Urban and rural landscapes – management of stormwater runoff and natural waters

Urban and rural landscapes require efficient water management. Novel solutions and computational methods offer tools and opportunities for sustainable, cost efficient and nature-based solutions. However, changing conditions challenge function of traditional water protection methods and new solutions are urgently needed in both national and international scales. Especially, within urban landscapes, application of new methods is hindered by many challenges including inaccurate data sources, lack of measurements and common standards, together with uncertainty due to influences of climate change.

National modelling seminar is a traditional annual seminar, joining water researchers from the fields of practical water management, research and governance together to discuss from topical themes and future directions (http://mallinnusseminaari.fi/). We welcome everyone working with environmental modelling, monitoring and restoration to participate to this seminar in Viikki!

Time: 11th December 2018 at 9.30–16.00
Location: Finnish Environment Institute, SYKE-LUKE conference center, A building, Seminar room A4. Latokartanonkaari 9, 00790 Helsinki
Organizer: Finnish Environment Institute, Water Association Finland, Aalto University, University of Oulu

The event is free of charge and in English.

Program
9:30-10:00 Morning coffee and registration
10:00-10:20 Forewords Hannu Marttila and Nora Sillanpää

Session I – Management of urban stormwaters
10:20-10:40 Key note – Laura Wendling – Reactive transport modelling to understand processes, potential risks and long-term performance
10:40-11:00 Ambika Khadka - Towards natural water balance in urban areas: Modelling stormwater management designs
11:00-11:20 Camilla Tuomela - Modelling of decentralized stormwater management scenarios for the treatment of urban runoff pollutant loads
11:20-11:40 Eero Assmuth - Impact of biochar on treatment performance of roadside sand filters – field monitoring and geochemical modelling
11:40-12:00 General discussion - New challenges and needs with urban stormwater management
12:00-13:00 Lunch (own cost)

Session II – Modelling tools in urban and rural landscapes
13:00-13:20 Tero Niemi - GisToSWMM5 – An Automated Approach for SWMM Model Generation in Urban Areas
13:20-13:40 Chapagain Yogesh - Simulating controlled drainage and subsurface irrigation in acid sulfate soil
13:40-14:00 Mikko Huokuna - The use of 2D surface flow model to produce pluvial flood maps
14:00-14:20  Coffee

14:20-14:40  Key note - Teemu Kokkonen – Spatial description of urban landscape in hydrological modelling

14:40-15:00  Ulla Sihvola and Anna Klobut, Hydraulic network modelling in alliance projects

15:00-15:20  Jari Koskiaho - SWAT nutrient calibration and validation with a 6-year data set of continuous data in Vantaanjoki catchment in southern Finland

15:20-  General discussion – Future direction with modelling tools in research and practical planning

Further information:  http://www.vesiyhdistys.fi/ or jari.silander@ymparisto.fi and nora.sillanpaa@aalto.fi
Towards natural water balance in urban areas: Modelling stormwater management designs

Ambika Khadka¹, Teemu Kokkonen¹, Tero J. Niemi¹, Elisa Lähde², Nora Sillanpää¹ and Harri Koivusalo¹

¹Aalto University, School of Engineering, Department of Built Environment, Espoo, Finland
²Aalto University, School of Arts, Design and Architecture, Department of Arts and Design, Espoo, Finland

Abstract

Urbanization modifies the water balance particularly by decreasing infiltration and reducing water storage capacity of urban catchments. The recent paradigm shift of stormwater management from drainage-based to nature-based solutions is expected to restore urban water balance (Burns et al., 2012). The shift is referred to with different terms e.g. Water Sensitive Urban Designs (WSUDs) in Australia or Low Impact Developments (LIDs) in USA. Stormwater management design is a subset of WSUD (Fletcher et al., 2015) and LIDs are smaller scale stormwater management techniques such as bioretention cells, green roofs, permeable pavements, vegetated swales and rain gardens located near the source of runoff (Fletcher et al., 2015).

