



# A revised model of rainfall depth-duration-frequency for the UK

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# Outline

- Motivation for the project and objectives
- Key components of FEH FORGEX methodology
- Approach to analysis
- Data management
  - Annual/seasonal maxima
  - Extreme event archive
- Analysis leading to revised DDF model
- From statistical analysis to hydrological practice

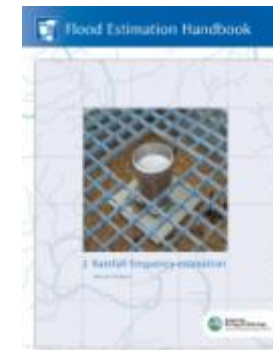




## Flood Estimation Handbook

A unified set of procedures for rainfall and flood frequency estimation

- Five-volume handbook published 1999
- Rainfall model described in Volume 2
- Implemented on FEH CD-ROM v. 2.0



1 day

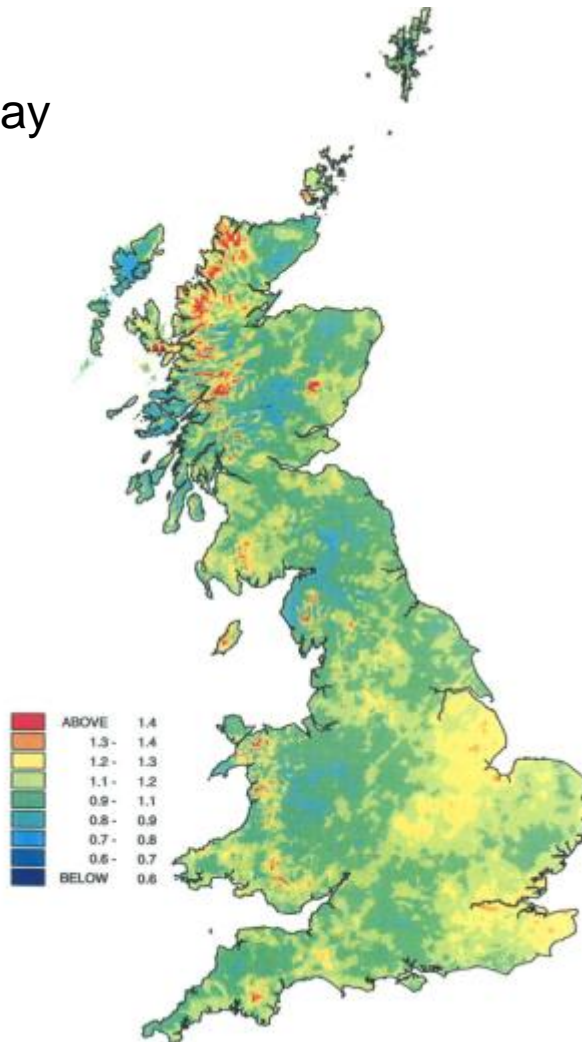


Figure 11.7 Ratio of FEH to FSR 1-day rainfall for T = 100 years

1 hour

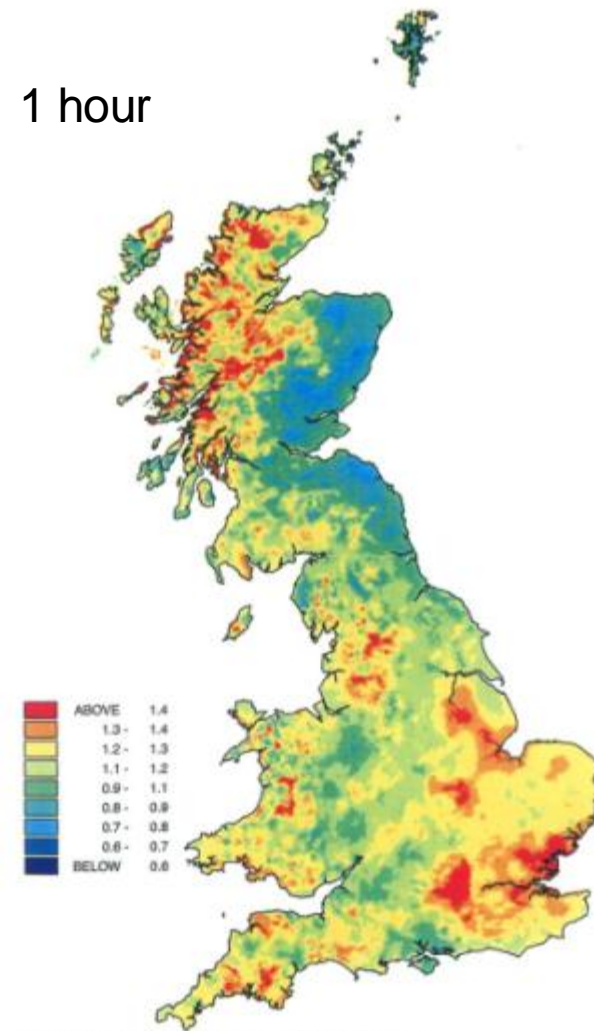
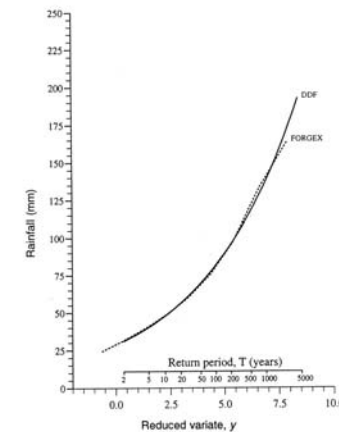


Figure 11.8 Ratio of FEH to FSR 1-hour rainfall for T = 100 years

## Ratio of FEH to FSR rainfall for 100-year return period

# Use of FEH Model in Reservoir Safety Studies

- MacDonald and Scott (2000 & 2001):
  - FEH & FSR depths diverge significantly at 10,000-year return periods
  - In some instances > PMP
  - Conclude that problems stem from extrapolation of a line of best fit (DDF model rather than statistical analysis)
- Babbie Group (2000):
  - FEH estimates found to be > 50% greater in many upland areas in west and in much of Eastern England
  - Ratios greatest for  $T=10,000$  years



