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Hydrology and Earth System Sciences Discussions

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Interactive Comment

Interactive comment on "Research on the initial abstraction – storage ratio and its effect on hydrograph simulation at a watershed in Greece" *by* E. A. Baltas et al.

E. A. Baltas et al.

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Thank you very much for your constructive comments. They have contributed to the improvement of the paper. All suggestions and technical corrections have been taken into account and all sections in the revised paper have been rewritten.

Author comments on Referee 3 Specific comments

1) P.2172 L. 17-29. Which hydrologic soil groups do these formations correspond to?

Geologically, the study area consists approximately of 60% schists, 23% conglomerates, 9% marls and 8% marbles. The hydrologic soil groups, commonly associated

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with the soil infiltration rate, are obtained based on measurements of native, undisturbed soil samples (Gregory et al., 1999; Lim et al., 2006). The hydrologic soil group that corresponds to the geological formations of the entire watershed, except for marls, is Group A, based on measurements of infiltration rate and hydraulic conductivity at different sites of the study area. All data and measurements are publicly available via the website of the experimental watershed: http://www.xbasin.chi.civil.ntua.gr. The limit values of water transmission for the classification of soils into hydrologic soil groups are included in Appendix A (NRCS, 2003). Marls are impervious geological formations consisting mainly of clay and are classified into the hydrologic soil group D with very low to zero infiltration rate and high runoff potential.

2) P.2173 L.26 and P.2174 L.4 Why were these two conditions imposed?

Regarding the criterion for the selection of storm events: ‘’The antecedent soil moisture conditions to be as high as possible’’. This criterion was rewritten as: ‘’The antecedent runoff condition (ARC) of the watershed should be average or high, ARC II or III, correspondingly’’. According to Hjelmfelt (1980b), SCS method performs better if the amount of water retained during runoff is a small fraction of rainfall. ARC II or III implies that the retained water will be comparatively a smaller fraction of rainfall. Therefore, the selected events were predominantly winter and spring events. ARC depends on antecedent soil moisture condition, which is closely associated with antecedent precipitation. The 5-day and the 10-day antecedent precipitation were determined for each event. The 5-day antecedent precipitation ranged approximately from 20 to 100 mm in ten out of the eighteen storm events, while in the remaining eight, it was lower than 3 mm. However, the 10-day antecedent precipitation ranged from 15 to 60 mm in five out of these eight events and only in the remaining three events it was insignificant. NRCS now uses antecedent runoff conditions rather than antecedent moisture conditions and has determined that the prior 5-day precipitation is not the best indicator of the antecedent runoff conditions (Woodward and Plummer, 2000). The Antecedent Runoff Condition

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(ARC) depends on rainfall intensity and duration, total rainfall, soil moisture conditions, cover density, stage of growth, and temperature (NRCS, 2004). ARC is divided into three classes: II for average conditions, I for dry conditions, and III for wetter conditions.

Regarding the criterion for the selection of storm events: ‘’The peak flow rate of the hydrograph should be higher than 0.2 m3/s’’. This criterion was defined, since a lower peak value in a watershed area of approximately 15 km2 indicates an insignificant event for analysis.

3) P. 2179 L. 2179; P. 2188 tables 3 and 4. Are the CN values consistent with regards to the soil types, landuse characteristics and soil moisture conditions? Is the variation of CN values between events to be expected? Is this span “logical”? What is it due to? If the authors do not intend on discussing the CN values, it would be advisable to delete equation 4 and remove the corresponding columns in tables 3, 4 and 5.