Water balance approach has been widely utilized in the hydrological studies of rural catchments to provide insights on their storage capacity and resilience to flooding. However, the quantitative assessment of the catchment storage in urban areas with LIDs has received limited attention and is often neglected. In this study, we assessed how the storage capacity regulates urban water balance to provide insights into how an urban catchment released stormwater and how resilient it was to pluvial flooding.

Three alternative stormwater management designs with different densities of LIDs are analysed in the study area located in Kirstinpuisto in Turku. The analysis is based on results from a process-based SWMM model simulations (Rossman et al., 2016). The simulations were conducted for a seven-month period, including an extreme rain event during summer and another intense rain event after summer. The results showed that stormwater management designs with LIDs had positive impacts on urban water balance especially through storage of stormwater runoff during extreme events. The storage provided by the LIDs increased resilience of urban catchment to pluvial flooding during extreme events. The study showed the possibility of restoring the natural water balance in the urban areas by enhancing storage, which eventually converted into losses during a long-term period. The detailed parameterization of stormwater management designs in SWMM model proved effective in water balance analysis.

References


Modelling of decentralized stormwater management scenarios for the treatment of urban runoff pollutant loads

Camilla Tuomela¹, Daniel Jato-Espino², Nora Sillanpää¹ and Harri Koivusalo¹

¹Aalto University, ²Universidad de Cantabria, Spain

Urban runoff is a diffuse pollution source that may lead to degradation of surface water quality. The management of stormwater is slowly developing toward more sustainable options, with decentralized treatment units aiming at capturing and treating runoff and its pollutants near their source areas. These decentralized treatment units are referred to as Low Impact Development (LID) systems. To design efficient decentralized stormwater management and maximize the potential of LIDs, there is a need to understand the pollutant contributions in urban areas. The pollutant contributions from various sources were simulated using literature-based event mean concentrations (EMCs) for different land cover types at a residential catchment (11 ha) in Espoo. The simulated pollutant loads were compared against measured loads at the catchment outlet. Based on the simulated pollutant contributions, a simple and an optimized approach was used to form stormwater treatment scenarios with different locations for LIDs. Ten different management scenarios with LIDs were simulated to evaluate their impact on runoff generation and pollutant washoff on a catchment scale. The US EPA Storm Water Management Model (SWMM) and a model with detailed spatial resolution was used.

A high variability in the modelled loads was observed and the simulated loads were usually larger than the measured loads. The difference can be explained by lack of local data for source area EMCs and by varying weather conditions. In addition, mechanisms affecting loads along the pollutant pathways from catchment to the sewer outlet are not taken into account in the model. A single land cover type, such as roofs or road areas, did not dominate the pollutant contribution; however, impermeable areas contributed with a majority of the runoff volume and pollutant loads.

Based on the assessment of pollutant contributions, the treatment units were assigned to the asphalted areas: parking areas, walkways and/or roads. Bioretention cells and permeable pavements were chosen as the most likely LID alternatives to retrofit in an existing urban area. Following a simple approach, six scenarios were formed by assuming that pollutants were mainly contributed from one specific land cover type and one LID type was located in those areas. Following an optimized approach, four management scenarios were formed by utilizing GIS and combining local catchment conditions with simulated pollutant washoff and siting restrictions for LIDs, in order to prioritize and locate the units in the most critical areas.

For the simulated management scenarios, large variability was observed in the simulated load reduction, depending on the LID type and its location and on the pollutant. Due to the diffuse nature of the simulated pollutant washoff, simple approaches treating runoff from a single land cover type reduced pollutants unevenly on a catchment scale. Scenarios with permeable pavements reduced pollutants effectively while scenarios with bioretention cells benefitted the most from optimized location prioritization due to their smaller spatial coverage and storage capacity. The optimal management scenario will vary with the management targets, depending on if the target is to maximize the runoff and pollutant reduction or in addition to minimize the areal coverage of LID units for a cost-efficient solution.
Impact of biochar on treatment performance of roadside sand filters – field monitoring and geochemical modelling

Eero Assmuth, Sitowise
eero.assmut@sitowise.com

Abstract

Urban runoff contains a wide range of pollutants originating from human activities and thus degrades surface water quality. One of the simplest stormwater treatment structure types is a roadside filter, which is a sand-containing pit next to a road. The sand filter matrix can be mixed with amendments, such as biochar, to improve its performance. In this study, conducted in Aalto University, the main objective was to investigate stormwater filters in real field conditions in Southern Finland and apply the obtained data in modelling to reveal mechanisms occurring in pollutant removal. Similar studies of biochar-amended sand filters are rare and the current study is among the first under field conditions.

