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Interactive comment on "On the sensitivity of urban hydrodynamic modelling to rainfall spatial and temporal resolution" *by* G. Bruni et al.

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We thank the reviewer for his time and effort in commenting our manuscript. Our response:

RC1: The study tries to draw general conclusions from what must be regarded a case study with only four events. This approach makes the manuscript appear rather confusing; on one hand the hydrological model and the rain events are described too superficially to really act as good case study, on the other hand the data basis seems not to be enough to support the general conclusions that the authors would like to make. I recommend to include (a lot) more data and to better describe the catchment and the hydrological model for the reader to understand the reasoning behind choice of sub-catchment among others. Furthermore, a more thorough reasoning on why the dimensionless indices make the evaluation is needed as they do not seem as the most obvious choice for this reader.

AC1: We agree that the study must be regarded as a sensitivity analysis on a case study with four rainfall events; we will modify conclusions to make clear that general conclusions cannot be drawn. We specified the need to investigate further the topic, but we will stress it further, since we also think this is only a first feeling of the impact that fine resolution rainfall can have in sewer hydrodynamics, and need to be further investigated. Rainfall events were chosen among the available data: unfortunately the historical records did not allow making a broader selection. IDRA radar started working with a fine resolution only in 2010, we were able to acquire and process data only from November 2010 to November 2012. The selection of events was made according to the following criteria: good data quality, significance of the event in terms of duration and magnitude (namely 1hour and 5mm/h respectively) such as they could have an impact on the specific sewer system. The system has 9 mm storage capacity and a high pumping capacity (namely 2215 m^3/h), so that many events did not have an impact on it, and differences between rainfall scenarios were very low. Therefore, we prefer to select rainfall events having a moderate to high rainfall intensity, also because we are interested in studying the impact that high intensity storms have in urban catchments. Unfortunately, only these four events met the requirements. During this time period, there were several weeks where the radar was not working due to hardware issues. Moreover, the data quality control process reduced the number of interesting data cases. In addition, storm events that do not propagate continuously, for example at least 1 hour, over the location of the virtual catchments and those storms with low rainfall rate, for example less than 5 mm/hr, were discarded. By consequence, the number of reliable and independent data cases that we could have used was limited. This study is the first of a series of studies focused on analysing the hydrodynamic behaviour of urban catchments under heavy storm conditions, so that as soon has more data will be available, we are going to extend the analysis to make it deeper and more robust. A more detailed hydrological description of the catchment and the model will be added, as the reviewer suggests, and a deeper description of the dimensionless indices will be provided (see AC9 for the amended text). Also, a deeper description of rainfall events will be provided, including storm speed, storm direction, duration of the most intense part of the storm, and what locations of the catchment where more affected. Section number 2.2 will be modified as follows: “Rainfall data were provided by CESAR, they belong to the X-band radar records. The data have been collected at 30 m range resolution and a maximum unambiguous range of 15 km approximately. Other specifications on the new generation X-band radar device can be found in Table 1. Aggregations were made from radar rainfall rates at 30m polar pixels based on reflectivity for values smaller than 30dBZ, differential phase otherwise (Otto and Russchenberg, 2011). Four rainfall storms were selected for analysis. According to the classification adopted by Emmanuel et al. (2012), they have been grouped as follows: Event 1 and Event 2: Storm organized in rain bands Event 3: Storm less organized Event 4: Light rain In Event 1, a long lived squall line was measured on January 03 2012. The convective storm moved eastward with a velocity of 20 m/s approximately. A squall line is a line of convective cells that forms along a cold front with a predominately trailing stratiform precipitation (Storm et al., 2007). Squall lines are typically associated with a moderate shear between 10 and 20 m/s and strong updraft (Weisman and Rotunno, 2004). If winds increase rapidly with height ahead of a strong front, thunderstorms triggered along the boundary may organize into severe storms called supercell storms. The X-band radar was able to capture storm features associated with supercell. The overall duration of the event was short, 1 hour in total, but the most intense peak lasted 10 minutes at the end of the storm, and with rainfall intensities higher than 100 mm/h. The most affected part of the catchment was the central and the North-western part, while the southern part was affected by light rain. Event 2, occurring on 10 September 2011, can be characterised as a cluster of convective and organized storm cells that moved in north-east direction. The storm moved north-eastward with a velocity of 16 m/s approximately. The storm system showed a convective spread area larger than the first event and with slower shift. The storm lasted 2 hours, between 1800 – 2000 UTC, being the most intense part concentrated between 1900 and 2000 UTC. Intensities ranged between 30 mm/h and 60 mm/h, and the whole central part, from South to North of the catchment was affected, while East and West bands were less exposed. In Event 3, occurred on June 28 2011 from 2200 UTC to 2400 UTC, mesoscale observations showed a non-organized squall line moving north east, with a speed of 15 m/s approximately and containing rainfall rate cores of at least 10 mm/h. Rainfall rate values of 50 mm/h were founded over small areas during 2200 – 2300 UTC, travelling from South-west toward North-east and affecting all the catchment. Lastly, Event 4, occurred in October 29 2012, is a stratiform precipitation moving eastward at 13 m/s approximately and showing uniform rainfall rates. Rainfall retrieval was based on reflectivity only, of about 8 mm/h. Storms motions and directions were estimated based on centroid-based storm association algorithm, inspired by Johnston et al (1998). For each event, total rainfall volumes in terms of minimum, maximum and mean value of all pixels affecting the area can be found in Fig.1, as well as their standard deviation, giving a first insight of the variability of the event. Fig.2 displays radar images showing the maximum intensity minute of each one of the selected rainfall events, as well as the location of the catchment with respect to them and the main direction of the storms.".

