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Use of continuous simulation model (COSIMAT) as a complementary tool to model sewer systems; a case study on the Paruck collector, Brussels, Belgium.

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Abstract

The episodic discharge of Combined Sewer Overflow (CSO) discharge, in most of cases, effectively controls the ecological status of a receiving water body. Hydrodynamic models like Storm Water Management Model (SWMM) are used to model such events in a sewer system which requires long computational time especially when performing long term simulations of an integrated modelling system. Hence, we developed a continuous simulation model (COSIMAT) using the MATLAB™/SIMULINK™ in view of using it in an integrated modelling chain. We validated the COSIMAT using the hydrodynamic model SWMM. We tested the methodology in the case of a fairly important Brussels' sewer collector, Paruck. The results showed that the accuracy of the COSIMAT simulation is comparable with the SWMM but with much reduced computation time. We believe that such development would be very helpful to minimize the computation time of an integrated model, especially when the models are linked dynamically, e.g., in OpenMI platform.

Key words:
Combined sewerage system, CSO, COSIMAT, SWMM, Integrated modelling, Paruck

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1 Introduction

The continuous growth of human population and rapid development in urban areas is affecting the physical characteristics of these areas very considerably, consequently leading to a constant change in the hydrological regime of urban areas.

In the past the construction and operation of urban drainage systems was driven by two main objectives: (1) to prevent flooding and (2) to maintain public health and hygiene. Due to concerns been raised on the ecological status of receiving waters; for example, that imposed by the European Water Framework Directive: WFD (EU, 2006), the aspects of waste water treatment plants were introduced to reduce the pollutant loads sent to receiving waters. More importantly, the WFD calls for integrated river basin management to be put in practice in view of achieving good ecological status of all inland or coastal water bodies. The issue of achieving that ecological status and reducing flooding in urban areas is further complicated by the fact that these problems have to be tackled using different and directly opposite approaches. One is to get rid of the storm water out of the urban area as fast as possible to prevent flooding while the other is to delay the water outflow as long as possible in the WWTP to ensure that all the pollutants are removed to maintain the good ecological status of the receiving waters. The objectives of EU WFD can be achieved by using integrated river basin management approach which depends largely on integrated models. To attain the objectives of EU-WFD, one component of the integrated model should be a model that describes the sewer system(s). In a highly urbanized catchment, such model is very important because the effluent from the sewer system can determine the ecological status of a receiving water body. For example, the river Zenne in Belgium, carries more than 50% discharge coming from the Waste Water Treatment Plants (WWTPs) (Garnier et al., 2012) and the river water quality is sometimes very poor because of episodic emissions of CSOs.

The design, operation and management of these complex sewer networks have been facilitated recently by the development of numerical simulation packages (hydrodynamic models) and the rapid progress in computer soft/hardware. Though these hydrodynamic models are continuously been developed, most of them are very expensive and can’t be applied by most of users, secondly there is a problem of long computation times especially when performing long term simulations.

Despite this rapid development of software, the challenge has moved from the simulation of individual sub-systems to an integrated approach of managing urban drainage systems. In this approach, integrated or conceptual models of the whole system(s) can be developed and used to test the performance of the system under historical and future scenarios. However the development of integrated models is a challenging and complicated task. The complex nature of these systems is the main reason why existing models of the sub-systems cannot directly be linked together to form a single entity.

The issue of integrated modeling is further complicated by the fact that, when a detailed hydrodynamic model like SWMM is a component of an integrated model and the integrated model is linked dynamically in a platform like Open Modelling Interface: OpenMI (Gregersen et al., 2007; Moore and Tindall, 2005) the calculation time step is too large, as observed by Shrestha et al. (Submitted) and Shrestha et.al. (2012).

We tried to solve the above stated problem in this study by developing a continuous simulation model (COSIMAT) in the MATLAB™/SIMULINK™ platform. The conceptual model COSIMAT is then used to calculate the volume of CSO sent to the receiving water during heavy rainfall events. Meirlaen (2002) suggested the use of reservoir or conceptual models to solve the problem of long computational time usually associated with detailed models. The development and application of conceptual models does not require a lot of experience for the modeller(s) as most of the parameters have a physical meaning. In addition, these models can easily be extrapolated and used in other similar systems. An important feature in conceptual models is that their parameters are not directly measurable and must be calibrated from observed data (Beven and Binley, 1992) or from a detailed model. This is very important for what we are heading to, as we want to develop an integrated model including COSIMAT to represent the sewer system(s). The integration is sought to be made via OpenMI which is an interface allowing dynamic data exchange between the component models, which is an opposite the file based offline linking.

Our present study will contribute to this research and further investigate the accuracy of the conceptual model, COSIMAT against a detailed hydrodynamic model, SWMM. In order to attend this objective, the SWMM and COSIMAT models are calibrated against a number of storm events. The objective on the calibration process for the models is to accurately estimate the total CSO volume sent to the receiving water. A brief description of the study catchment and models used are given in Section 2. Section 2 also provides details on how the model has been built-up, calibrated and validated. Results are presented and discussed in Section 3. Final conclusions are formulated in Section 4.