A filtration system for road runoff located in the City of Vantaa, Finland, was investigated during summer 2017. The site includes two different filters: a sand filter and a sand-biochar filter. The filters were built to be as identical as possible, except for the 300-mm thick birch (Betula) biochar layer in the sand-biochar filter.

Rainfall and flow rates of the filter effluents were measured at the study site during the study period. Water samples were manually collected from the filter outflows throughout the rain events. To assess the impact of the filters, also the influent (untreated) stormwater was sampled. In total, 122 influent and effluent samples were gathered, which were analyzed for 14–29 water quality parameters. The laboratory results were analyzed with statistical methods, and event mean concentrations (EMC) and pollutant removal efficiencies were determined for the filters. Additionally, geochemical modelling (PHREEQC) was utilized in order to reveal the pollutant removal mechanisms occurring within the filters. Results of filter effluent water quality analyses were used as an input to the geochemical modelling.

The pollutant concentrations and the outflow rates from the filters expressed clear temporal variability both during and between the examined rain events. More than 1000-fold variability in the concentrations underlined the importance of sample timing and need for continuous sampling throughout rain events for accurate estimation of pollutant attenuation.

Both filter types were observed to efficiently remove heavy metals and suspended solids from the stormwater. Also total phosphorus removal was efficient although both filters leached phosphate. Biochar amendment showed improved performance especially in nitrogen removal, whereas it impaired total organic carbon retention. Otherwise, sand alone provided similar treatment performance as the sand-biochar filter.

Geochemical modelling showed that precipitation is a possible mechanism for pollutant removal, but that the dominant pollutant removal mechanisms are likely physical sieving and sorption processes. Where physical sieving is the main pollutant removal mechanism, biochar amendment yields little additional pollutant removal benefit.
Due to the high temporal variability, studying of similar filters clearly requires several samples per examined rain events, but also the number of studied events should be higher than in this study. Based on the results, biochar amendment seems to be an interesting option especially for areas with high nitrogen loadings. Also slightly improved heavy metal retention capacity and water holding capacity could be useful properties for some locations.
Manually constructing hydrological model descriptions for urban areas tends to be laborious due to the detailed mosaic land cover and the required high-resolution model setup. Here, the performance of a novel automated subcatchment generator tool, GisToSWMM5, is assessed against observations and manually constructed models. The open source tool automates the tedious stages in SWMM model construction process by automatically generating subcatchments for a studied area based on available land cover and elevation information. Furthermore, the tool connects the subcatchments together and into the stormwater network providing a detailed DEM-based surface flow routing between the subcatchments. In general, the automatically generated models perform well against observations and comparably to manually constructed models regardless of the detail of land cover information input. The introduced inter-subcatchment connections may require previously acquired model parameters to be re-calibrated. This is due to the parameter values, calibrated using manual models, compensating for the flow routes existing in the automatically constructed but missing from the manually constructed models. Overall, the tool greatly reduces the effort required for constructing SWMM model descriptions especially in large urban areas.
Simulating controlled drainage and subsurface irrigation in acid sulfate soil

Chapagain, Y.¹, Salo, H.¹, Virtanen S.², Koivusalo, H.²

¹Aalto University School of Engineering, Department of Built Environment
²Drainage Foundation sr, Simonkatu 12 B 25, 00100 Helsinki, Finland

Acid sulfate soils are located mainly in the coast of Gulf of Bothnia in Western Finland where there is a large share of cultivated fields with subsurface drainage systems. To avoid the formation of acidic discharge from these fields, the groundwater level needs to be controlled to stay above the soil layers containing sulfidic materials. Water management practices like controlled drainage and subsurface irrigation can be used to maintain the groundwater table at a desirable depth. Hydrological models provide a tool to quantify the effects of these management practices on field hydrology and to distinguish other processes or field activities affecting the field water balance. In this study two one dimensional (1D) models (Drainmod-based model and Hapsu were used to simulate water flow in three acid sulfate field sections with 1) conventional drainage, 2) controlled drainage and 3) controlled drainage with subsurface irrigation management practices. The objective was to assess the effect of these practices to field water balance and groundwater level using theoretical description of the field drainage and field measurements.