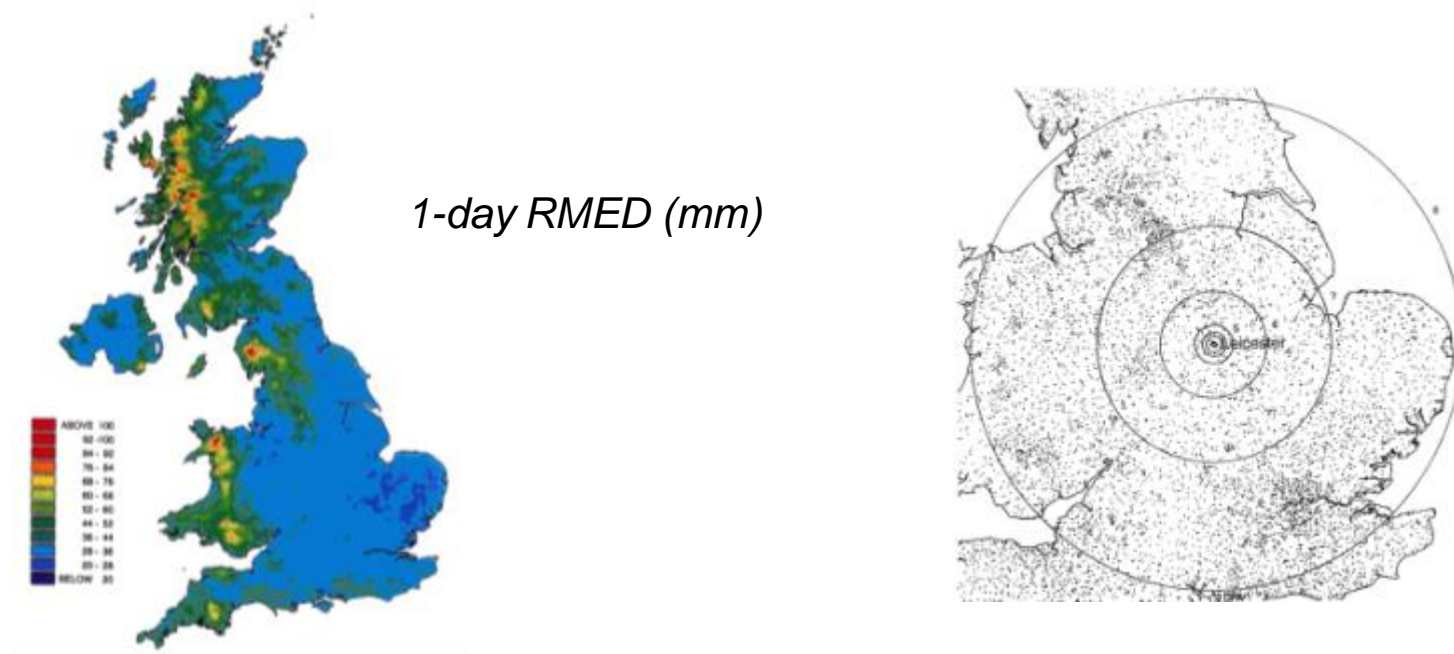


# Project objectives

- To revise the FEH FORGEX methodology with specific reference to the estimation of very extreme rainfall for reservoir safety assessment
  - Return periods from 100 to >10,000 years
  - Durations from 1 hour to 8 days
- To compare frequency estimates with Probable Maximum Precipitation (PMP)

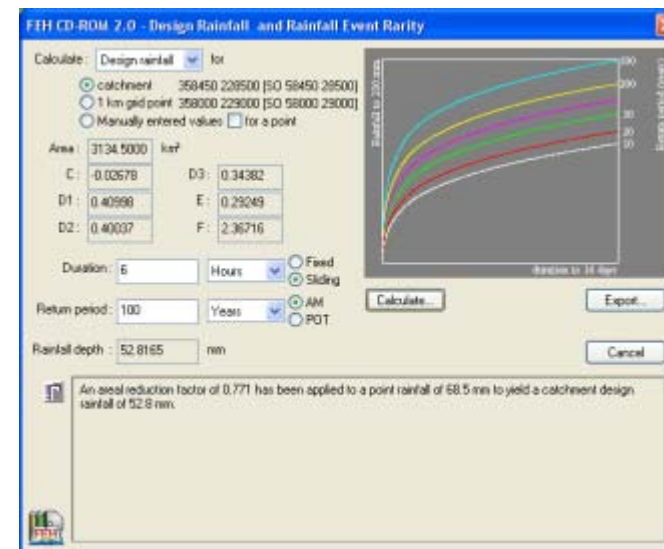
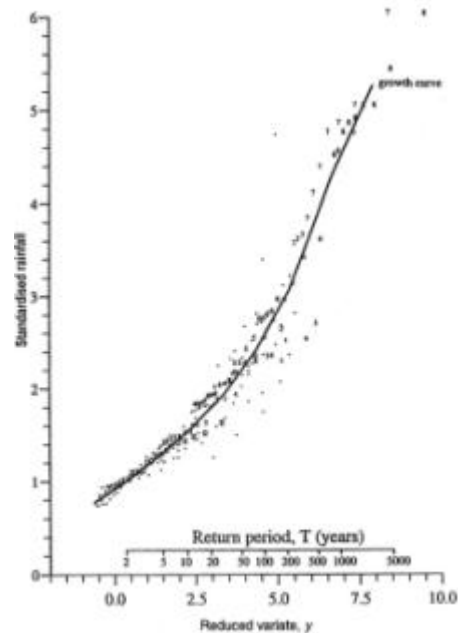
# Key components of FEH FORGEX methodology - 1

- Standardisation by RMED (median annual maximum rainfall of required duration)
- Growth curves focused on a particular site of interest



## Key components of FEH FORGEX methodology - 2

- Empirically-derived FORGEX growth curves in which pooling allows for spatial dependence in rainfall extremes
- Depth-duration frequency (DDF) model fitted simultaneously to all durations and return periods

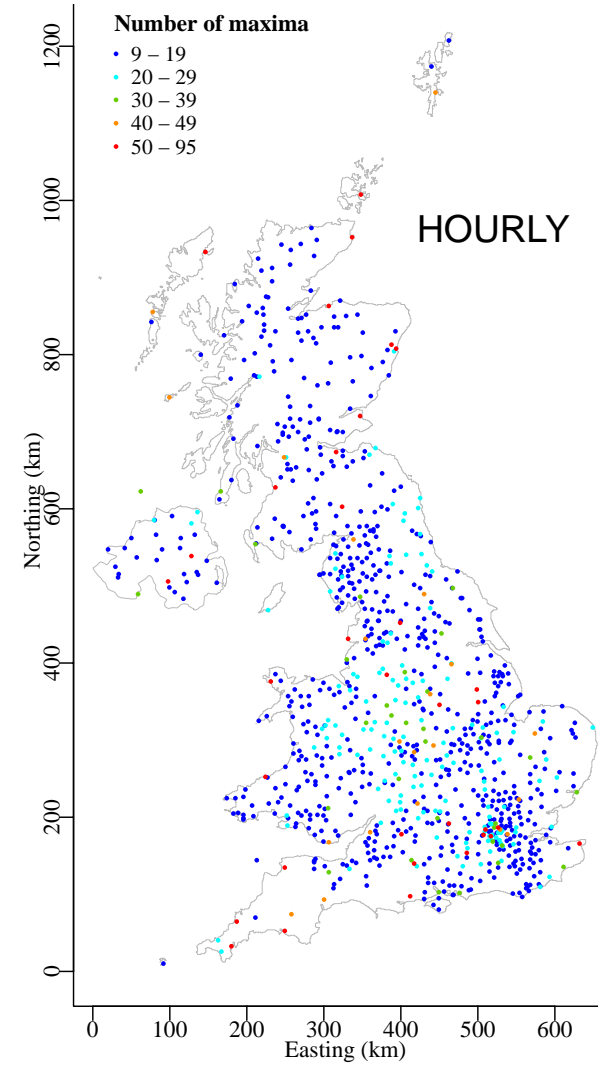
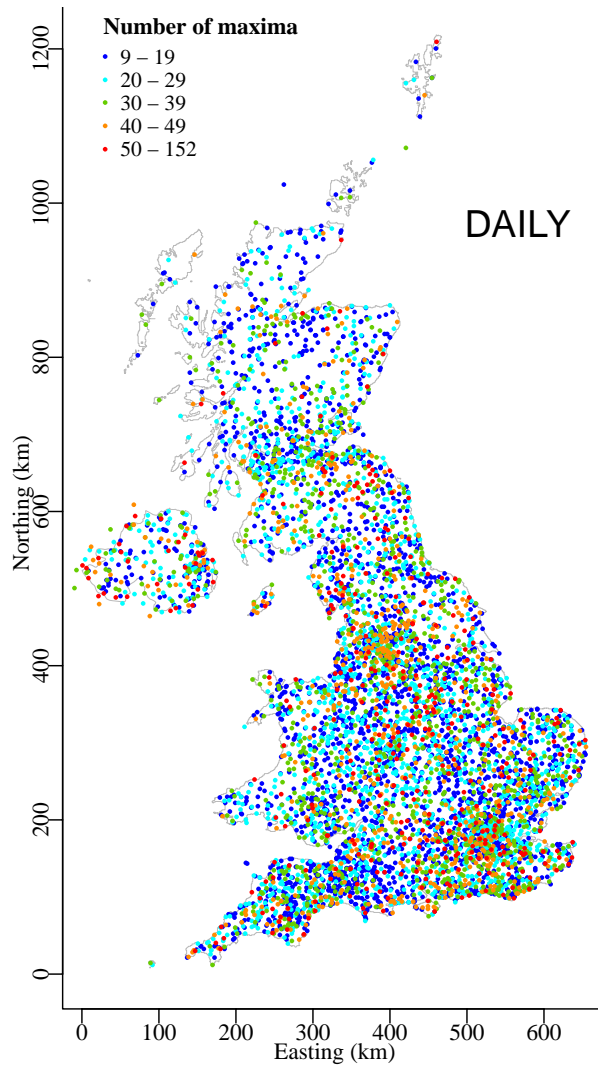




