Defra / Environment Agency
Flood and coastal erosion risk management
R&D Programme

Technical Summary W5-032/TS

Impact of climate change on flood flows in river catchments

Background to R&D project

This report details work undertaken during R&D project W5B-032. The objectives are to improve the scientific basis for the guidance on climate change to the flood management community by applying a wide range of climate change scenarios to selected catchments, making explicit use of UKCIP02 scenarios.

The basic technical approach is to 'drive' catchment hydrological models with input climate data from the 1961-1990 period, and with climate data indicative of future periods (namely the 2050s and the 2080s) and compare the flood frequencies and magnitudes for these two periods. Two types of hydrological model have been used to suit the wide range of catchment size. Five of the study catchments have been modelled at the daily time step, and five at the hourly time step. The models, their calibration and performance are described, as are the uncertainties due to model calibration. Model simulations have assumed similar hydrological processes and land use between baseline and scenario time periods.

Three types of scenario data have been used to generate the climate change information for the project:

- A 'combined' scenario based on the UKCIP02 rainfall scenarios, and the percentage changes in average rainfall and the change in frequency of daily rainfall required for each month
- Statistical downscaling for rainfall, using the Statistical Downscaling Model (SDSM, Wilby 2002)
- Data from the 25km Hadley Centre Regional Climate Model (RCM).

Table 1 summarises the scenario data used for the study catchments.

Table 1 Summary of scenarios and methods

	UKCIP02	**RCM**	**SDSM**
Catchments	All 10	All 10	27009 (Ouse) 54001 (Severn)
Time periods	2050s 2080s	2080s	2050s 2080s
Emissions scenarios	High, Medium-high, Medium-low, Low	A2 (Medium-high)	A2 (Medium-high) B2 (Medium-low)
Description	Perturb baseline (observed) climate	Modelled baseline and scenario rainfall	Modelled rainfall (1961-2099)

Results of R&D project

The results show the impacts of climate change on flood frequency in the study catchments, under the selected scenarios, to be considerably lower than those previously simulated (Reynard *et al.* 1998, 2001). This is determined primarily by the fact that the current version of the Hadley Centre GCM, driving the climate changes, produces significantly drier and warmer summers and autumns, so that, despite the wetter winters (on average), flood frequencies in many catchments decrease. This does not necessarily apply to those catchments that are more responsive, i.e. steep-sided, small or urban catchments, but even in these

the precise response is determined by the spatial and temporal detail of the climate changes.

Table 2 summarises the percentage changes in the 20-year flows for the study catchments by the 2080s. For each of the catchments a range of climate impacts can be seen. In only a few of these are there obvious tendencies towards either a decrease (the Lymn - 30004 and the Beult - 40005) or an increase (the Duddon - 74001 and the Anton - 42012). The results for the Duddon (74001) under the UKCIP02 scenarios are shown in Figure 1. All other catchments present a range of change, both positive and negative.

Table 2 Percentage changes in the 20-year return period flows for the 2080s.

Catchment	UKCIP02				Resampling UKCIP		SDSM		RCM	Resampling RCM	
	Low	Med Low	Med High	High	Min	Max	B2	A2	A2	Min	Max
27009	-2.2	-3.6	-3.8	-4.2			7.0	-3.8	10.7		
28039	6.4	-2.5	-2.6	-5.5	-28.5	**20.5**			-14.0	-35.6	**38.6**
30004	-3.5	-5.6	-9.9	-13.1	-28.3	7.1			-12.0	-30.0	**29.7**
39001	-1.6	-1.6	0.0	2.8					16.7		
40005	-0.5	-1.5	-3.9	-3.7	-24.7	9.4			-13.8	-38.4	**20.3**
42012	2.5	3.2	4.6	5.0	-8.4	**29.6**			3.5	-73.0	**474.3**
54001	-2.1	-2.7	-5.4	-6.7				6.8	-19.4		
54057	1.2	1.2	3.0	4.4					-14.5		
74001	6.6	8.3	16.1	**21.9**	-13.0	**30.4**			16.3	-2.9	**39.6**
96001	0.1	-0.9	-3.1	-4.6	-22.1	16.0			-8.9	-28.7	**30.6**

A wider range of impacts was presented using resampled rainfall data, but even with these data the maximum impact from UKCIP02 scenarios was only above 20% for three of the catchments by the 2080s. In general, the range of impacts in this study is wide, across catchments, time slices and scenarios, but usually below the 20% increase. These results suggest that, under these scenarios, the current 20% sensitivity band appears appropriate as a precautionary response to the uncertainty of future climate change impacts on flood flows. To a very large degree this conclusion is determined by the dry and warm nature of the Hadley Centre model used to generate all the scenarios, and using other GCMs will undoubtedly produce different results.