The Drainmod-based model was calibrated (2010-2014) and validated (2015-2017) for the conventional drainage field section using measured drain discharge and groundwater table depth. For calibration period, the model produced NSE values of 0.56 and 0.68 for hourly drain discharge and groundwater table depth, respectively. Field hydrology of controlled drainage and subsurface irrigation field sections was simulated using calibrated parameters of conventional drainage field section. The HAPSU model was run for all water management practices with the Drainmod-based model parameters. The Drainmod-based model simulations showed that drain discharge decreased 18.6% and 14.9% using controlled drainage and subsurface irrigation, respectively. However, the numbers were 1.5% and 7.2 % based on HAPSU simulations. The decreased drain discharge was not seen from the long-term measurements. Comparing the simulated and measured effect of water management practice revealed that not all water flow processes in field were taken into account in the modelling, for example water flow between the field sections and water level in main drain. Due to lack of groundwater outflow to the main ditch, HAPSU simulated higher cumulative evapotranspiration and drain discharge, but also higher groundwater level compared to the Drainmod-based model. The model comparison revealed that implementation of seepage enhances the predictions of groundwater levels in the studied field sections.
The use of 2D surface flow model to produce pluvial flood maps

A “Preliminary Pluvial Flood Map” was produced by SYKE for municipalities to be used in preliminary flood risk assessment for pluvial floods. The map was produced for almost all urban and suburban areas in Finland by using numerical surface flow model which utilize GPU-computing. The most important input data for the model is KM2 DEM produced by National Land Survey but also other GIS-data, for example land use data and imperviousness degree data, is used.

According to the flood risk legislation municipalities are responsible for pluvial flood risk management and the preliminary flood risk assessment has to be updated before 22.12.2018. To help municipalities to compile preliminary flood risk assessment SYKE published a pluvial flood map service in the beginning of March 2018. In the map service the possible flood areas for two rain events are presented. The modelled rain events are four hours rain event with the probability of 1/100a and a modified four hours event which is based on the observed rain event in Pori 2007. The 1/100a precipitation values for one and three hours rain events, which are quantified by Finnish Meteorological Institute, are used to define the modelled 1/100a rain event. So it can be considered as 1/100a rain event also for 1 hour and 3 hours precipitation. The maximum water depth and flow velocity during the whole computation period in each cell were stored to be used for the production of the flood maps.

For the purpose of the surface flow modelling the original KM2 DEM (2x2 m) has to be modified at the locations of buildings and culverts. A semi-automated ArgGIS ModelBuilder script was developed to modify the input topology and also to create the other input data for the model. Culverts have been automatically added at the crossings of small streams (GIS-data) and roads (Digiroad). The diameter of an automatically added culvert is based on the size of the stream and it is either 800 mm (stream width smaller than 2 m) or 1200 mm (stream width from 2 to 5 m). The flow equations are modified at the locations of the culverts so that the diameter of a culvert is taken into account correctly. There are a lot of errors in the automatically added culverts and because of that municipalities have an opportunity to correct the culvert data. After the corrections the model is run again and a new version of the map is produced.

The production of the pluvial flood maps were done in square areas of 6x6 km (UTM10). A buffer area of 1 km was added around the UTM10-area for the calculation so that the each calculation area was 8x8 km. That means that there were 16 million calculation cells in every area. Flood maps were produced for over 1400 UTM10-areas. The time dependent precipitation intensity was assumed to be same for the whole calculation area and same precipitation values were also used in different parts of Finland. Corine-2012 land use data was used to define roughness coefficient (Manning-n). Corine-2012 and the imperviousness degree (Soil sealing, EEA, Copernicus/EU) were used to define infiltration. The area was assumed to be flooded if the calculated maximum depth in a cell was more than 0,1 m.