# Approach to the analysis

- Extend systematic rainfall data archive
- Analyse seasonal as well as annual maxima
- Retain basic elements of FORGEX
- Develop a new DDF to revised rainfall frequency curves
- Consider form of extrapolation to very long return periods

# Data management: systematic rain gauge data



Duration	No. gauges	Station-years	Approx. station-years in FSR
1 day	6,106	150,245	96,000
1 hour	375	7,389	2,300

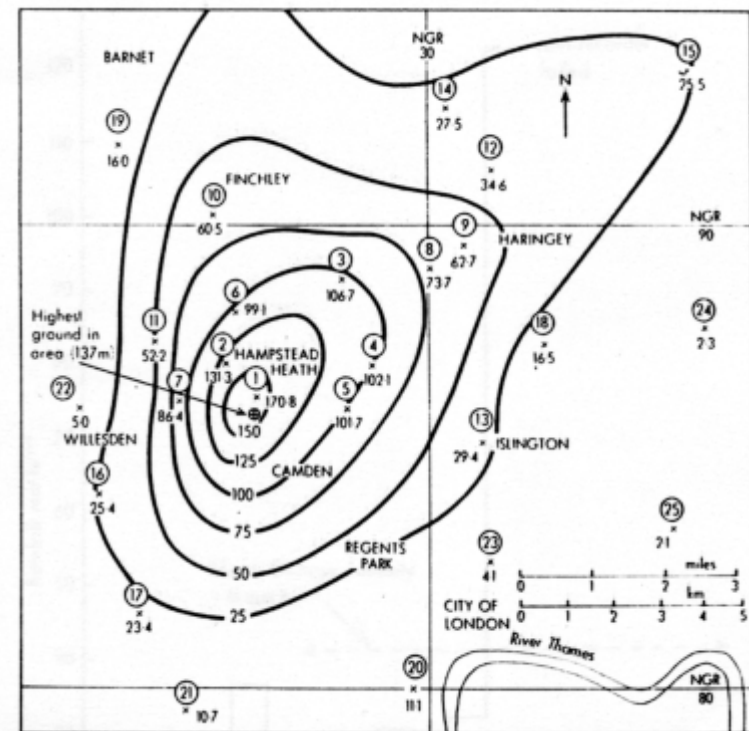
**Table 1 Summary statistics of data used in FEH and FSR analyses**

Duration	No. gauges	No. station-years		
		Annual	Summer	Winter
1 day	6,504	171,904	171,588	164,278
1 hour	969	17,010	13,105	13,300

**Table 2 Summary of data available to current study**

# Extreme event data

- Details of 63 extreme storms from 1886 to 2006
- Range of durations and storm types
- 5 events exceed PMP estimates



Isohyetal map of the Hampstead storm 14 August 1975

## Analysis leading to revised FORGEX methodology: Standardisation

The basis of the FORGEX procedure is that rainfalls have been pre-processed to remove differences between the statistical distributions of rainfall at different locations

FEH standardisation by median:

$$R_{standardised} = \frac{R}{RMED} = 1 + \frac{R - RMED}{RMED}.$$

Revised standardisation

$$R_{revised} = 1 + \frac{R - RMED}{f \times RMED} = 1 + \frac{1}{f} (R_{standardised} - 1).$$

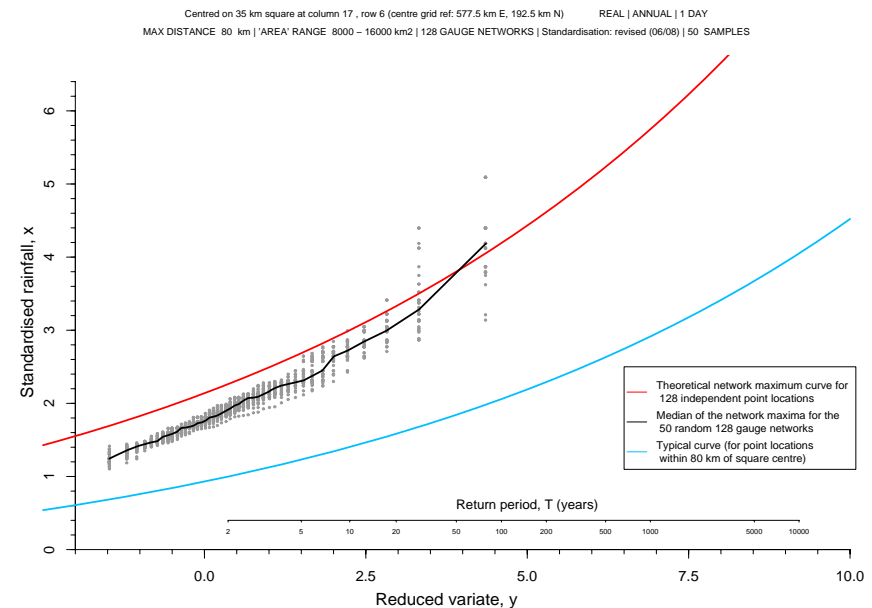
Where  $f$  is a function of

*SAAR*: Standard annual average rainfall

*ngy*: Northing (National Grid)

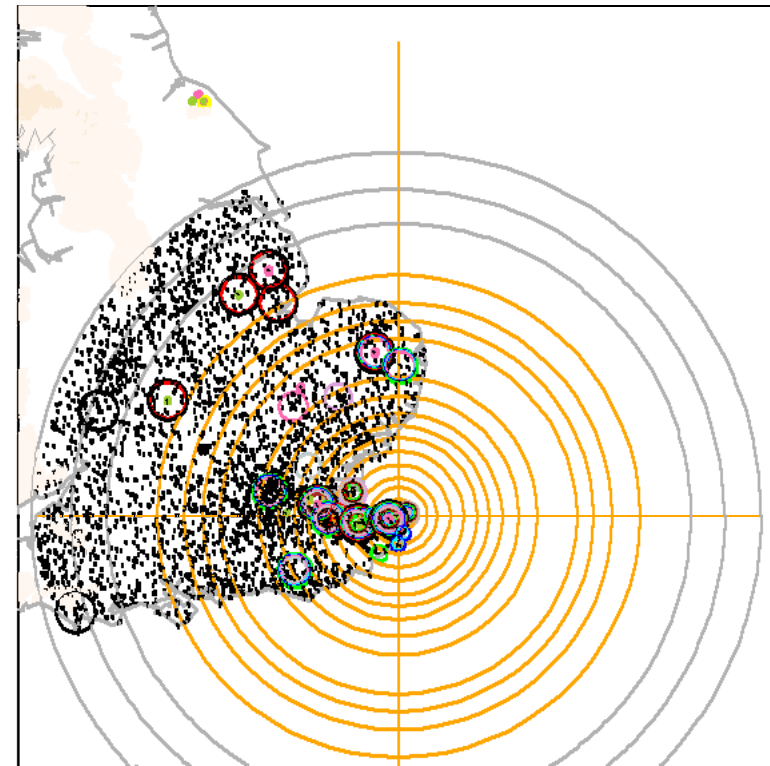
# Analysis leading to revised FORGEX methodology: Spatial Dependence Model

- Used to assign plotting positions to the highest annual maxima in a given network
- In original model spatial dependence assumed constant with return period (Dales & Reed, 1989)
- New model allows independence to be approached at high return period
- Model fitting based on extensive data analysis



## Analysis leading to revised FORGEX methodology: Revisions to growth curve construction

- Growth curves are fitted to network maxima only
- New rules for the definition of network radii
- Additional networks used up to radius of 300 km
- New rules for selection of network maxima
- Network maxima are weighted