The original CN table (SCS, 1964) has been produced based on the assumption of the empirical 20 percent Ia/S ratio (Lim et al.2006; Hawkins et al. 2002). A new CN table needs to be calculated if a 5 percent ratio is used in runoff estimation, since the value of S with a 5 percent Ia/S value is not the same as the one used in estimating direct runoff with a 20 percent Ia/S value. Hawkins et al., 2002 determined a relationship that permits conversion from the 0.20-based CNs to 0.05-based CNs and a table with conjugate curve numbers that gives the CN0.05 corresponding to values of CN0.2 (ARS/NRCS, National Bulletins/NB.210.6.2). In this paper, the average Ia/S ratio of the watershed was equal to 1.4 percent. This was approximately the ratio value in most of the events. The table with conjugate curve numbers from Hawkins et al., 2002 was used to convert the determined CN values to the values of the original CN table and then relate these values to hydrologic soil groups, landuses and hydrologic conditions. This CN conversion contains a small error, since the table concerns only CNs based on 20 and 5 percent (Ia/S) ratios and not 1.4 percent, but constitutes a

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satisfying approach. The average CN for the northern subwatwershed was 24 and CNs varied only slightly. CN 24 corresponds to CN 39 in the original table, indicating Pasture, hydrologic soil group A and good hydrologic condition. This is consistent with regards to the description of this part of the watershed in the section of the study area of the paper. The average CN for the entire watershed was 42. This corresponds to 57 in the original table, indicating Pasture, hydrologic soil group A and moderate to poor hydrologic condition, which is consistent with regards to the description of the watershed. The CNs were not steady from event to event. The variation in CN values was noticeable in the events with rainfall depth lower than 20 mm, in which the CN values were comparatively the greatest. On the contrary, CNs varied slightly in the events with rainfall greater than 40 mm. In the events with rainfall depth lower than 20 mm the average CN was 56 and the greater CN values were noticed in the events with the lowest rainfall depth. CN 56 corresponds to CN 68, indicating Pasture, hydrologic soil group A and poor hydrologic condition. In the events with rainfall depth greater than 20 mm, the average CN was 31, which corresponds to CN 46, indicating Pasture, hydrologic soil group A and moderate hydrologic condition. Overall, the determined CN values are consistent with regards to the geological formations and the landuses of the watershed. Ponce and Hawkins, (1996); Jain et al., (2006) mention that the variability in CN is largely attributed to the spatial and temporal variability of rainfall, quality of measured rainfall-runoff data, and the variability of antecedent rainfall and the associated soil moisture amount. According to (NRCS, 2004) the variability in CN results from rainfall intensity and duration, total rainfall, soil moisture conditions, cover density, stage of growth, and temperature.

4) On page 2181 L.1 the authors state that “The time to peak flow is defined as the period of time from the beginning of the rainfall to the time of the peak flow”. For the multi-modal hydrographs (i.e. events of Nov. 25 and October 31), which peak was considered? The one with the highest value or the first one in time?

In multi-peak hydrographs, the peak with the highest value was considered and not the

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first one in time.

5) On page 2182 L.12 the authors state that the initial storage influence is greater on the time distribution of short-duration events. But given the fact that these events seem to have lower flow values, can it not also be due to measurement errors?

The peak flow estimates of SCS(2) method were higher than those of SCS(1) for the most of the events e.g. events of 23-25/11/2005 in Fig. 5. The use of the empirical ratio in SCS(2) method led to the overestimate of initial abstraction, which ranged from two to ten times the observed, with the greatest differences in the highest rainfall/runoff events. This overestimate led to the substantial delay in the beginning of excess rainfall. Therefore, the total excess rainfall of the event was allocated in a shorter time period, resulting in overestimated excess rainfall values and consequently, overestimated flow rates. In the category of low-rainfall events, with rainfall depth lower than 15 mm and duration shorter than 6 hours, the relative errors in SCS(2) simulated peak flow values were consistently higher than those for the other events. This is attributed to the great delay in the starting point of the simulated hydrograph, in relation to the total duration of the event. The probability and the effect of measurement errors are greater on large storm events with very high peak flow rate (greater than 7 m3/sec - this is approximately the greatest flow rate that has been measured). The measurement errors at low flow rates are insignificant.

6) On page 2182 L. 20 the authors state that the low amount of initial abstraction is owed to the impervious areas of the Drafi settlement. Can’t it also be related to the fact that all events are in nearly saturated conditions (P. 2173 L. 26) ?

