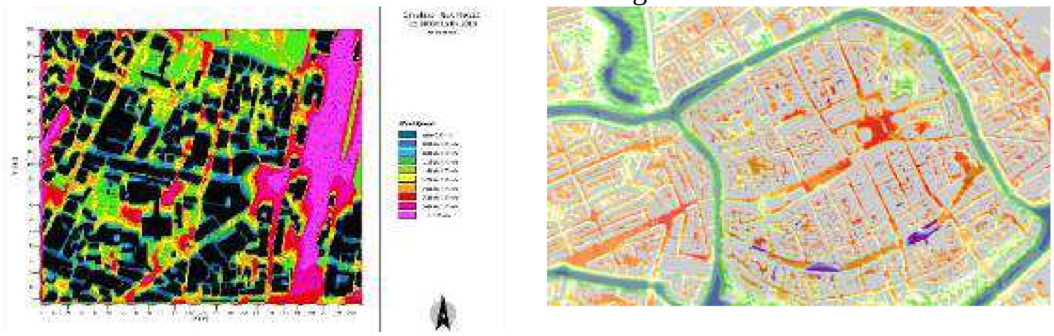

Fig. 3 Thermal thermal map in Tainan (Taiwan) and thermal map and flooding map in Groningen (The Netherlands)

Wastewater analysis

An analysis into the wastewater treatment and collection system (i.e. reticulation) for the Pateros area was done using the Wastewater Management Expert System (WAMEX) tool that was jointly developed by UNESCO-IHE, Asian Development Bank and Worley Parsons.

The preliminary analysis show that the combination of anaerobic, facultative and maturation ponds with constructed wetlands will be the most satisfactory treatment option given the influent wastewater characteristics and desired effluent water quality requirements. The desired water quality standards to be achieved are:

COD = 102 mg/l

TSS = 100 mg/l

BOD_5 = 50 mg/l

Fig 4 provides the most suitable (i.e., preferred) technology options taking into consideration land requirement, energy requirements, operation and maintenance simplicity and flows and loads-shock resistance (to cater for flood related loads and flows).

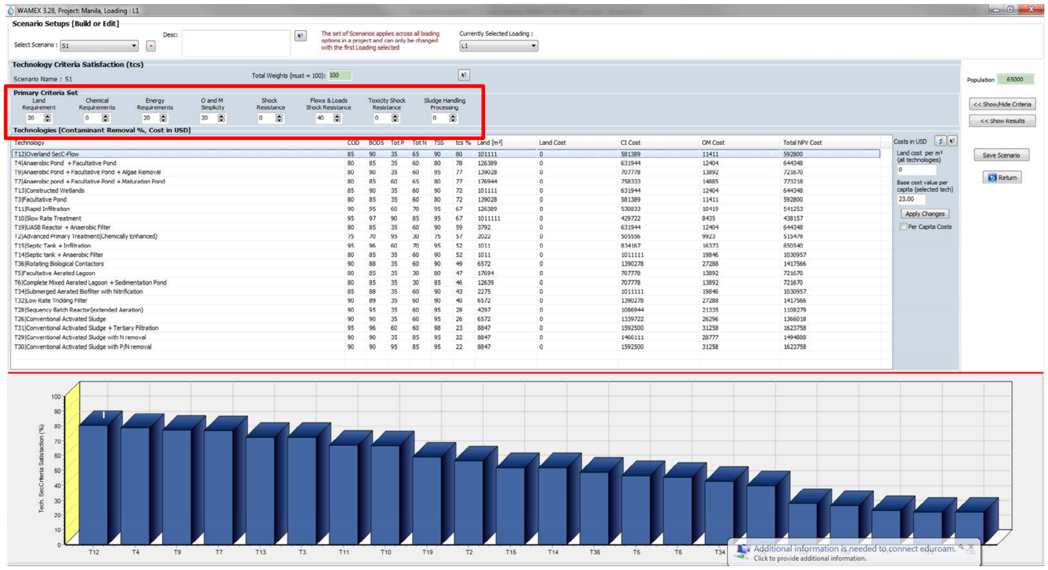

Figure 4: Screenshot from WAMEX tool displaying the list of technologies that satisfy the criteria set;

In addition to the technology options, the preliminary analysis also provides options for potential location of the preferred treatment technologies. Figure 5 depicts a GIS view in WAMEX displaying the Pateros catchment boundary and the potential locations for wastewater technologies.