The impact of climate change on the duration of high flows has been explored through the seasonal Q3 statistic (the flow exceeded 3% of the time). Most catchments show an increase in Q3 in the winter but a decrease in all other seasons, normally greatest in the summer. However, for the Anton (42012) and the Thames (39001), autumn shows a more extreme impact due to the contribution of baseflow sustaining runoff during the summer. Comparison of downscaling methods shows the pattern of change is similar across the seasons.

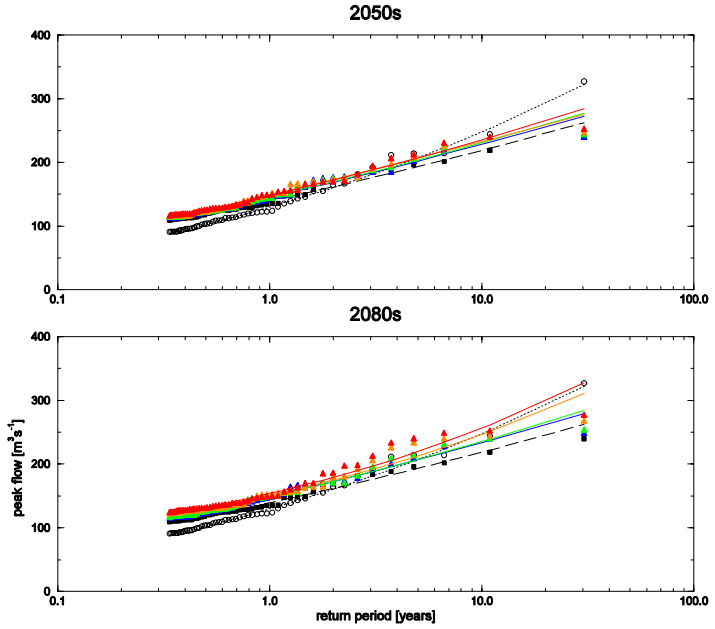

Figure 1 Flood frequency curves for the Duddon (74001) for the baseline (black dashed line) and the four emissions scenarios (Low – blue, Medium-Low – green, Medium-High – orange, High – red) for the 2050s and the 2080s.

Some tentative relationships between catchment properties and the impact of climate change on flooding are suggested. It seems that location may be the dominant factor in determining the impact of climate change on flooding. Whether this is due to the spatial pattern of climate change or to the partial dependence of catchment type on location (or both) is difficult to distinguish given the relatively small number of catchments studied.

Simply analysing percentage changes in flows can be misleading, particularly when the baseline flows are low. The Anton (42012) has a mean flow of just 1.9m^3s^{-1}, so even the 500% increase, calculated as the difference between the minimum (5%) baseline flow and the maximum (95%) resampled scenario equates to an increase in flows of 4.8 m^3s^{-1} over the 20-year flow. Of course, the impacts on flood flows provide an indication of change in flood frequency, but do not tell us of possible changes in flood risk. To gain an understanding of this impact a simple stage-discharge relationship has been applied to the flows in the Anton (42012) to assess the potential change in river flow levels. The 500% increase in flows discussed above means a 420 mm increase in the current 20-year level of 212 mm.

Finally, it is important to consider all the various sources of uncertainty involved in climate change impact studies, and how this uncertainty impacts on the decision that the research informs (Willows and Connell 2003). This research has, to a degree, addressed some of these uncertainties.

R&D Outputs and their Use

The primary output of this project is the final report W5-032/TR. This details the research modelling methodology, including detailed model descriptions and an assessment of the hydrological model uncertainty. The report describes the study catchments and the methods used to construct the various climate change scenarios and presents, in particular, a discussion of the rainfall series produced to drive the hydrological models, both for the 1961-1990 baseline period and the future time periods under climate change.

The research has been undertaken to inform the development of Departmental guidance on climate change impacts on flood flows in the UK. While efforts have been made to draw out some generalised conclusions, relating catchment properties with the impact scenarios, the small number of sample catchments means that the results should not be taken as representative of regional or national changes

in flood frequency under climate change.

This R&D Technical Summary relates to R&D Project Impact of climate change on flood flows in river catchments No. W5B-01-010 and the following R&D outputs:

- **R&D Final Report -** Impact of climate change on flood flows in river catchments. W5-032/TR**.** Published March 2004
- **Two papers have been written and presented at the Defra conference 2003 and 2004.**

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