2 Methodology

2.1 The Study Area

The Zenne river basin (Figure 1) drains an area of 1162 km² and runs through the three administrative regions of Belgium: the Walloon region (574 km²), the Brussels Capital region (162 km²) and the Flemish region (426 km²). About 103 km downstream, it meets the river Dijle, where it is subject to the tidal influence of the river Scheldt. Parallel to the river runs the canal Brussels-Charleroi and about 1.5 million people are connected to the river. Out of this, more than 80% of the population live in Brussels region alone. The hydraulic behaviour of this system is very complex due to the interaction between the different discharge elements at the various outlets (collector, siphons, and weirs), the receiving water (the river Zenne) and the canal and tidal influence at the river outlet (the river Dijle). There exist several WWTPs in the basin and among them, two biggest WWTPs (Brussels South and Brussels North), are found in the Brussels (Figure 2). With a capacity of 1.1 million of equivalent inhabitants, the Brussels North is the biggest of two. The sewer system of Brussels North has four distinct sewer systems, namely, the left bank collector system, the right bank collector system, the collector of Haren and the collector of Woluwe (Figure 2). One of the important trunk sewers of the Left bank collector (of the WWTP North) is the Paruck sewer system (Figure 2).

The siphon is placed such that it passes under the canal and discharges its CSO to the river that flows parallel to the canal. The quantification of the volumes of CSO sent to the receiving water during storm events through the siphons and weirs is thus very complex. This complexity was simplified by the application of both hydrodynamic (SWMM) model and a conceptual model.

2.2 Models

2.2.1 The SWMM model

2.2.1.1 The model

SWMM is a dynamic rainfall-runoff simulation model computing runoff quantity and quality (primarily) from urban areas as developed by the United States Environmental Protection Agency (US EPA). It can be used for both continuous and single event modelling. A drainage system in SWMM is modelled as a series of water and material flow between four major subunits: the atmosphere, the land surface compartment, the groundwater and the transport or conveyance compartment (Gironas et al., 2008; Rossman, 2009). SWMM adopts a distributed non-linear reservoir concept to simulate the runoff from a specific sub-catchment after depression storage; infiltration loss and evaporation are satisfied. While doing so, the sub-catchment is divided into impervious and pervious zones, the infiltration phenomena being considered only from the latter zone. The one dimensional flow routing in the transport compartment is based on the full set of equations of Barré de Saint-Venant.

2.2.1.2 The SWMM model build up

The Paruck catchment drains an area of about 1001ha with more than half of the catchment covering about 520ha of impervious area (urbanised). We prepared the system by splitting the catchment into twenty four sub-catchments with 189 conduits of a total length of about 19km.There are 188 junctions in the network, two weirs and a battery of four identical siphons placed side by side at the outlet of this catchment. Most of the sewers are brick laid with oval shape of minimum height of 1.30m.

In the configuration of the network under study, there is a single collector that receives waste water at the outlet of each of the sub-catchments from the secondary sewers and transports it to the WWTP. The collector is equipped with a device such that it sends all the wastewater to the WWTP during dry weather. When the incoming flow increases because of wet weather:- this device can send only a maximum discharge of 1.8m³/sec to the WWTP. When the maximum discharge to the WWTP is reached, the remaining CSO is sent directly to the river via the siphons. When the capacity of the siphons is also exceeded, the rest of the CSO is first stored in the system by the use of a CSO storage chamber with a capacity of 2200m³ equipped with two sideflow weirs of the same lengths of 19m each and different crest levels of 1.8m and 2m for weirs1 and weir2, respectively and identical discharge coefficients of 2.215. When the storage capacity of the CSO storage chamber is exceeded, the excess CSO is then discharge to the canal through the first overflow weir and the process continues for the second overflow weir. The schematic representation of the system is shown in Figure 3 and some characteristics of the system are presented in Table 1.

2.2.1.3 Model calibration and validation

The SWMM model was calibrated and validated using observed flow data recorded at the outlet of the Paruck catchment and recorded by FlowBru (www.flowbru.be), an agency that monitors surface water flows and rainfalls in Brussels. For calibration, a rainfall time series was selected containing a number of high rainfall records with the corresponding discharge at the outlet of the catchment. The results of simulation produced by SWMM at the outlet of the catchment were plotted against the observed flow and the parameters of the model were adjusted to have a good fit between the simulated flow and the observed flow and also the volume of flow recorded.

These parameters were maintained and used to validate another rainfall time series containing flood events as well. Due to some errorsin the recorded data, the data-sets that were used to calibrate and validate the model were very limited.

2.2.2 The COSIMAT

2.2.2.1 The model

COSIMAT is an acronym for Continuous Simulation Model in MATLAB^{TM}/SIMULINK^{TM}. It is a conceptual model that can be used for both continuous and single event simulations to calculate water fluxes (volumes, discharges) sent to the receiving water during flood events.

COSIMAT is composed of two main components; the hydrologic and the hydraulic components. The hydrologic component contains the sub model components for routing of runoff including rainfall abstraction losses, Dry Weather Flow (DWF) and flow through the sewer system. Runoff and DWF are first routed into a linear reservoir model using the notion of continuity and storage equations whereby the storage is linearly related to outflow by a reservoir constant as a function of time. This model component is made of three identical reservoirs placed in series and there all have the same reservoir constant (Nash cascade concept). COSIMAT uses the Nash Cascade, which is a reservoir model, to describe the combination of both overland flow and the flow through the sewer pipes. However this approach offers too limited possibilities to model accurately the routing process because it requires only two parameters (reservoir constant (k) and number of reservoirs which is 3) which moreover have to remain constant throughout the simulation period.