RC2: The use of symbols (e.g. RR) is not strict enough and differs between text, tables and figures. Furthermore, an i is introduced without explanation in equations 2 to 4 a long with a 100 that should rather be something like RR,1.

AC2: We apologise for the lack of uniformity in using symbols and we will correct that in the new version of the manuscript. We also will explain the "i" in the equations 2 to 4.

RC3: Generally the figures lack common communication. The manuscript would gain a lot from having the figures and tables harmonized in their appearance.

AC3: We will edit figures and table according to a uniform format. RC4: The introduction to the field is quite ok even though studies doing spatio-temporal analysis of rainfall based on rain gauge networks could be added as they from a methodological point of view is important; e.g. Niemczynowicz (1988, 1991). " AC4: we would like to thank the reviewer for the suggestion, we agree that spatio-temporal analysis based on point measurements is relevant as long as the network density is such that the interpolated field still represents in a reliable way the true rainfall field, that is the case of Niemczynowicz (1988, 1991) works, so we agree mentioning his work in the introduction.

RC5: The section heading is misleading as the section is also used to introduce the case study.

AC5: the section heading will be modified into "Presentation of the case study and datasets"

RC6: The case study area and the model used in the study to represent it are both quite poorly described. A map of the area to show where it is relative to a bigger picture would be useful. Furthermore, a map including the sewer network and flow directions would also help the reader to understand how the system works under influence of rainfall. The use of a semi-lumped model (which even does not include green areas) seems less appropriate when the systems response to fine scale spatio-temporal rainfall is to be assessed. Carter and Vieux (2012) used a fully distributed model (with the smallest investigated catchment having a total area of 4 km2) to test the influence on rainfall movement on small catchments. All in all the description of the model is to superficial for me to judge whether it is suitable for the purpose.