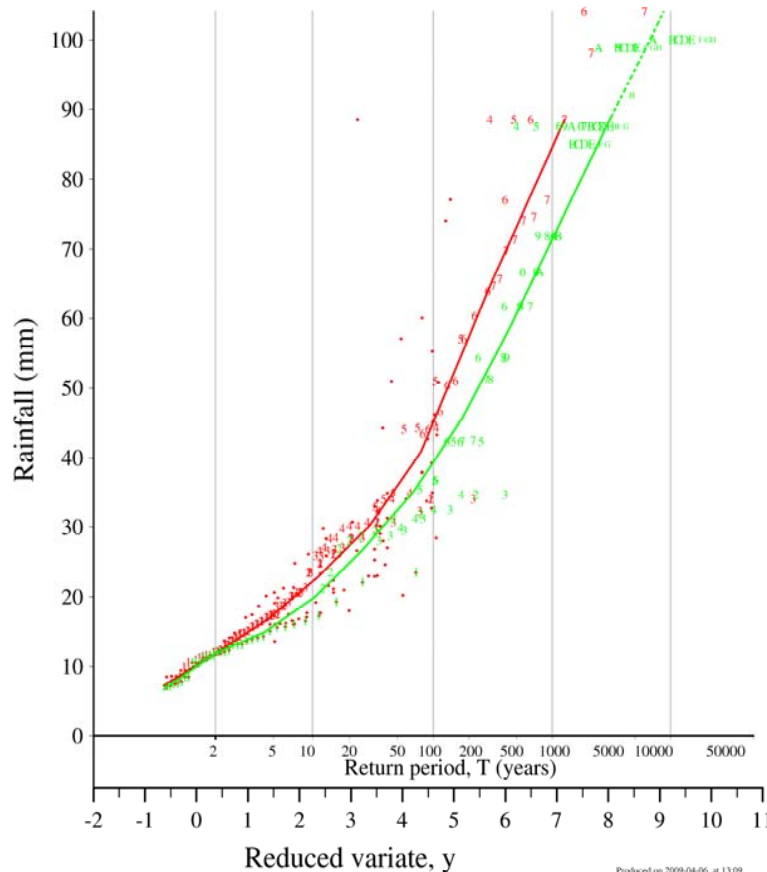




FORGEX rainfall-frequency

Duration:	1 hour	1 hour
Season:	annual	annual
Data type:	Res. Saf.	Res. Saf.
Focal point:	GB 4380 3598	GB 4380 3598
Radius (km):	200	# 200 (+100)
Netmax shift method:	geometric	# gam1_gam2
Segment fitting method:	FEH	# netmax (03/09)
Standardisation method:	FEH	# revised (06/08)
No. networks & segments:	7 7	--> 15 9 (+3 +2)
Rmed (mm) **:	11.8 g	11.8 g
SAAR (1961-90) (mm):	796	796

\*\* med source at focal point: f = FEH DDF, g = gauged

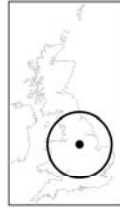
A typical example of the effect of all the revisions to FORGEX for the 1-hour duration  
(green curve shows new method)



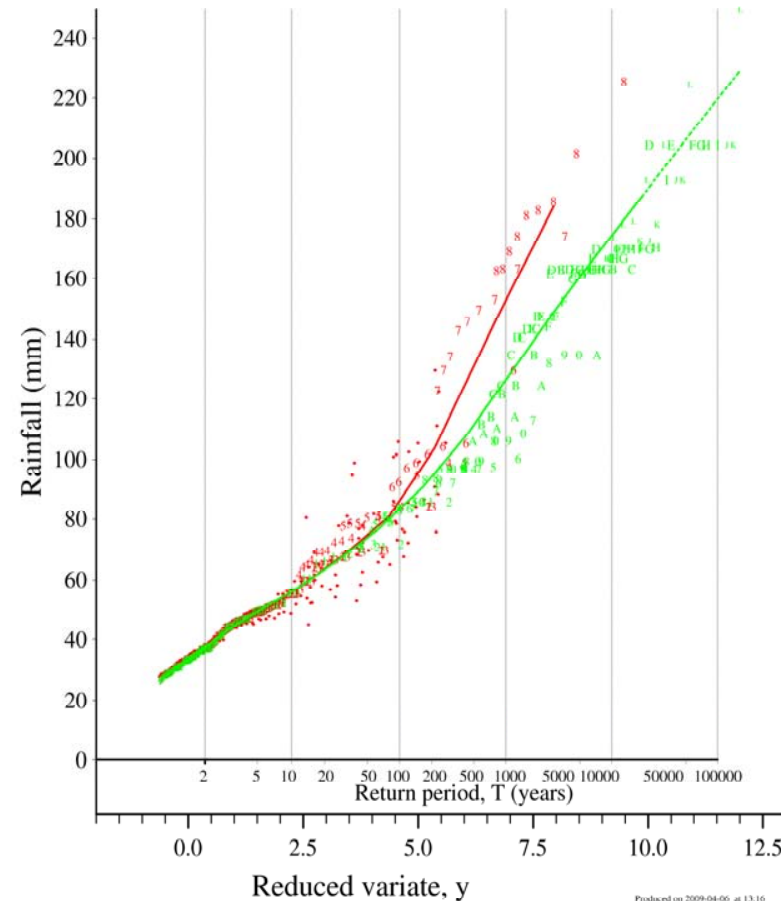
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Segment fitting method:	FEH	# netmax (03/09)
Standardisation method:	FEH	# revised (06/08)
No. networks & segments:	8 8	--> 19 11 (+3 +2)
Rmed (mm) **:	37.4 g	37.4 g
SAAR (1961-90) (mm):	796	796

\*\* rmed source at focal point: f = FEH DDF, g = gauged

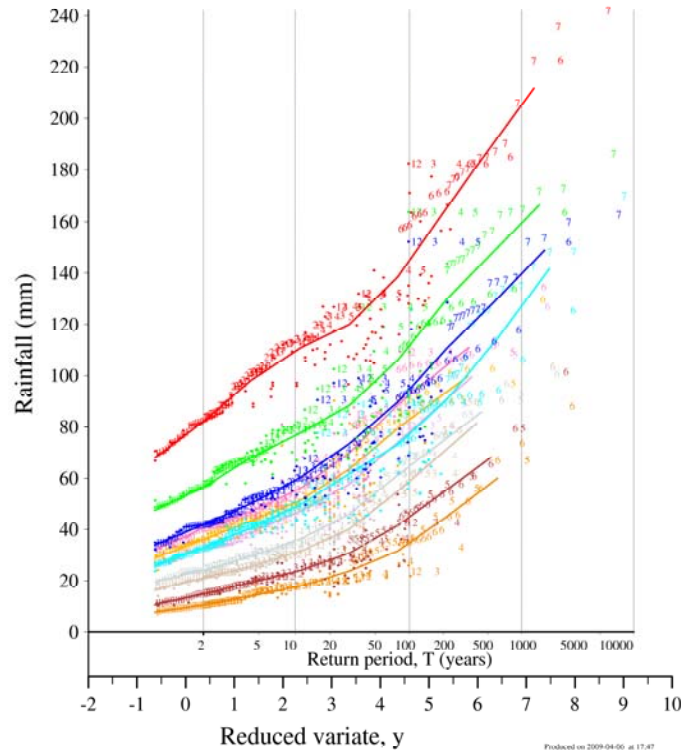
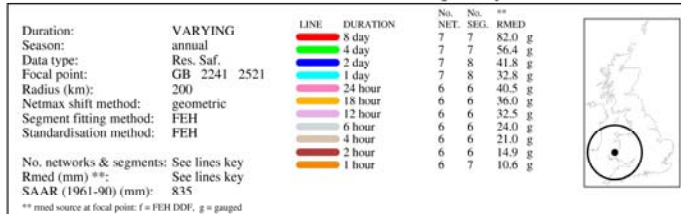