In the hydraulic component of COSIMAT, the discharge elements at the out let of the catchment are represented by hydraulic equations for collector, siphons and weirs which are programmed using special functions of SIMULINK^{TM}. The storage reservoir at the outlet of the system is represented in COSIMAT by a lookup table function and the storage volume varies as a function of height of water in the reservoir. Most equations used in COSIMAT are physically based equations which are also used in hydrodynamic models, however the difference between the two is that most of the processes in COSIMAT are lumped thus only the most dominant processes occurring in the sewer system are used to study the system using a few parameters as mentioned in the preceding paragraph. The time step of data input into COSIMAT is same as the time step of the rainfall input which is converted into seconds before being used in MATLAB^{TM}/SIMULINK^{TM}.

2.2.2.2 Model build up

The sub components include: the wetting losses, depression storage, runoff coefficient, dry weather flow, and reservoir model. The hydraulic components include a collector, a battery of four identical siphons, CSO storage chamber and two weirs.

The total rainfall is converted into net rainfall and routed as overland flow (discharge). It is added to the dry weather flow and the sum is sent to the linear reservoir model. From the linear reservoir model, it is sent to the various discharge elements at the outlet of the catchment and each of these discharge elements including the storage reservoir is activated depending on the volume of inflow present in the system.

Two methods are used for the calculation of net rainfall in the COSIMAT depending on the inflow to the CSO chamber. For design storm simulations, only the runoff coefficient is used to calculate rainfall losses while for continuous simulations, other types of losses are included. This approach was suggested by Viessman et al. (1989). Viessman et al. (1989) suggested that, while estimates of losses due to interception can be significant in annual or long term simulations, accounting for interception losses might be unnecessary for heavy rainfalls during individual storm events. For continuous simulations, other parameters like the wetting losses and depression storage are included and used as fixed values. This is because, in running continuous simulations which usually concern long period of time, it is considered that there are some rainfall episodes which do not generate any runoff. This could be lost either as wetting losses or depression storage. For continuous simulations, 0.5mm and 1.40mm were used for wetting losses and depression storage respectively. These values were obtained from literature (Anonymous).

When the maximum discharge at the outlet of the catchment, i.e through the collector and siphons, is reached, storage is activated within the system due to the presence of weirs and the incoming CSO is stored within the system in the storage reservoir. The storage in the system is represented by a hypothetical storage reservoir as shown in the figure 4 below.

At the beginning of a rainfall event, the conceptual storage reservoir (Figure 4) is assumed to be completely empty, i.e with V=0. In this situation, the lowest level of water in the sewer pipes in the network and the minimum water level upstream of the siphon is Hu_min. In this instance, all the flow coming into the system is sent to the WWTP via the collector (not shown here). Storage only occurs in the system when the siphons are full and are flowing at full capacity. During storm events, the volume of storm water in the system may increase eventually to V_{siphon} corresponding to water level of Hu_siphon in the system. At that moment, a volume V_{siphon} is already present in the system and the siphons are flowing at full capacity and under pressure. For activation of weir1, the volume of water in the system must be equal to V_{weir1}which corresponds to the crest level of weir1 given by Hweir1 and this water is fixed. When this level is exceeded, weir1 is activated. For activation of weir2 a fixed volume V_{weir2} corresponding to crest level Hweir2 must also be present in the system and when this level is exceeded, weir2 be activated.

Generally, the maximum water levels Hu_max corresponding to the maximum storage of the hypothetical reservoir will hardly occur except the case of backwater. However, this level is needed in order to be used as an upstream boundary condition in COSIMAT. Table 2 shows the parameters of the COSIMAT.

2.2.2.3 Model calibration and validation

The strategy for calibration and validation of COSIMAT was the same as that of SWMM but the comparison was done between the outflow hydrographs of SWMM and COSIMAT using the same data. However our interest was to compare the volumes of CSO produced by both models and comparing the hydrographs was only an additional indicator showing the correctness of the calibrated parameter for both models.

Among the parameters shown in table 2, only the reservoir constant (k) was calibrated. This is because:- most of the other variables like area, DWF, runoff coefficient, number of inhabitants etc were obtained directly from the SWMM model or determined using the lookup table function in SIMULINK^{TM} (extrapolation graph).

The runoff coefficient was maintained at 0.8 as the SCS CN value used throughout SWMM is 80, though this value may not reflect reality and thus have a significant influence on the generation of runoff.

The reservoir constant (k) was calibrated because it is a parameter that influences the travel time of water in the system and consequently the shape of the outflow hydrograph and the quantity of CSO discharge at the outlet of the system.

2.3 Modelling with design storm

The system was first analyzed using design storms. For this, the analysis made by Delbeke (2001) of The Royal Meteorological Institute (RMI) of Belgium was used. Indeed, the design storms were derived to reduce the number of runs needed to analyze and understand the system's performance and behaviour under design flow conditions. We used a composite design storm corresponding to 20, 10, 5 and 2 years of return period to represent both extreme and moderate storms.

2.4 Modelling with historical storm

For this, we selected some interesting historical storms, a time series of hourly rainfall data (recorded by FlowBru) between 2000 and 2008. The storm events of different intensities and different durations were selected to cover the wide variety of rainfall patterns that occur in Belgium. Altogether we selected 16 storm events, with storm duration ranging from 33 hours to 310 hours.

