Design for Storage using Synthetic Rainfall

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Introduction

One of the longest running arguments in the use of urban drainage models concerns whether the behaviour of the system is best represented using synthetic storms derived from rainfall statistics, or using a time series of real storms.

The argument in favour of using synthetic storms is that they are readily available for all locations in the UK, and that they are easy to use and require only a few storms. The argument in favour of time series is that they include a wider range of conditions, and therefore are likely to contain the conditions which are critical on each catchment.

There are two crucial areas in which synthetic storms may not adequately represent the response of a catchment. The first of these is in the design of detention storage tanks, where modest storms falling on a very wet catchment may give a larger volume of runoff than a larger storm with average catchment wetness. The second area is in predicting spill from overflows in small frequent storms for pollution impact studies.

This study set out to derive synthetic storms which could be used for these situations, so avoiding the problems of using time series. The study was divided into three areas, analysis of the annual time series to see whether the variations could be represented by a few synthetic storms, the development of synthetic storms and testing on real systems.

The Analysis of the Annual Time Series

During the development of the annual time series it was ranked by severity; this involved using the time series rainfall for simulation in a number of models in order that the largest discharge volumes could be identified. This project attempts to rank the series by comparison with statistical rainfall data.

The annual time series from the South East, South West and Yorkshire were analyzed for depth ratio, peakedness, UCWI ratio and skew.

Depth Ratio

Each storm in the annual time series was analyzed for a range of durations and the for each duration the depth of rain as a proportion of the 1in1 year depth was calculated. Each duration was then considered and the storms were ranked with decreasing depth ratio. Graphs of depth ratio against return period could then be plotted. Regression was carried out to fit a ln/ln curve to the data however no suitable curve was found and therefore to evaluate the depth of rain for a storm with a return period less than 1 year the depth ratio was interpolated from tables.

Peakedness

The definition of peakedness was altered during the study. The final definition was the depth of rain in a given duration of storm divided by the depth in twice that duration. initially we used one value for each storm, chosen as that for the duration with the largest depth ratio. This gave values of about 0.8; similar to the 50 percentile summer and 75 percentile winter storms. The final results used peakedness varying with duration from 0.67 to 0.84.

UCWI ratio

The UCWI ratio was the UCWI for the storm divided by the standard UCWI for the season. Winter UCWI ratios of 1.0 and 1.2 and summer UCWI ratios of 1.6 and 2.0 were found. Increasing the UCWI had a greater affect on larger storms therefore the winter UCWI is recommended to compensate for the low UCWI of the summer storms.

Skew

Skew defines the position of the peak of the storm. The skew for each storm in the series was calculated and the frequency distribution graphs indicated no predominance of either left or right skew. Therefore a central skew is recommended.

Synthetic Design Storms

Synthetic design storms based on the analysis of depth ratio, peakedness, UCWI ratio and skew were developed and compared with the annual time series using a simple storage model.

The storage model allowed both the catchment and model characteristics to be varied and 30%, 60% and 70% pervious catchments were considered for two extreme outflow limits. These limits were approximately 90% and 10% the runoff calculated from the PR equation,

PR = 0.829*PIMP + 25*SOIL + 0.078*UCWI - 20.7

using 40% pervious area and the average UCWI.

For comparison the time series were re-ranked for maximum storage in descending order and graphically compared with the design storms (Fig 1). The critical storm in the time series was found to be catchment specific while the design storms could cover a broader range of catchment characteristics.

The design storms based on a profile where peakedness varied with storm duration performed slightly better than the storms using the 75 percentile winter and 50 percentile summer curves.

Testing on Real Models

The design storms are to be tested on a number of real models which cover a broad range of model and catchment characteristics. The results of the first tests were promising. However, the design storms were based on the time series rainfall whereas it is recommended that the design storms should be based on analysis and comparison with the full 40 years of rainfall record.

Uses of the Synthetic Time Series

The synthetic time series can be used in place of the rainfall time series when designing for storage, overflows, general network enhancements or a new system. The synthetic series has approximately 8% of the number of storms in the full time series and 50% of the storms required to run the first five then every fifth. Further it is not catchment specific.

Summary

A synthetic time series has been developed and it can be used in place of a real time series for many design purposes. However further research using the full rainfall record is recommended for further development and verification of the synthetic time series.

Where the real time series is used the effects of catchment characteristics should be recognised and the first five then every fifth storm should not be run before the series is re-ranked for catchment characteristics.