A typical example of the effect of all the revisions to FORGEX for the 1-day duration  
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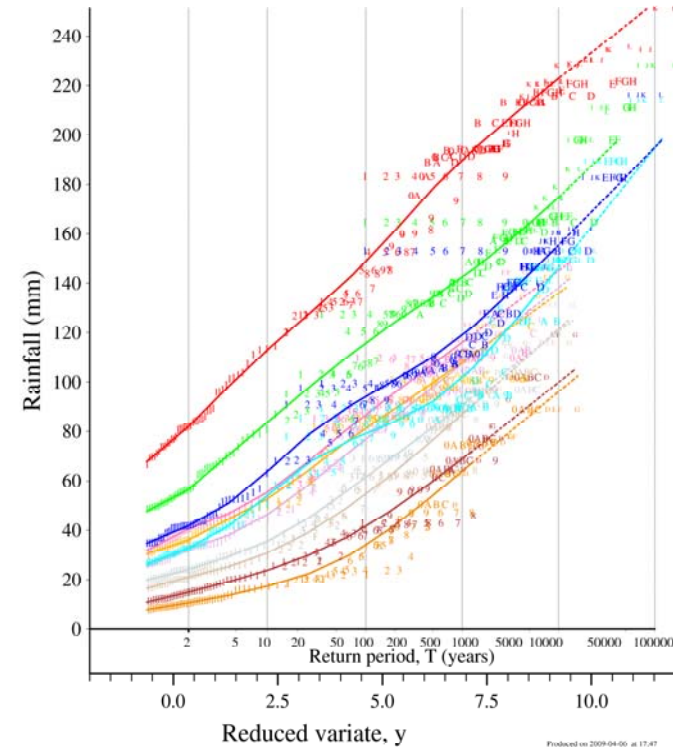
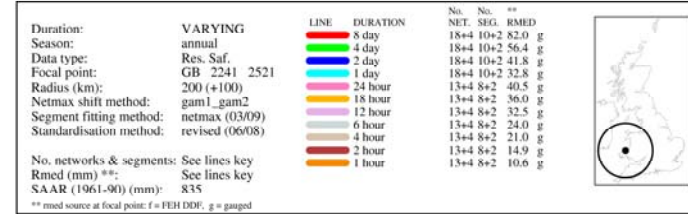


FORGEX rainfall-frequency

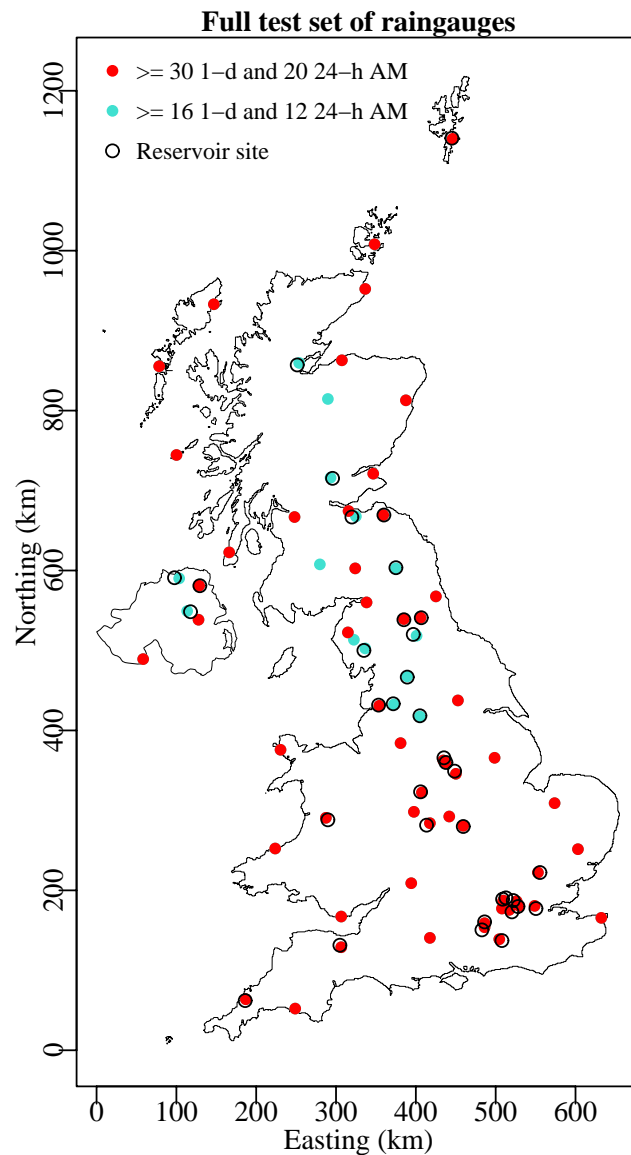


FEH FORGEX

FORGEX rainfall-frequency



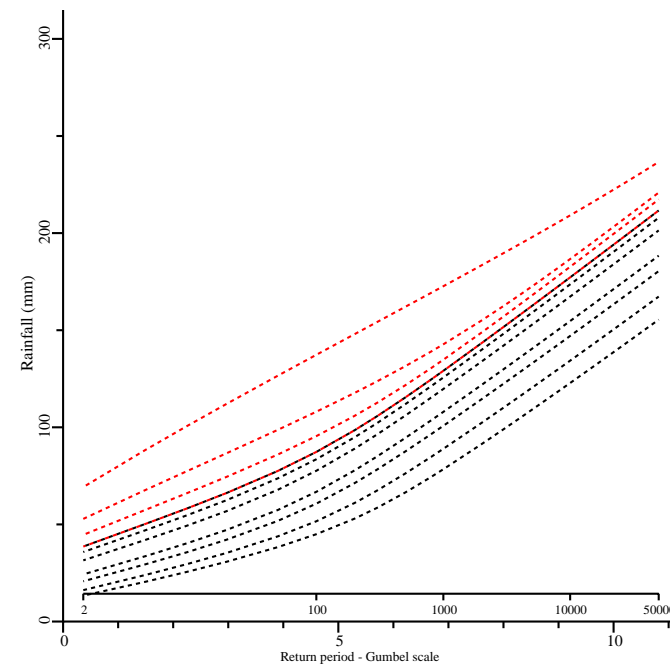
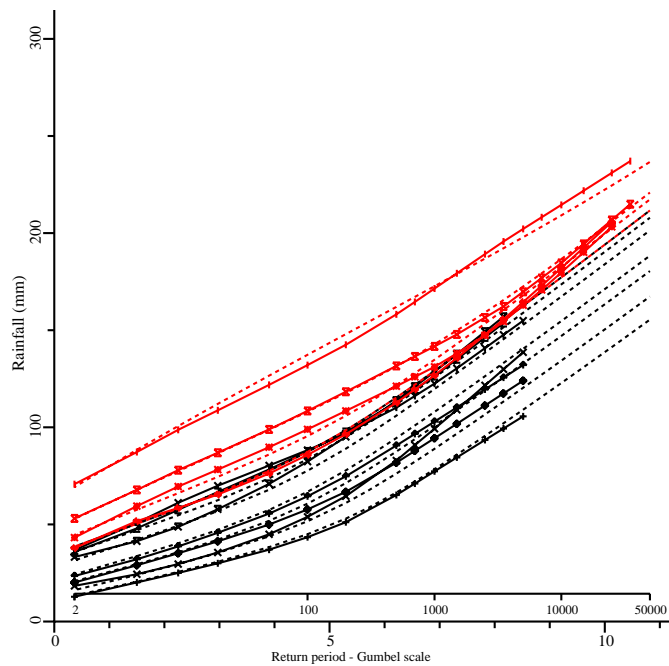
Revised FORGEX