3 Results and Discussion

3.1 Modelling with design storms

Table 3 shows the comparison of total CSO volume sent to the receiving water simulated by the SWMM and COSIMAT. As it can be observed, the error in the total CSO volume discharged into the receiving water ranges from 10.6 % to 4.73%. As expected, a lower error was observed in the case of the less extreme design storms with the lower return period. In average the CSO volume simulated by COSIMAT was underestimated by 8.63% which can be evaluated as reasonable regarding the simplifications introduced in the conceptual model compared to SWMM. But for all the cases, the COSIMAT underestimated the CSO volume as compared to the SWMM. This can be explained by Figure 5 which shows the SWMM and COSIMAT simulated hydrograph for one hour duration storm event (total depth 26.41 mm) corresponding to a return period of 10 years. As can be observed, the hydrographs are fairly matching. The problem in particular is in the rising limb as well as the recession limb of the COSIMAT simulated hydrograph. The recession limb of COSIMAT simulated hydrograph ceases too early as compared to the SWMM simulated hydrograph which leads to the underestimation of the total CSO volume. However, the peak discharge of COSIMAT matches closely with that of SWMM and this is typical for most of the CSO volumes sent to the receiving water.

3.2 Modelling with historical storms

Table 4 shows the comparison of total CSO volumes sent to the receiving water from SWMM and COSIMAT for 16 historical storms. The difference ranges from -12.57 % (underestimation by COSIMAT) to +4.67 % (overestimation by COSIMAT). In average, the CSO volume simulated by COSIMAT deviates from that of SWMM by 7.40%.

Figure 6(a) shows the observed and SWMM simulated hydrographs for storm event 14 (258 hours starting on 29/11/2007 at 14:00). As it can be observed, the model fairly reproduced the observed discharge at the outlet of the system. Figure 6(b) shows the scatter plot of the same storm with the discharge transformed using Box-Cox (BC) transformation (Box and Cox, 1964). The parameter ‘λ’ of the transformation is chosen to be 0.25 as suggested by Willems (2009). The transformation is needed because the model residuals in rainfall-runoff model increases with higher flow values (Willems, 2009) which is undesirable since these high values significantly influence the model results when calculating goodness of fit statistics such as Nash-Sutcliffe Efficiency – NSE (Nash and Sutcliffe, 1970) and Mean Squared Error (MSE). The BC transformation with appropriate ‘λ’ makes sure that the model residuals are homoscedastic (Willems, 2009). As it can be observed in Figure 6(b), the mean deviation is slightly below the bisector line indicating a slight underestimation by the SWMM. Also, the model results show some scatterings (discharge points outside the standard deviation lines) too. In this case, the discharge points are normally distributed; the standard deviation lines represent 68% confidence limits too. The NSE and MSE values are found to be 0.79 and 1.14 m^3/s respectively. These goodness of fit statistics complemented by the graphical plots show that the SWMM simulated flows are very good according to Moriasi et al. (2007)’s criterion.

Figure 7(a & b) show an identical plot as Figure 6(a & b) but the comparison is between the SWMM simulated discharge and COSIMAT simulated discharge for the same storm event (storm event 14, Table 4). As it can be seen, the COSIMAT has fairly reproduced the SWMM simulated discharge but with lesser accuracy. As it can be seen in Figure 7(a), the COSIMAT underestimated most of the peaks which is reflected in Figure 7(b), where the mean deviation lies slightly below the bisector line. Also, the model results show more scatterings as the number of discharge points could not be contained by the standard deviation lines. The NSE and MSE values are found to be 0.66 and 1.32 m^3/s respectively. These goodness of fit statistics complemented by the graphical plots show that the COSIMAT simulated flows are good, according to the Moriasi et al. (2007)’s criterion although the COSIMAT showed problems reproducing the peak flows.

4 Conclusions and recommendations

We tested the potential of a continuous simulation model (COSIMAT) to mimic detailed hydrodynamic model, the Storm Water Management Model (SWMM) in view of simulating the total CSO volume sent to receiving water. We tested it to simulate CSO and flow at the outlet of a fairly important collector of WWTP-North, the Paruck collector. We observed that the COSIMAT model could reproduce the total CSO volume sent to the river with some accuracy. The average difference in total CSO simulated volume between the COSIMAT and SWMM was found to be 7.40 % for the 16 considered storm events. COSIMAT also reproduced the hydrograph at the outlet of the considered sewer system with reasonable accuracy and with substantial decrease in calculation time. The problem of COSIMAT showing quick response in simulated hydrographs compared to SWMM is an issue that requires further investigation though this had a little influence on the results of total CSO sent to the receiving water. From this, we conclude that it is not always necessary to represent a sewer system with a detailed hydrodynamic model. Conceptual models like COSIMAT can reproduce the situation with reasonable accuracy, with reduced calculation time and without numerical instabilities. Such a conceptual model can be a part of an integrated modelling system to represent the sewer system which in turn can decrease the calculation time substantially and thus, a feasible integrated modelling system can be put into operation.