AC6: We will add an appendix a more detailed description of the case study together with a map showing the sewer network main directions and a deeper description of the, for conciseness of the manuscript. For a further description of the modelling software we refer to the Sobek manual, cited in the manuscript. As for the type of model used, we strongly agree with the reviewer that (fully) distributed models (here after DM) are

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best suited for the purpose of testing rainfall impact on catchments. However, we also believe that our model is what most approaches DM: runoff areas size are smaller than typical grid cell sizes of DM, usually ranging from 10 x 10 m^2 to 30 x 30 m^2.As such, our model can be considered fine enough to capture the rainfall movement across the catchment. Green areas were not included in the model, because the focus if this study is on runoff and sewer flow, the two most critical processes in urban areas. Green areas only contribute to runoff towards the sewer system during very intense rainfall events, which is not the case of our study. In Figure 1 the reviewer can find a plot in which runoff area size is shown against the percentage of exceedance. According to the plot, the maximum size of runoff area is 0,8 ha, which is less than 1 ha, namely the finest rainfall resolution used in this study. Therefore, we think that the approximation used sufficiently describes the real hydrological behaviour of an urban catchment and captures the rainfall variability described by the radar product. RC7: The rainfall data is also presented in a way which is very hard to follow. Why are these four events chosen? How do the move in relation to the catchment? There must be a lot more data available from the radar as the four events seem to be spread over at least six months and it would be very useful to include this in the analysis. It is actually not presented in this section what the native resolution of the radar is; it should be. Furthermore, spatial aggregation is discussed here; these should rather be in the methodological section and ideally be accompanied by a reason for the choices made.

AC7: Please refer to AC1. As for spatial aggregation, it will be moved to the methodological section as the reviewer suggests.

RC8: I cannot see the link between figure 1a and 1b. Why are they not termed figure 1 and 2? and why is figure 1a not made in the same way as the subsequent box-plots? AC8: Figure 1a and 1b will be separated and Figure 1b will be moved to the methodological section, together with the spatial aggregation discussion (see AC7).

RC9: In this section I expect to have a short precise description of how the proposed indices are calculated and why they are relevant. Table 2, presented early in this

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section, holds as I see it results and should as such be in the results section. In Table 2 Rr and RRL are both given units of meters but in Figure 2 they seem to be areas.

AC9: Table 2 will be moved to results section. Figure 2 will be modified, since the proposed units are indeed meters. The description of the proposed indices will be improved in the method section as the reviewer proposes. The section “3.2 Dimensionless parameters” will be followed by (text amended from original manuscript):

3.2.1 Rainfall sampling number

“Rainfall sampling number” was defined as the ratio between rainfall spatial resolution (RR) and storm de-correlation length (CD) in order to study rainfall gradient smoothing in terms of the relationship between the estimated rainfall field and the storm inherent structure. This parameter is similar to the “storm smearing” effect defined by Ogden and Julien (1994); it accounts for the deformation of the storm structure caused by rainfall measurements of coarser resolution than the storm length. For instance, rainfall intensities in storm cells with sizes smaller than applied rainfall spatial resolution will be averaged out, leading to an underestimation in rainfall rates in the area affected by the storm cells and a overestimation in the area surrounding the cells. In other words, as RR tends to CD, rain rates in high intensity regions tend to decrease, and conversely rainfall intensities in adjacent regions tend to increase. The overall effect is a reduction of rainfall gradients. Dimensionless rainfall sampling number quantifies this effect. 3.2.2 Catchment sampling number The second dimensionless parameter, “catchment sampling number”, also named by Ogden and Julien (1994) as “catchment smearing”, was defined as the ratio between rainfall resolution RR and catchment length CL. It accounts for rainfall transfer across catchment boundaries, as the rainfall spatial resolution approaches the size of the catchment. When the parameter exceeds 1, rainfall variability is not captured by the catchment. In other words, when dealing with small size storms, the position of the storm with respect to the catchment affects the response: a storm localised at the boundaries of the catchment, can “disappear” or “shift” if rainfall intensities are aggregated to lower resolution. This averages the rainfall over the catchment and may lead to rainfall falling outside the catchment boundaries but inside the low resolution rainfall pixel to be affecting the catchment. This effect is quantified by the catchment sampling number, relating the size of the catchment to the size of the radar pixel. 3.2.3 Runoff sampling number The third parameter is called “runoff sampling number”, which is the ratio between rainfall resolution and runoff area resolution. This, similar to catchment sampling number, quantifies the correct assignment of rainfall values to the corresponding runoff area. The higher this ratio, the less precise is the rainfall assignment to the correct runoff area, but also the lower this ratio, the more unable is the model to capture rainfall variability, as the model resolution is coarser than the rainfall resolution. Here we are focusing on the rainfall-runoff module of the model, which has rainfall as input and runoff discharge into one of the nodes of the sewer network as output. Runoff sampling number relates model input data resolution to runoff model resolution, and intends to measure the “smearing” of runoff flows induced by low rainfall versus runoff area resolutions. Sewer sampling number The fourth dimensionless parameter is the “sewer sampling number”, defined as the ratio between rainfall spatial resolution and intra-sewer length, computed as the average length of conduits in the system, which corresponds to the inverse of sewer network density. The lower the sewer sampling number, the less sensitive is the drainage network to rainfall variability: a low “sewer sampling number” means that the inter-pipe distance, is higher than the rainfall pixel size, so the sewer system cannot catch rainfall variability. Conversely, for higher sewer sampling numbers rainfall input is too coarse compared to the sewer network density and this may result in lack of accuracy of modelled water levels and sewer overflows. The “smearing effect” for sewer flows is related to the runoff smearing effect, quantified by the runoff sampling number, but they differ in this respect: the latter focuses on runoff model output, namely discharge towards the sewer network, while the sewer index represents the routing within the piped system and so it quantifies the smearing effect in in-sewers water levels. Water levels in pipes are affected by runoff discharge but also by upstream sewer inflows, so it is not possible to isolate the effect at the level of individual pipes but it is measured at the outlet of each independent sub-catchment.