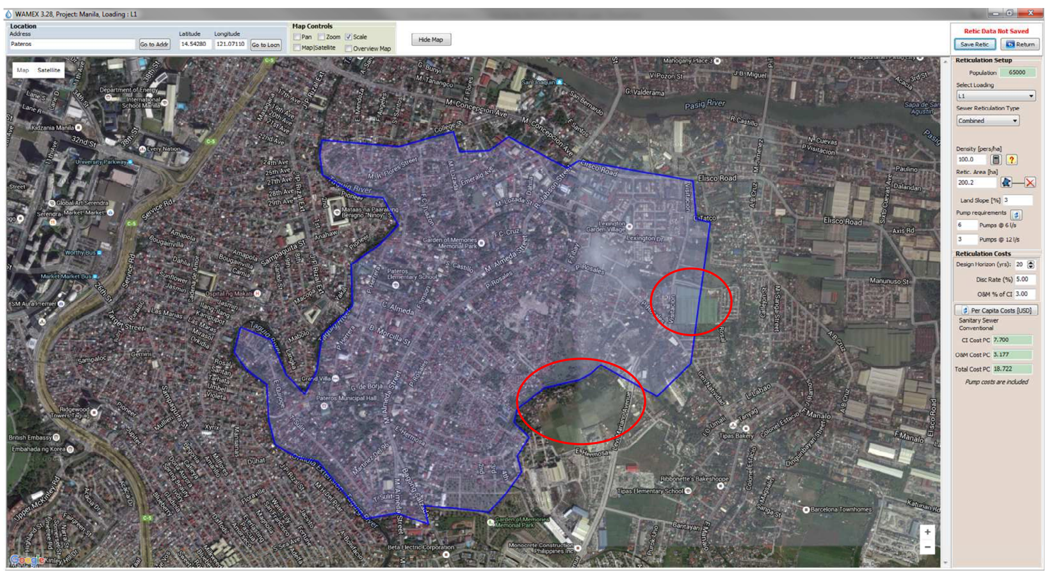

Figure 5: Pateros catchment boundary and potential locations for preferred wastewater technologies.

The collection system (i.e., reticulation) analysis is also part of WAMEX tool and results obtained are shown in figure 6.

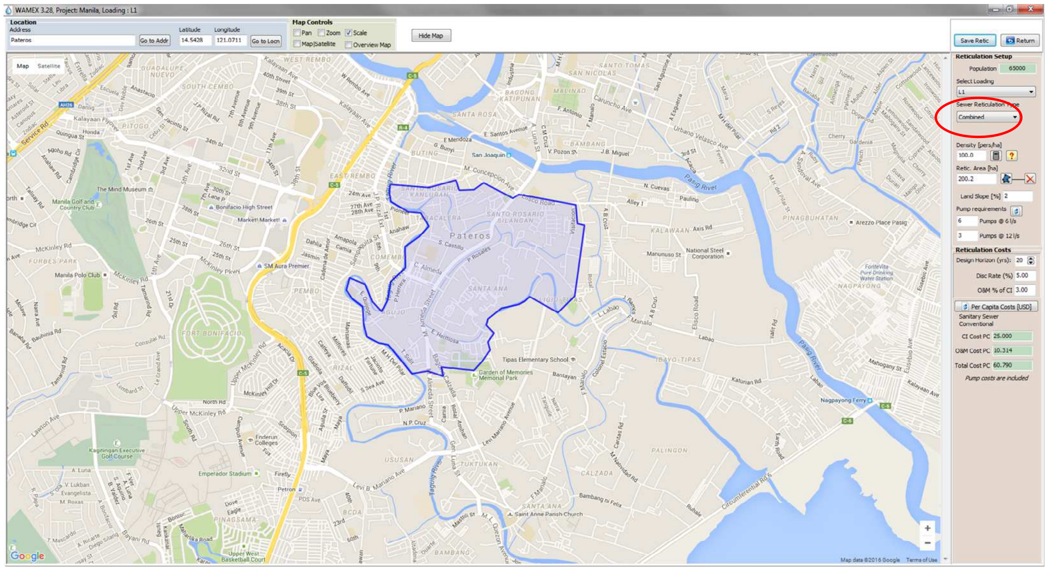

Figure 6: The collection system (i.e., reticulation) analysis including an estimate of potential costs for the construction of the new system;