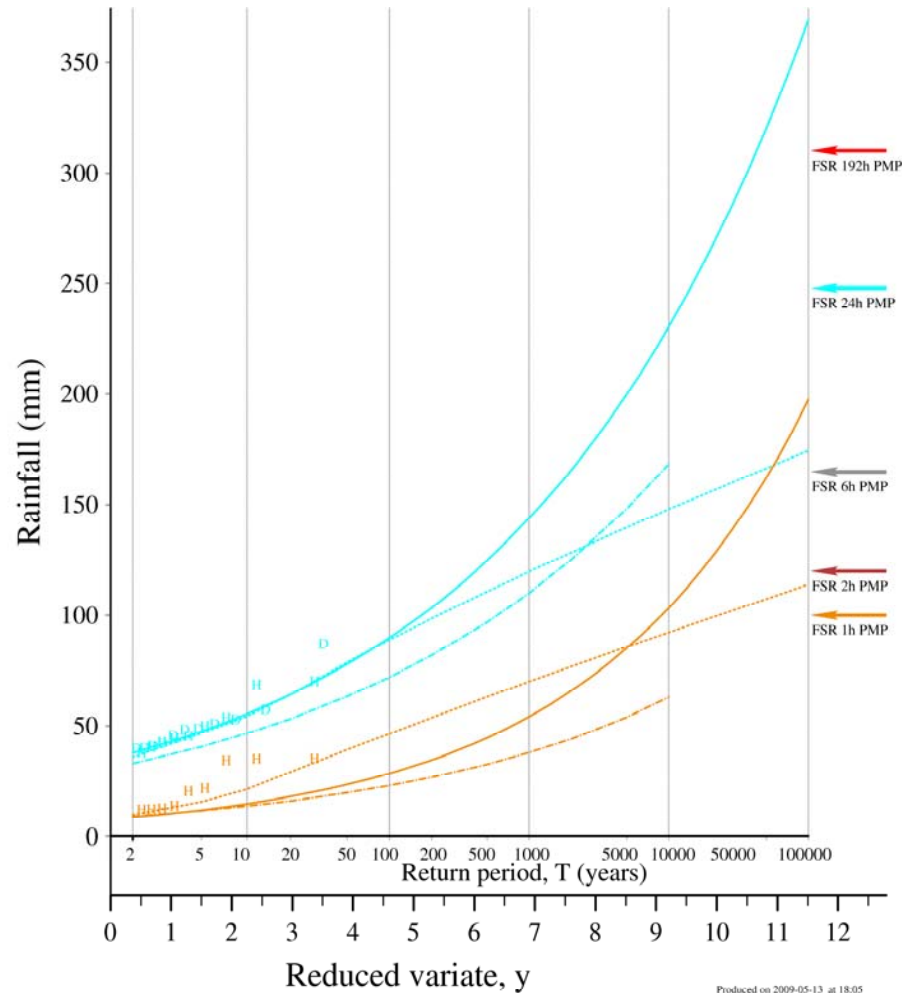
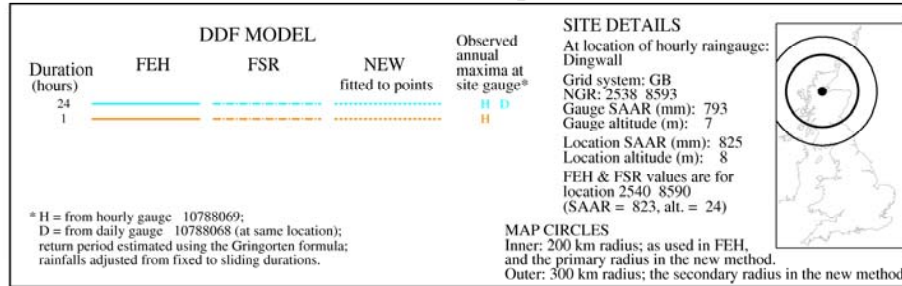
**Locations of 71 test sites, selected on the basis of record length and/or location.**

# New Depth-Duration-Frequency model

Generalised mixture of Gamma distributions in which the scale and shape parameters vary smoothly with duration