RC10 Directional semi-variograms are used to calculate de-correlation length of the storm events. As radar data is used it would seem very appropriate to use a cell tracking algorithm (e.g. Crane (1979) or something newer) instead and use the shortest distance across the cell as a measure for the critical distance. Also the direction of the semi-variogram is mostly interesting if it is linked to the dominant storm movement direction and to the design of the sewer system in an assessment of whether it is mowing upstream of downstream through the catchment (as done by Carter and Vieux (2012)). You discuss how the characteristic lengths of the model is a choice of the modeller, but does it make any sense to do the analysis you do unless you have very fine-scale distributed models?

AC10. We agree with the reviewer that the storm cell algorithm is an interesting approach and a reliable method to assess the critical distance. However, we believe the semi-variogram method is also reliable, when the size of the storm has to be addressed. The semi-variogram is used in several studies to describe storm properties, such as Haberlandt, U. (2007), Verworn, A. and U. Haberlandt (2011), Emmanuel et al. (2012), among others. We decided to cover the whole angle spectrum at angle step of 45°, instead of choosing the storm direction, since the latter is not unique but it varies according to its temporal evolution. The analysis carried out by Carter and Vieux (2012) is indeed very interesting, but the case study is rather different from ours and in general from lowland urban catchments: in our case study the sewer network does not have a single dominant direction, but each subcatchments drains toward the main pumping station, which is located at the centre of the catchment. Consequently, an analysis focused on the direction of the storm with respect to the catchment flow is rather unfeasible. As for last sentence of RC10, we refer to comment AC6, where it is explained that the resolution of the runoff model is in fact very high with maximum runoff area sizes below 1 ha.

RC11. It is very unclear how the sub-catchments are chosen, and if the system is such that the water can flow in many directions depending on where there is water in the system it seems to me to be a very poor area to use for demonstrative purposes.

AC11: the case study has been chosen as pilot case to address the impact of rainfall on sewer hydrodynamics in lowland areas, such as delta cities, where almost half of the world population lives (44% of world population lives within 150km from a coastline, according to UN Atlas of the oceans, see web reference). Characteristics of our case study are representative of lowland areas: looped sewer networks with no unique flow direction storage dominating over drainage under most rainfall conditions. In this light, we believe it is an interesting and relevant case study to analyse. This will be stressed in the introduction (From line 9 page 5995) by the following sentence: “Rotterdam catchment has been chosen as pilot case of urban districts in lowland areas, representative of delta cities, where almost half of the world population lives. Lowland catchments are characterised by flat terrain, therefore the mechanism dominating sewer flow is different from sloped terrain, where flow is driven by gravitation.”