Acknowledgements

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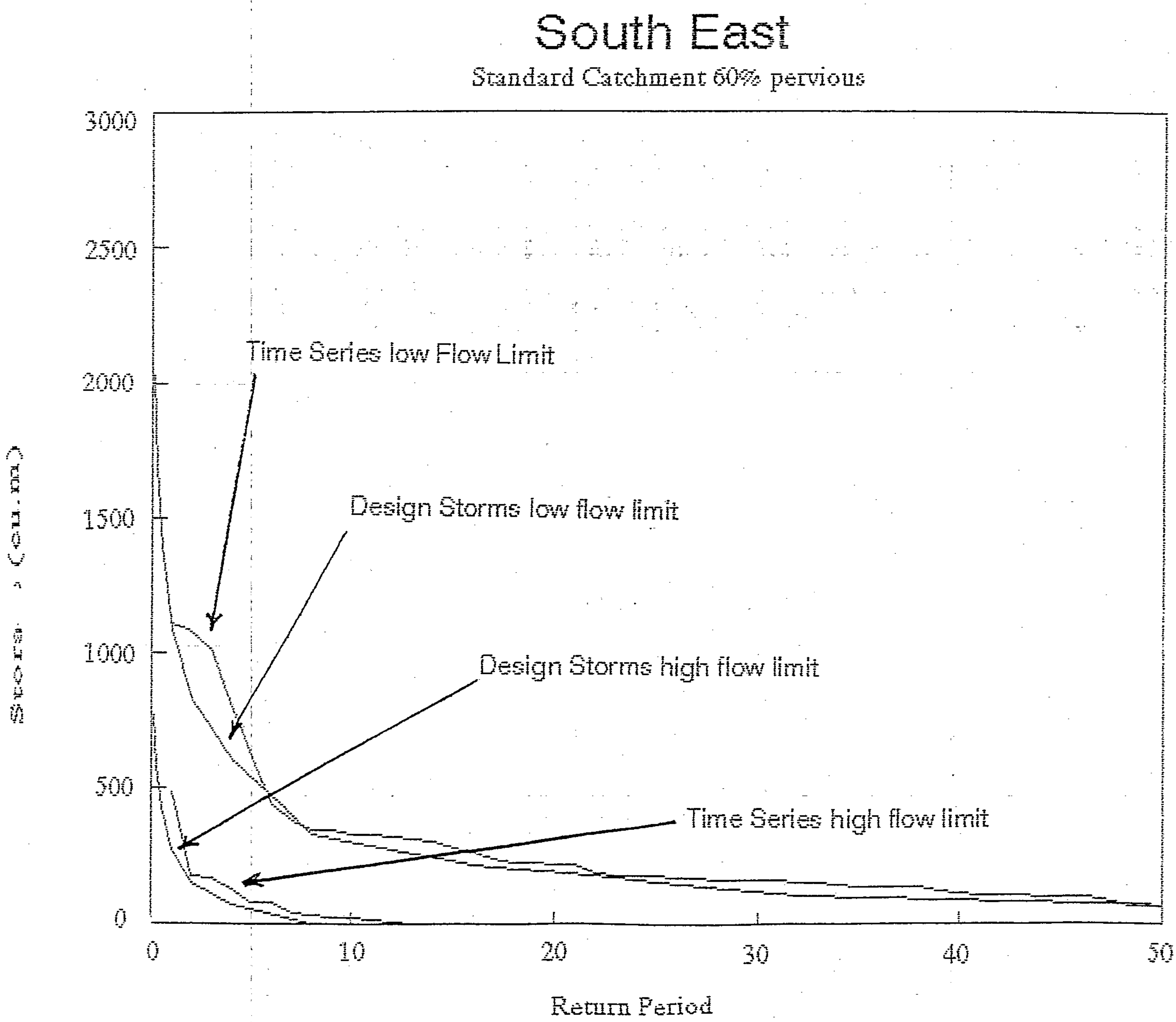

Figure 1

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A Delegate : The simplified "design storms" have been calibrated by comparing output from models using both design storms and time-series storms as input. Have any results been compared using real systems with recorded rainfall data input?

Ans : No, as we did not have suitable data sets available. It would be a useful further stage in testing the method.

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Reply to Dave Walters about the importance of skew storms : We investigated the importance of skew by running a series of storms of varying skew from fully left skewed to fully right skewed. We showed that skew had very little effect on the storage volume required. The critical skew was slightly to the right of centre and this gave at most 10% more storage volume than a centrally skewed storm. The graphs of results that we reproduce the storage requirements of the time series. We would be interested in seeing the effect of running the synthetic storms on the Bolton model to see if they can reproduce the time series results there.