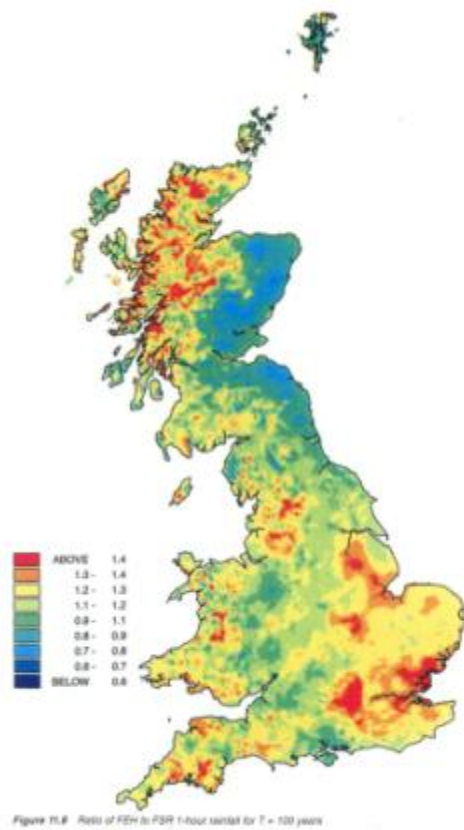
# DDF model comparison



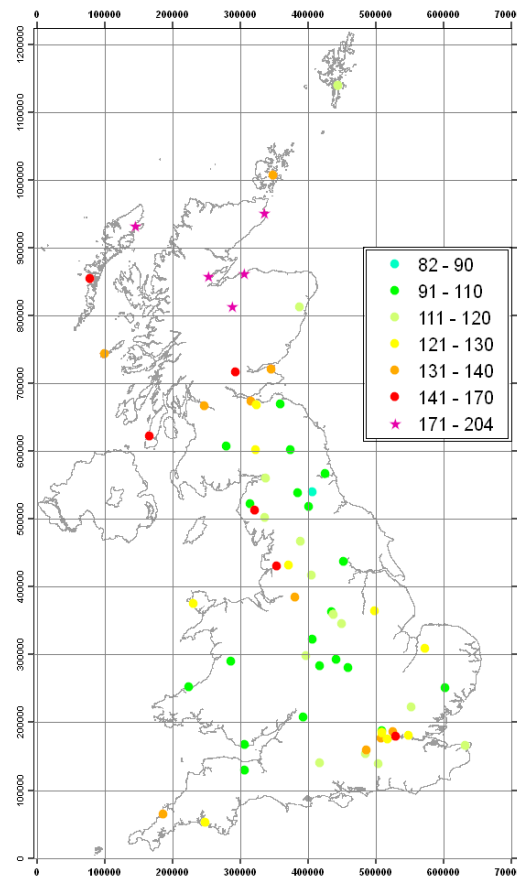
## DDF model comparisons for Dingwall

## Comparison with FSR & FEH : 1-hour duration, 100-yr RP

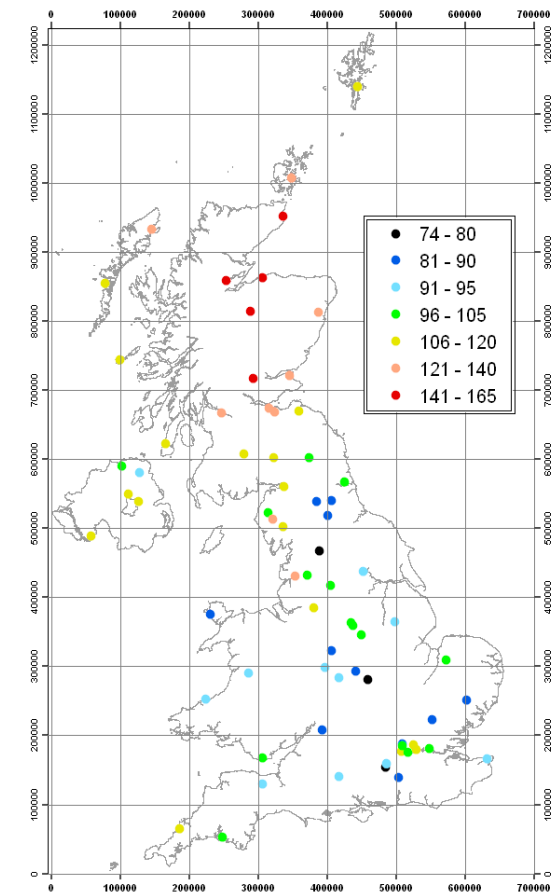
FEH as % of FSR for 1 hour 100 year



New as % of FSR for 1 hour 100 year



New as % of FEH for 1 hour 100 year





# Comparison with FSR & FEH : 24-hour duration, 100-yr RP

FEH as % of FSR for 1 day 100 year

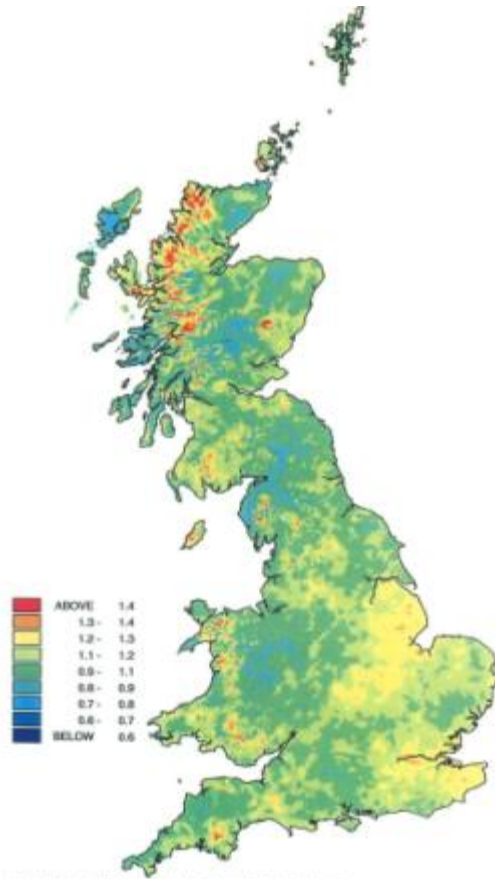
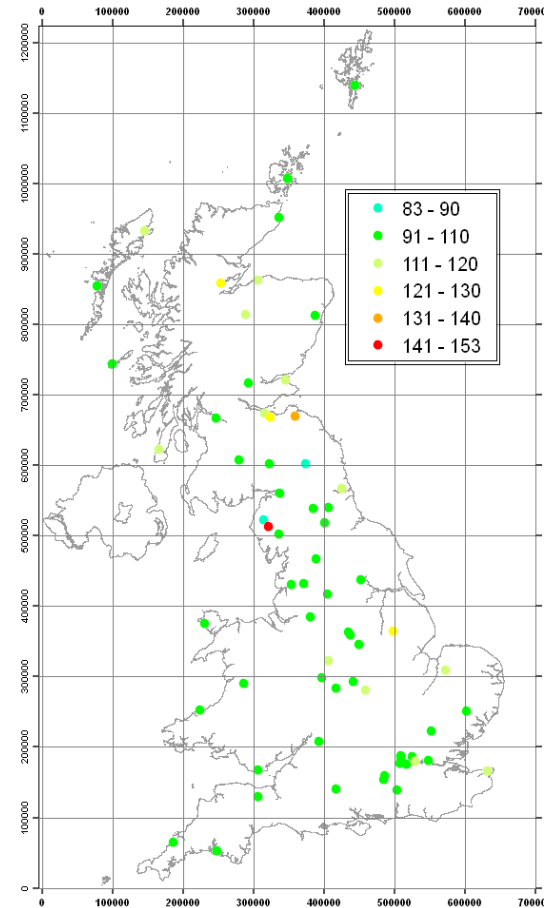
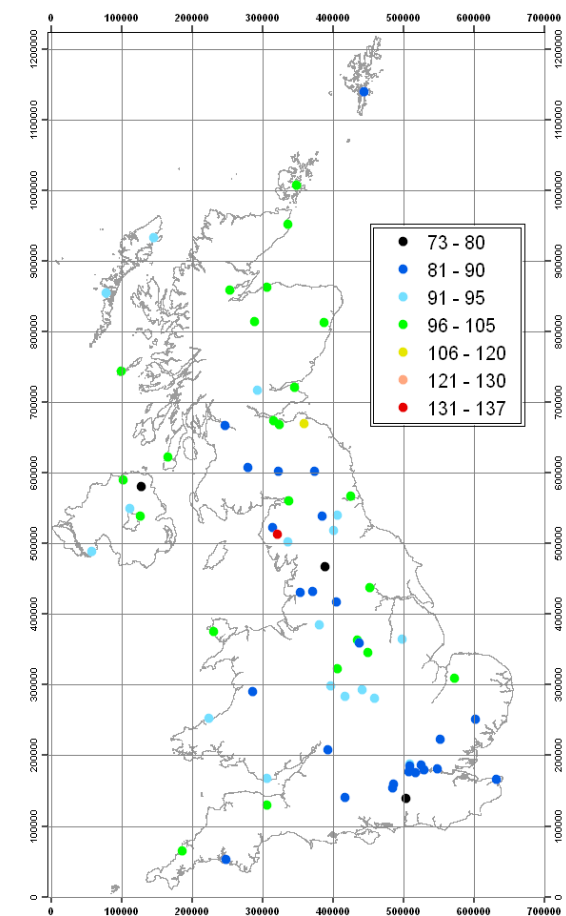