As for subcatchments delineation, in order to explain better how they were defined, we will remove lines 10 to 12 on page 8 and we will add instead:

“For this reason, in order to define subcatchments boundaries, we performed the following steps (according to a previous work of ten Veldhuis and Skovgård Olsen (2012)): We run simulations under long-lasting uniform storms We made sure no overflow towards surface water bodies occurred (in that case, a direction change would affects the sewer flow) We detected sewer pipes with $Q \leq 0$ We delineate subcatchments as if the latter were removed We compared flows at outlets of the 11 subcatchments in “looped” conditions (the original model) and “branched” conditions (model after the removal of cross boundary conduits). We found high agreement between the two results; therefore we accepted the catchments delineation as a satisfactory approximation. A visual inspection of the sewer network helped to understand the direction of flow: since no overflows occurred for the events used in this study, the system drains received water toward the main pumping station. uUnder this condition the main sewer conduits collect all water from peripheral conduits. We could therefore observe the flow direction in the main conduit."

RC12: The dimensionless parameters presented in Table 3 appear as results and should as such belong in the results section. The methods section should rather include a clear reasoning for why they are relevant and how they are estimated.

AC12: The authors agree with the reviewer. Table 3 will be moved to results section, and more explanation will be delivered on the reason and the way parameters are estimated. For the reasoning behind the choice of dimensionless parameters, we refer to AC9.

RC13: In the 'Effect of spatial resolution' section sentences like "the storm cell shift southward due to the spatial aggregation but the core of the storm remains within the catchment boundaries" (p6004, l2-3) are used and it is concluded that in general the location of the storm is of major importance. On that basis there need to be a very through description of the input data for the reader to follow your reasoning.

AC14: The rainfall event description will be improved, see AC7.

RC15: In Figure 5 it would help the reader a lot if each row had the same y-axis, as it is presented now it is not very clear that the spread for the first event is much larger than for the others.

AC15: Figure 5 will be modified to give the same y-axis for an easier comparison.

RC16: In Section 4.1.3 you present quite some methodology (p6005, l8-15) which would be more suited in the methods section. Moreover, if 0 and 180 degrees are the same then only report one of them and the manuscript lack reasoning for the choice of angels and there relation to dominant wind directions (or other relevant weather variables).

AC16: We agree with the reviewer; the methodology description will be moved to the methods section. As for semi-variogram angles, please refer to AC10.

RC17: Also, I see a methodological problem in only using the 100 m resolution for determination of CD since if it can be determined that accurate there is really no reason for using coarse rainfall data. You need to determine CD for the different spatial aggregated products as it will likely change.

AC17: Storm correlation length (CD) is defined to give information about the real size of the storm, for that reason it is estimated from the finest rainfall resolution. Any coarse rainfall resolution is seen as a deformation of the storm field, so the CD derived from those is not used in the study. CD is used to obtain the rainfall sampling number, which represents the “rainfall smearing” effect caused by the coarsening of rainfall resolution. The variation of CD for different spatial resolutions is out of the scope of the paper.

RC18: The results presented in Figures 7 and 8 are what are really interesting. Unfortunately, with data from only four events it is impossible to say anything general. Propagate all the data you have available through your framework and one Figure 7 plot where it can be seen that the spread/variance/scatter increases with increasing RR/CD. And the same for Figure 8: More data and discussions regarding the trend. Figure 9 has some of these elements and the conclusions you can draw is hence much clearer.