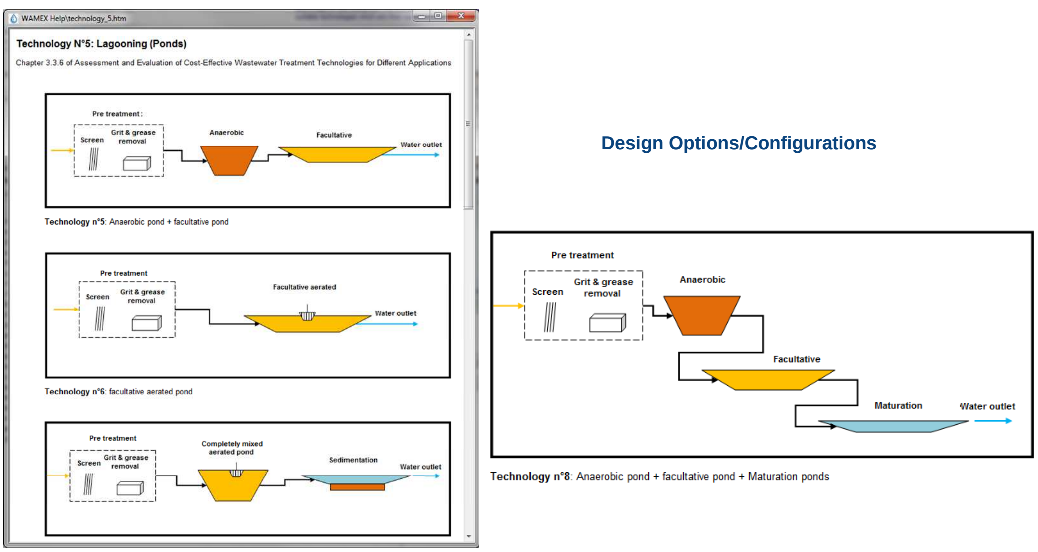

Figure 7: Possible design options and configurations of wastewater technologies in WAMEX;

Combining stormwater and wastewater systems benefits

The preliminary wastewater and stormwater analysis has shown the potential of combining several benefits into the set of ponds which can be used for alleviating excessive flood runoff as well as wastewater treatment. Furthermore, the treated stormwater/ wastewater can be then reused for several purposes, i.e. one of them is for alleviating heat stress in some critical parts in Pateros.

The planning and design of several measures including SUDS and wastewater treatment in Pateros need to be done in a combined and holistic manner to ensure multifunctionality of the measures to alleviate excessive flood runoff, improve water quality and alleviate heat stress in the Pateros area.

3-D visualization

The IWASTO project is about knowledge exchange and 3D visualization is a strong tool to bring international stakeholders together. Combining the elevation model, the dataset with buildings and aerial photographs we can make a 3d model of the city and get a better overview of the outcomes of the model. The model was shown in the 3D virtual reality theater on a cylindrical screen using 6 HD projectors to project an image with a resolution of roughly 5000x1800. To display this model on such a big screen a special 3D viewer, based on the open source OpenSceneGraph 3D toolkit, was used. The software was running simultaneously on 7 PC's, one master PC for the control of the model and 6 slave PC's to drive the projectors (Verlaat et al 2014).

Results and Conclusions

International knowledge exchange in projects as IWASTO with the lessons learnt from counties as The Netherlands will help other countries as the Philippines to avoid costly investments and implement their strategies cost effective in the limited space of urban dense areas in a short timeframe. Lessons learnt that will be addressed in the project:

- The ‘Meet in the middle’ strategy as a combination of ‘top down’ and ‘bottom up’ engages all stakeholders and show quick concrete results that are needed to keep people involved of different decision levels
- Mapping of multidisciplinary challenges give detailed info of priority locations and brings stakeholders together (3D visualisations)
- When SUDS are implemented all stakeholders should be involved and attention should be given to the maintenance efforts to guarantee their efficiency over time
- For high removal efficiency of SUDS only sedimentation will not be sufficient. SUDS that use the following techniques are advised to meet the quality ambitions: Filtration, adsorption and phytoremediation.

Challenges and further development: with combining thermal stress and floodings and even more climate issues in dense urban areas the datasets are getting bigger and researchers and customers get more demanding and want fast and good visual results. DEMs (digital elevation maps) are becoming more common and better, improving the accuracy with a higher resolution. For the implementation of SUDS for a better water quality treatment trains are advised: Using a treatment train approach achieves increased efficiencies that are generally not possible using single SUDS devices. For example, gross pollutant traps (GPS) can be used as the first treatment step to remove larger sediment particles followed by permeable pavement which can remove smaller sediment particles and nutrients to meet the required water quality standards.

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