The antecedent runoff condition (ARC) of the watershed in all events is classified as ARC II or III and plays an important role in the amount of initial abstraction. The graph of initial abstraction Ia versus retention S shows that the initial abstraction is not steady from storm to storm, but is proportional to retention. When the retention increases, the initial abstraction also increases. This indicates that the initial abstraction of the entire

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watershed is not only affected by the impervious areas, either those of the residential area or of the impervious marls. It also depends on ARC, which among others (NRCS, 2004), depends on the antecedent soil moisture condition of the geological formations. The ARC was average or high and contributed to the low amount of initial abstraction.

7) P. 2198-2204 fig. 5-10. Please rescale the Y axis so that the readers can visualize the relative importance of each event. These figures could also be presented on a single page.

The Y axis was rescaled so that the readers can visualize the relative importance of each event. The images of the events were grouped into 2 categories, high and low rainfall/runoff events.

Author comments on Referee 3 General comments

1) The literature review presented by the authors is poor: 12 references of which 4 are MSc theses! The introduction fails to highlight the originality of the presented work or to give proper credit to recent work on the SCS model (e.g. Michel et al., WRR, 2005; Chahinian et al., Journal of Hydrology, 2005; Mishra and Singh, Hydrological processes 2004, Mishra et al., 1999; Peugeot et al., Journal of Hydrology 1997, Michaud and Sorooshian, WRR, 1994 etc..).

The literature review of the revised paper has been clearly improved. Many more papers have been added in order to reinforce the literature of the paper. All sections have been rewritten.

2) No justification is made as to the choice of the model or insight given on the whole purpose of the study. Why have the authors chosen the SCS? Why are they attempting to model this catchment? The authors have used various methods to determine the initial abstraction and storage ratio. However, in most modelling applications, the SCS model is calibrated. Why didn’t the authors consider this possibility?

The scope has been defined more clearly in the revised paper. The objectives of this

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paper are two; the first is the determination of the initial abstraction ratio (Ia/S), in a 15.18 km2 experimental watershed in Greece, by analyzing measured rainfall/runoff events. Eighteen storm events of various rainfall depths were used for that purpose. Moreover, the initial abstraction ratio was determined in a subwatershed with different landuses and geological formations, based on common, but fewer storm events and conclusions were drawn regarding the change in ratio value. The second objective of the paper is to examine whether the use of a lower than 20 percent ratio in SCS-CN methodology improves hydrograph simulation at the time scale of individual storm events. For the implementation of this objective, the SCS method was used for the computation of the time distribution of excess rainfall for each storm event, using 2 different ratios, the ratio of the measured rainfall/runoff event and the 20 percent empirical ratio. The simulated hydrographs were evaluated by calculating the absolute and average relative errors in peak and time to peak flow rate. The SCS model was not submitted to a calibration process. This model has no parameters to be calibrated. However, in some modeling applications (Chahinian et al. 2005), it has been calibrated. Soil moisture measurements were linked to the S parameter for this purpose. In this paper the model was used only in direct simulation mode.

3) The section on the study area is well written. However, the authors fail to discuss the uncertainties related to the data (i.e. precision of streamflow and rainfall records) and to discuss their results in view of these uncertainties.

The data precision from the above hydrometric and rain gauge stations is high. All stations are weekly checked and annually calibrated in order to ensure their good operation and the reliability of the recorded data. Concerning the measurements, there is a low percentage of uncertainty, about 10%, in the measurement of great flow rates, higher than 7 m3/sec, which is the greatest flow rate measured. However, this does not affect the results of the paper, since there were only three events with peak flow rate greater than 7 m3/sec.

4) There are some repetitions regarding the methodology which can be avoided by

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shortening, deleting or relocating certain paragraphs (e.g. P. 2171 L11-L.28; P.2180 L.10-22).

The repetitions regarding the methodology were removed.

5) The results should be compared more thoroughly to those presented in the literature. This can be easily achieved once the literature review is improved.

The results in the revised paper are more thoroughly compared to those presented in the literature.

6) The conclusions should be extended and improved. The reader has no possibility of knowing whether the conclusions are specific to this catchment or could be extended to others.

The findings from other studies are also reported in the revised paper in order to link the results from this study to those of other studies.

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