AC18: Fig. 7 shows deviations in in-sewer water depths against rainfall sampling number. We looked at deviations only at the outlets of the 11 sub-catchments, and not at each internal node separately, because the water depth inside the sub-catchment is affected also by the contribution of surrounding nodes, so effects cannot be separated. Fig.7 shows fewer values on the x-axis because rainfall sampling number is computed as the ratio of rainfall resolution (4 values) and storm de-correlation length, derived from four rainfall events, while fig. 9 has more values in x-axis because sewer sampling number is the ration between rainfall resolution (4 or them) and sewer length (11 of them). Fig. 8 shows deviations in flows averaged within each of the 11 sub-catchments. Similar to Fig.9, results are plotted against indices customised for each sub-catchment. As for the reduced number of rainfall events, please refer to AC1.

RC19: With respect to the section on the effect of the temporal resolution it should have a more prominent place in the discussion as 1 min is extremely fine scale radar measurements and 5 or 10 min are much more in line with operational radar products.

AC19: In the light of the results we obtained, i.e. the impact of temporal resolution coarsening was very low on model results; we decided to give more room to the discussion on spatial resolution effect. We decided to postpone a more comprehensive discussion on temporal resolution once a more consistent dataset will be available, but we did not want to renounce to give this first flavour on temporal resolution impact on sewer results.

RC20: Generally I agree with you that “To give a more robust meaning to these sampling numbers, more storm events should be analysed to confirm the findings of this study” (p6013, l5-6), but I will actually take it a step further and claim that with only four events the actual location of the events relatively to the catchment is of such importance that no conclusions can be drawn.

AC20: From line 16 page 17 Conclusions will be re-written as: “- As the ratio RR/CL increases (in this particular case for RR/CL > 0.2), there is a progressive decrease of both rainfall volume mean and standard deviation: rainfall gradients decrease. This is the result of the smoothing effect of rainfall resolution coarsening and of the smoothed storm core extending beyond the catchment boundaries. Spatial resolution effect strongly depends on the location of storm cells relative to the catchment; the closer the cells are moving to the catchment boundary, the stronger the effect. - As the ratio RR/CD increases (in this particular case for RR/CD > 0.9), ‘rainfall smearing’ occurs, inducing deviations in maximum modelled in-sewer water depths. For the current case-study and for rainfall resolutions exceeding the storm de-correlation length, the flattening of rainfall gradients do have an impact on model performance and its magnitude depends both on the type of rainfall (as classified in rainfall description section) and on how much the rainfall field is de-structured by the coarsening. Results are in line with what was found by Odgen and Julien (1994), - As the ratio RR/RRL increases, deviations in runoff peaks occur. For RR/RRL > 20, deviations in runoff peaks are above 10%. This means that, in the case of Rotterdam case study, when operational weather radar product are used to feed the model (1000m spatial resolution), runoff model outputs are sensitive at runoff area resolutions lower than 50 m. - As the ratio RR/SWL increases (here for RR/SWL > 10), maximum water level depths start diverting from the reference case (100m resolution). However, deviations are small, i.e. of the order of 10% at most. In general there is a low impact on sewer model outputs due to rainfall spatial coarsening, due mainly to the smoothing effect of the flow routing through the pipe system.

Moreover, an analysis of the change in spatial structure of rainfall due to time aggregation has been conducted, and therefore of the impact on model results has been quantified in terms of time shift of maximum water depths with respect to the reference case, i.e. 1 min temporal resolution simulation. The experimental anisotropic semi-variograms computed for the three temporal aggregations show how rainfall field structure changes due to the temporal resolution coarsening. In these four events, it affects the rainfall correlation length, which increases along with time aggregation (see Table 3). In all rainfall events, the model smoothes the rainfall field variation caused by the temporal aggregation, and it results in peaks time shift generally lower than 6 min. Model performance is affected by rainfall temporal aggregation only when the rain field is completely distorted, this happens only in case of Event 3. This is a first attempt to characterise how the effect of space and time aggregation on rainfall structure affects the hydrological modelling of urban catchments. In other words, how the rainfall change in resolution is absorbed by the model, giving indication on the scale relationship between the resolutions of the main component affecting the modelling: storm structure, its representation, catchment size, and model resolution. This study shows the results of four rainfall scenarios inputted into a hydrodynamic model of Rotterdam central district. To give a more robust meaning to these sampling numbers, more storm events should be analysed and more catchments should be tested to confirm the findings of this study as well as sewer observations to test the performance

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of the model under different rainfall resolution scenarios. Such an extension of the study would allow giving reliable recommendations on what should be the model and rainfall resolution in order to prioritise either the improvement on rainfall estimation or catchment hydrological characterization."