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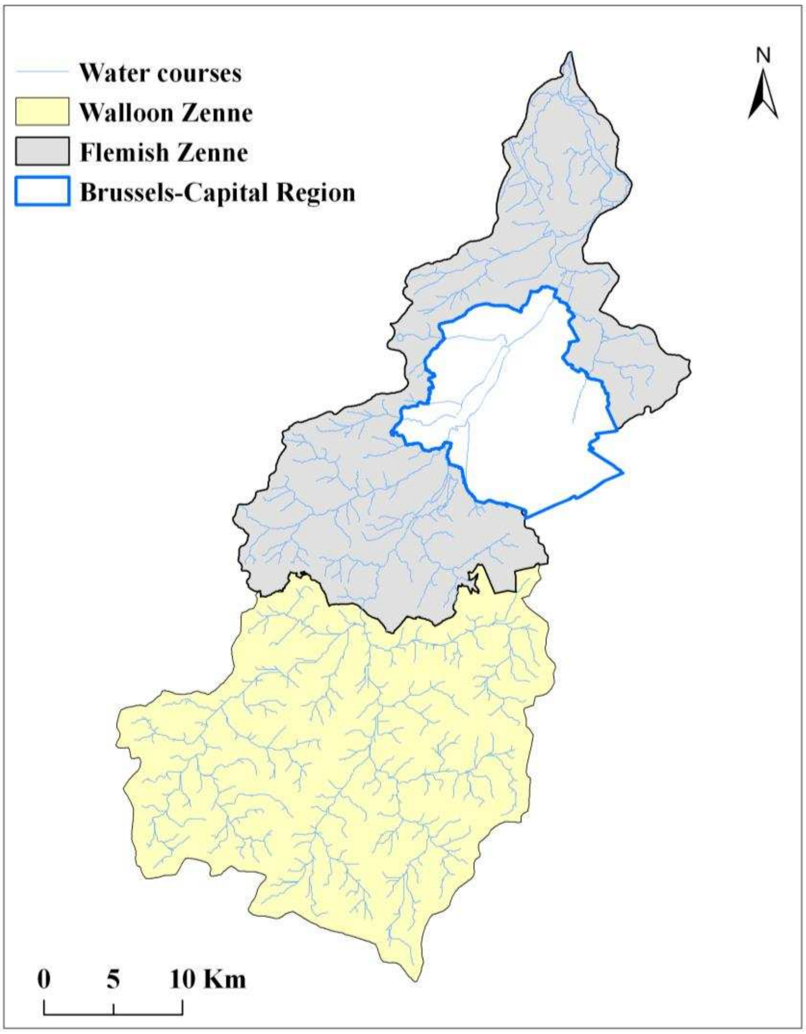

Figure 1: The Zenne river basin with its subbasins in three administrative regions of Belgium, and water courses.

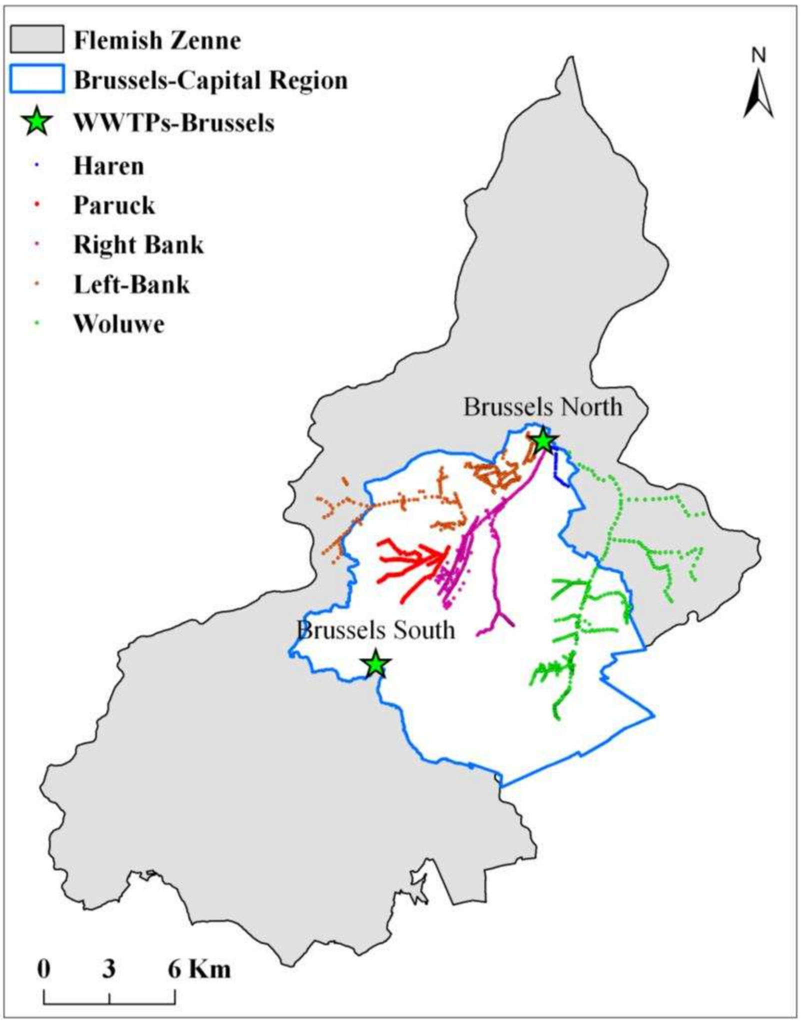

Figure 2: The Flemish subbasin of Zenne with two WWTPs located in Brussels and, the major sewer collectors of the WWTP-Brussels North.

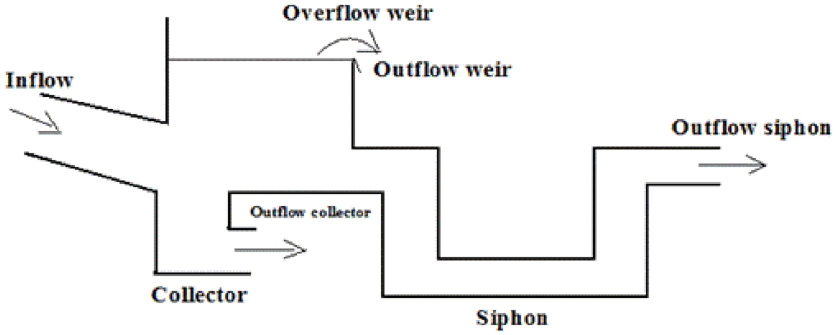

Figure 3: Schematic representaion of flow partitioning at the outlet of the Paruck collector in the SWMM