The flow simulation in the model is based on an algorithm presented by Bates (Bates et.al. 2010. A simple inertial formulation of the shallow water equations for efficient two dimensional flood inundation modelling.) Because of the relatively small cell size (2x2m) a small time step has to be used. At the beginning of the calculation it was 1 s and it was decreased during the calculation depending of the calculated maximum depth. The Froude number in the model was limited to be 0,95 or lower, so super critical flow can’t be modelled. That limitation is not assumed to be crucial for the production of preliminary flood maps in Finland. A GPU-version of the solution algorithm using CUDA C programming language was developed to produce the flood maps. A relatively inexpensive computer with two GeForce GTX 1080 GPUs (2560 cuda cores) was used for the production of the flood maps. For one GPU it took about 15 to 20 minutes to calculate one precipitation scenario for one UTM10-area.
National Modelling Seminar 11.12.2018

Title: Hydraulic network modelling in alliance projects

Performers: Ulla Sihvola and Anna Klobut, Pöyry Finland Oy

Abstract:

Alliance projects aim to efficiently seek cost savings. Water supply and sewerage is often one part of infra projects that are carried out as alliance projects. With hydraulic modeling different solutions regarding water distribution and sewer networks can be conveniently compared with relatively small amount of work. This comparison makes it possible to optimize the functionality and cost of the systems/pipes to be selected.

As water supply is not the core of many infra alliance projects, it is important to present the benefits of the modeling to the alliance organization. Modelling can be used for example to define the best routes for pipelines, to define pipe sizes and to test different designs for storm water structures. Modelling can also give more reliable results compared to other calculation methods, if the model is accurately built and even calibrated. Sewer network models also consider the delay of the water in catchments and network quite accurately.

Modelling of water distribution network, sewage network and storm water network has been used in Tampere tramway alliance project and in Kuopio Salli Savilahti alliance project. In our experience benefits have been gained from modeling especially in the design of storm water structures. In addition, the required pipe sizes have been more accurately determined in pipe displacement situations.
SWAT nutrient calibration and validation with a 6-year data set of continuous data in Vantaanjoki catchment in southern Finland

Jari Koskiaho*, Mikołaj Piniewski2, Paweł Marcinkowski2, Sirkka Tattari1
1 Finnish Environment Institute. Email: jari.koskiaho@ymparisto.fi (*corresponding author)
2 Warsaw University of Life Sciences.

Abstract
One of the important limitations of numerous applications of water quality models such as SWAT is calibration and validation against temporally scarce observational data (with typical monthly grab sampling frequency). In this study, carried out within the BONUS RETURN project (www.bonusreturn.com), a unique dataset of continuous measurements of water height, turbidity and nitrate-nitrogen (NO$_3$-N) concentrations collected at the Pitkäkoski automatic monitoring station in the Vantaanjoki river basin in southern Finland during 2011–2016 was utilized in calibration and validation of the SWAT model. The catchment is characterized by a high fraction of clayey soils and, in consequence, flashy runoff, with very large and short flood episodes with high nutrient concentrations. Data was recorded at 1-h intervals with a s::can nitro:lyser (www.s-can.at/products/spectrometer-probes#) sensor. Sensor-measured turbidity (raw data) was calibrated against simultaneous water-sampled turbidity and converted to total phosphorus (TP) concentrations by linear regression equations derived from water-sampled turbidity and TP. For the sake of calibration and validation in SWAT-CUP Sufi-2 programme, concentration and flow data were aggregated into daily loads of NO$_3$-N and TP. Preliminary results show good model calibration results, with the Kling-Gupta Efficiency values above 0.8 for flow and above 0.7 for NO$_3$-N and TP. In the next step, the added value of using such a unique, continuous data set for SWAT calibration will be more formally analysed by creating 'calibration scenarios' using discrete sub-samples of the continuous data set trying to mimic most typical grab sampling approaches (measurements with a monthly interval, flow-weighted sampling, etc.).