References

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Appendix 1

SOBEK software description

Sobek 212 is a semi-distributed hydrodynamic model from Deltares. It accounts for two modules: the rainfall-runoff module and the routing module. In the rainfall runoff module four different types of surfaces are used depending on the runoff coefficient and slope: closed paved, open paved, flat roof and sloped roofs (with a slope greater than 4%). These four categories show different runoff factor and storage coefficient. The resulting runoff is calculated based on "rational method", where the runoff "Q" is given by the following equation: Q (mm/h)=c (hˆ(-1))*p (mm) (a) where p is the net rainfall and c is a runoff factor which accounts for the delay of the rainfall as overland flow to the entry point of the sewer system. The runoff factor is a function of the length, roughness and slope of the surface (Sobek, 2012). The runoff coefficient is defined as a number between 0 and 1. A coefficient of 0.5 will mean that 50% of the runoff volume will reach the sewer entry point in 1 min. The runoff factor moves the centre of mass of the resulting hydrograph, thereby increasing the lag time. The runoff formula is applied to each one of the runoff areas connected to the node of the sewer. In semi-distributed models, the whole catchment is split into a number of sub catchments (runoff areas), each of which is treated as a lumped model (i.e. within each subcatchment rainfall input and hydrologic responses are assumed to be uniform; their spatial variability is not accounted for). Rainfall is inputted uniformly within each subcatchment and based on the subcatchment's characteristics, the total runoff is estimated and routed to the outlet point, which is a node of the sewer system. Once the water enters the sewer, the routing is computed by means of the complete 1 dimension De Saint Venant equations.

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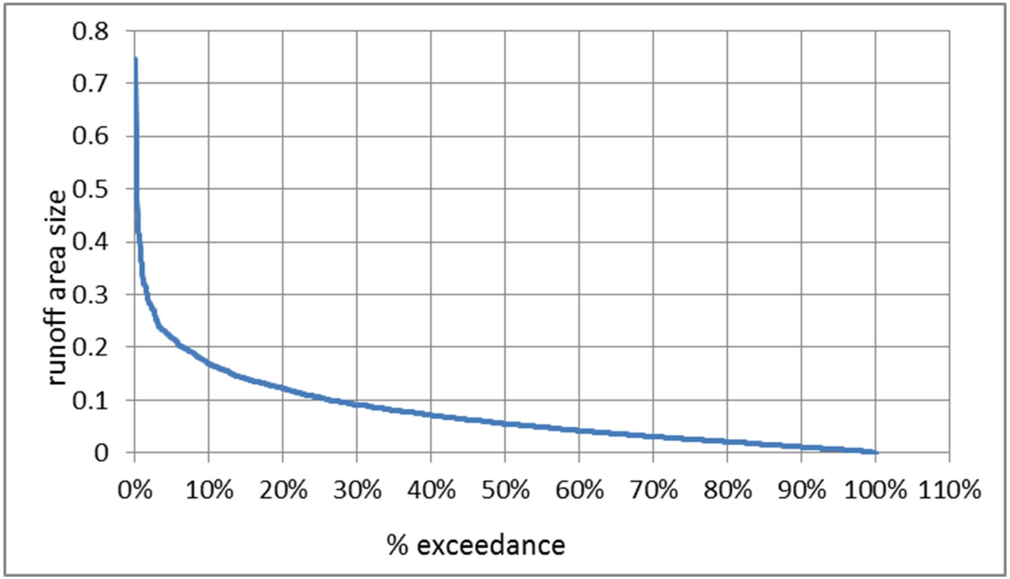

Fig. 1. Percentage of exceedance of runoff area size.