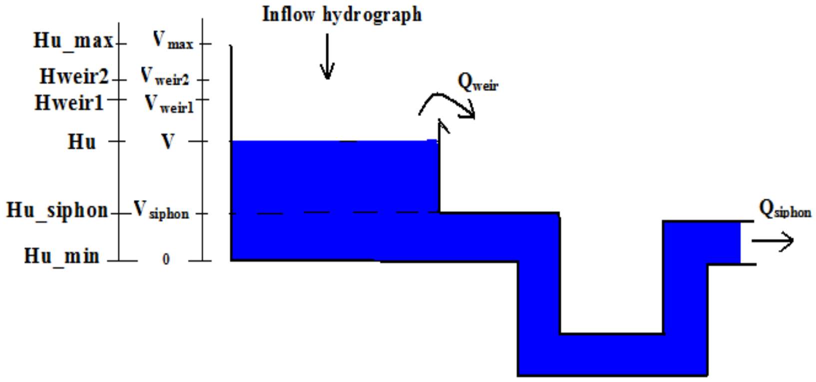

Figure 4: Schematic conceptual representation of the system in the COSIMAT

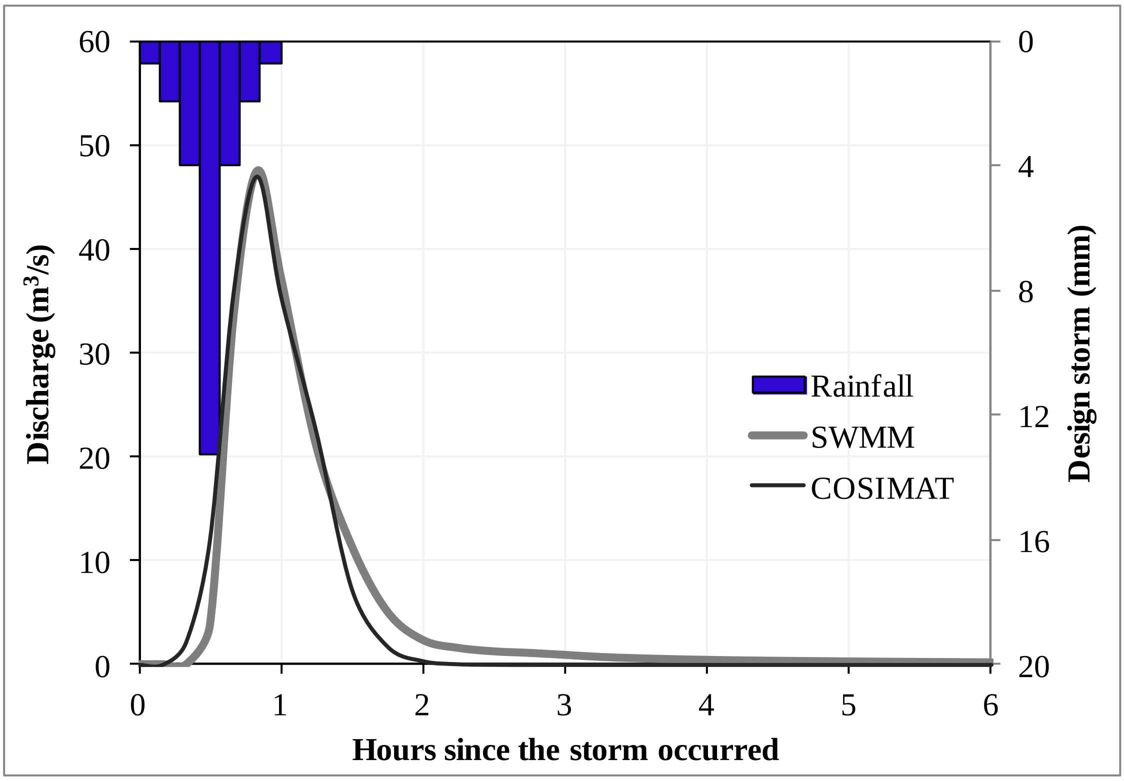

Figure 5: SWMM and COSIMAT simulated hydrograph for one hour design storm corresponding to 10 years of return period

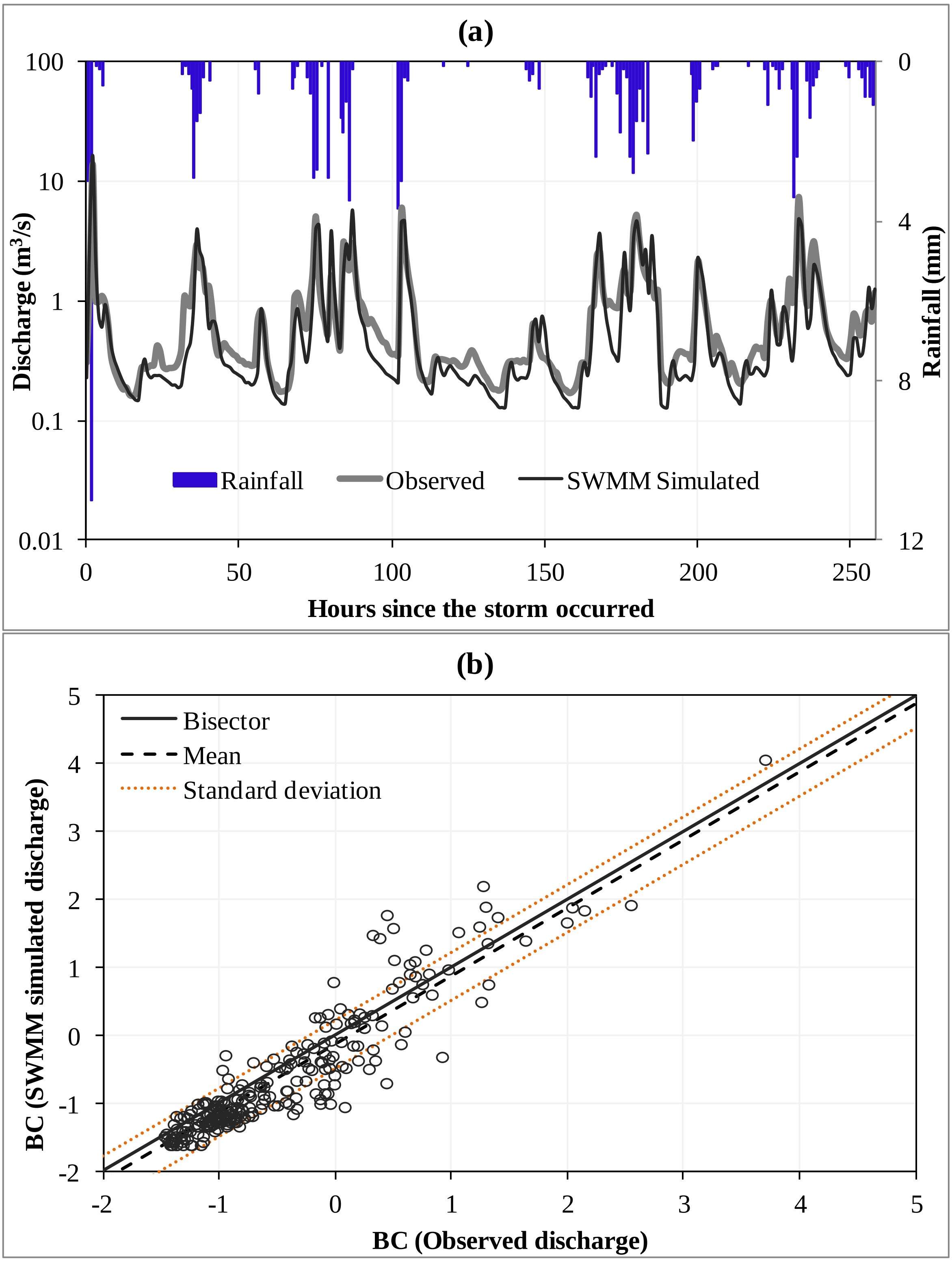

Figure 6: (a) Hydrograph and (b) scatter plot after applying Box-Cox transformation (λ = 0.25) with bisector, mean and standard deviation of observed and SWMM simulated discharge for the storm event 14 (29/11/2007 14:00 - 11/12/2007 03:00)

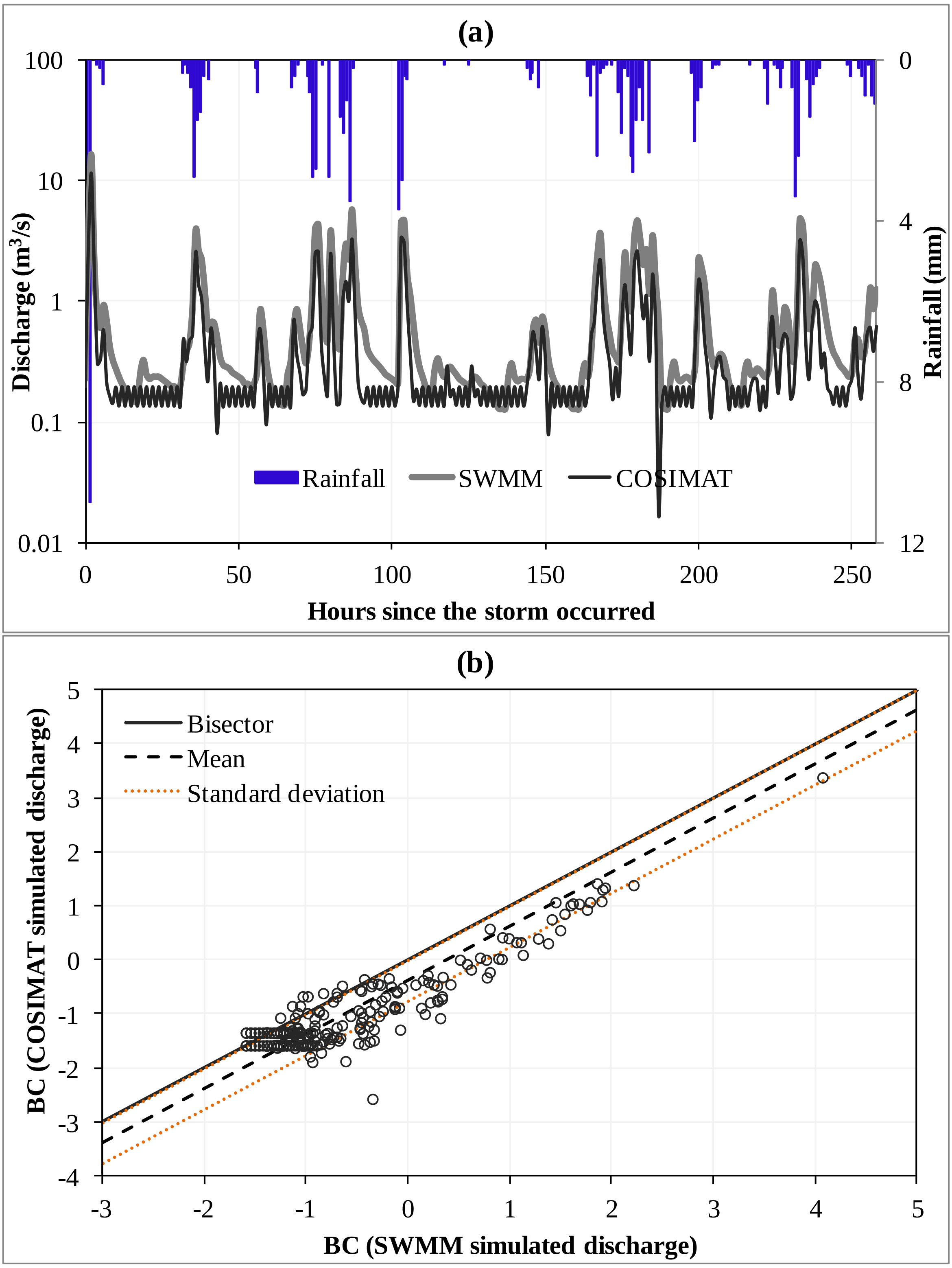

Figure 7: (a) Hydrograph and (b) scatter plot after applying Box-Cox transformation (λ = 0.25) with bisector, mean and standard deviation of SWMM and COSIMAT simulated discharge for the storm event 14 (29/11/2007 14:00 - 11/12/2007 03:00)

Table 1 The SWMM model characteristics of the Paruck system

Characteristics	**Values/Methods**
Area	1001ha
Impervious area	520ha
Number of subcatchments	24
No of inhabitants	101900
Dry Weather Outflow	340 lit/ha/day
Infiltration model used	SCS-CN
Number of rain gage	1
Routing model	Dynamic wave
Force main equation	Darcy-Weisbach
Number of conduits	189
Number of junctions	188
Number of weirs (side flow weirs)	2
Number of siphons (same characteristics)	4

Table 2: Parameters values of the COSIMAT used for the Paruck system

Model Components		**Parameter**	**Symbol**	**Values**	**Unit**
Hydrologic		Area	A	5200000	m²
		Wetting loss	-	0.50	mm
		Depression storage	L_{max}	1.40	mm
		Runoff coefficient	C	0.80	-
		No of inhabitants	Inh	101900	-
		Dry weather flow	DWF	340	lit/ha/day
		Reservoir constant (subjected to be calibrated, varies with the storm events)	K	180-360	sec
		Maximum storage capacity of reservoir	S_{max}	2198	m³
		Minimum storage capacity of online reservoir	S_i	0	m³
Hydraulic	Collector	Minimum discharge capacity	Q_{min}	0	m³/sec
		Maximum discharge capacity	Q_{max}	1.80	m³/sec
	Siphon	Diameter of siphon	D	1.20	m
		Length of siphon	L	60	m
		Roughness coefficient	f	0.016	-
	Weir 1+2	Level of weirs crests	H_{weir}	14.35&14.55	m
		Weir discharge coefficient	C_d	2.215	-
		Width of weir	W_{weir}	19	m

Table 3: Comparison of total CSO sent to receiving water from SWMM and COSIMAT models for different design storms

Return periods (yrs)	**CSO volume (m^3) SWMM**	**CSO volume (m^3) COSIMAT**	**Error (%)**	**Average error (%)**
20	132659	118600	10.60	8.63
10	113546	102100	10.08	
5	94099	85510	9.13	
2	66663	63510	4.73	

Table 4: Comparison of total CSO for SWMM and COSIMAT models for 16 historical storm events

SN	Storm start date/time	Storm end date/time	Storm duration (hr)	Rainfall (mm)	CSO volume (m^3) SWMM	CSO volume (m^3) COSIMAT	Error (%)	Average error (%)
1	07/02/2000 19:00	07/08/2000 17:00	142	48.1	134962	119600	11.4	7.40
2	07/23/2001 5:00	08/02/2001 23:00	258	55.91	280268	267000	4.73	
3	09/04/2001 13:00	09/09/2001 22:00	129	82.26	320486	280200	12.6	
4	07/22/2004 16:00	07/24/2004 1:00	33	44.92	204844	197400	3.63	
5	08/06/2004 20:00	08/19/2004 18:00	310	82.48	191555	177000	7.60	
6	06/29/2005 3:00	06/30/2005 23:00	44	61.56	254534	223900	12.0	
7	07/04/2005 09:00	07/08/2005 15:00	102	72.72	291227	254700	12.5	
8	09/10/2005 21:00	09/16/2005 5:00	128	59.48	253827	231200	8.91	
9	10/22/2005 15:00	10/25/2005 11:00	68	42.34	126681	132600	-4.67	
10	08/02/2006 21:00	08/04/2006 14:00	41	73.98	336183	298400	11.2	
11	08/11/2006 01:00	08/18/2006 7:00	174	89.54	324771	293900	9.51	
12	08/21/2006 14:00	08/29/2006 13:00	191	75.65	264964	239000	9.80	
13	05/07/2007 03:00	05/20/2007 20:00	314	47.7	50801	53410	-5.14	
14	29/11/2007 14:00	11/12/2007 03:00	258	94	185059	167400	9.54	
15	03/15/2008 23:00	03/22/2008 17:00	162	58.2	160216	149580	6.64	
16	08/03/2008 21:00	08/08/2008 17:00	116	60	246252	226300	8.10	