Figure 11.7 Ratio of FEH to FSR 1-day rainfall for T = 100 years

New as % of FSR for 24 hour 100 year

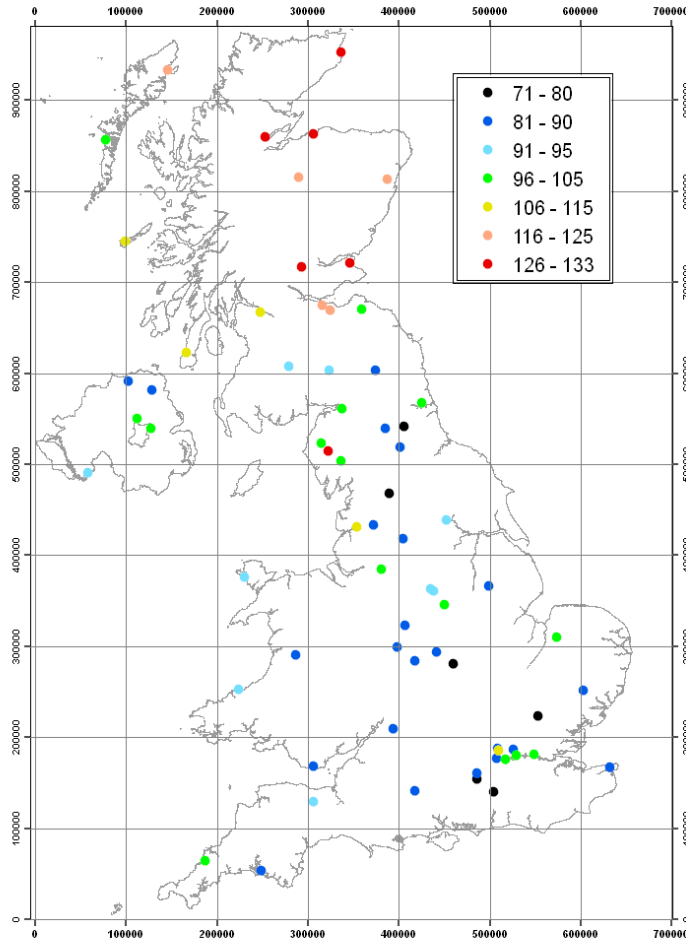


New as % of FEH for 24 hour 100 year

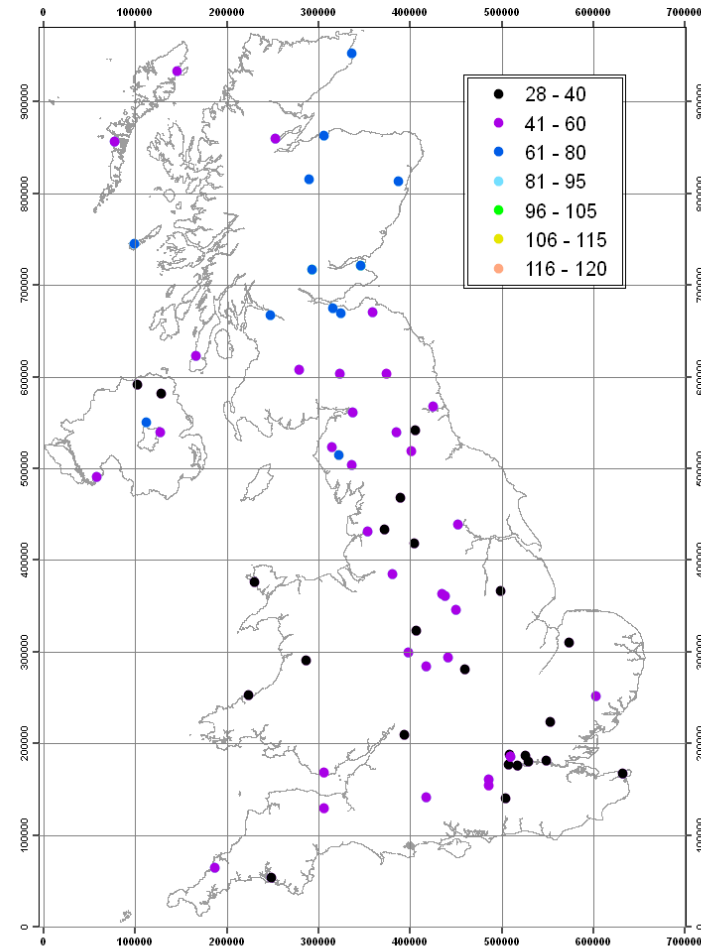


## Comparison with FEH: 2-hour duration

New as % of FEH for 2 hour 200 year

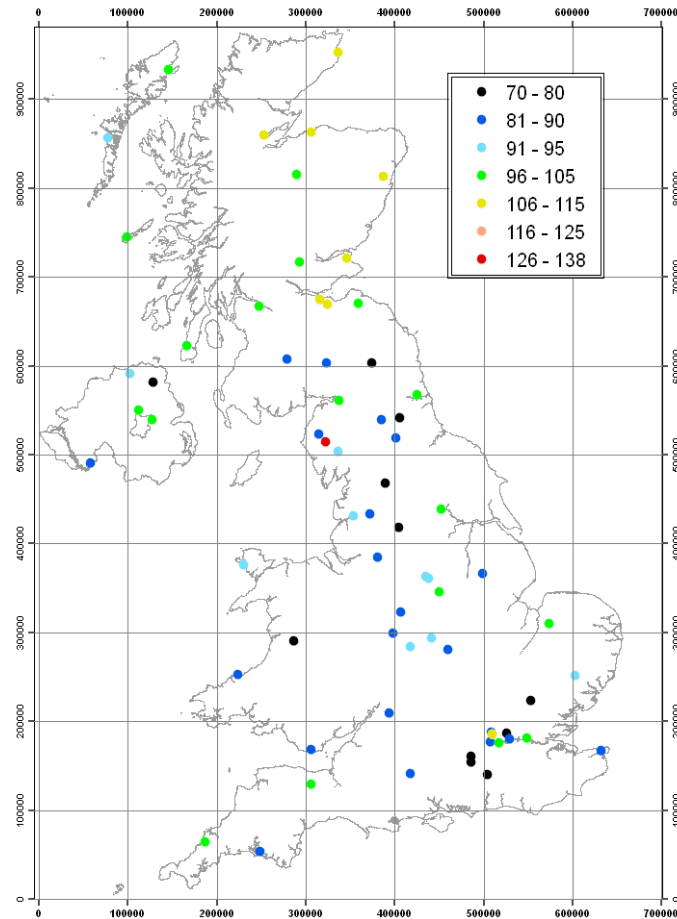


New as % of FEH for 2 hour 10,000 year

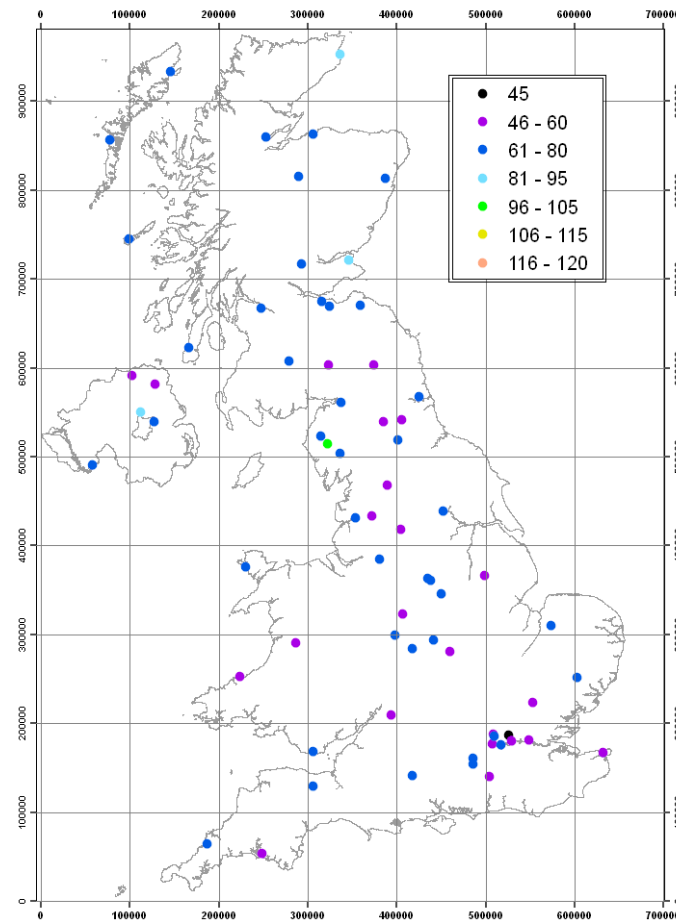


## Comparison with FEH: 6-hour duration

New as % of FEH for 6 hour 200 year

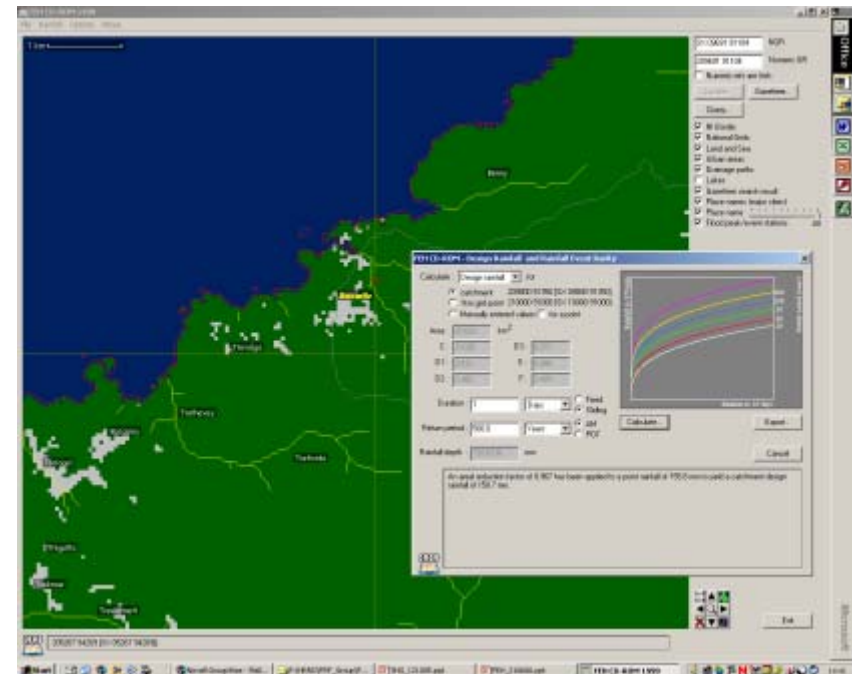


New as % of FEH for 6 hour 10,000 year



# From statistical analysis to hydrological practice

- Project report to be available on Defra website later this year
- Journal papers/newsletter articles
- FEH website
- Updated Defra guidance
- Development of new software tool



*Existing DDF model on FEH CD-ROM*



# Further information

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## Acknowledgements

Defra, Environment Agency  
Project Steering Group  
Colleagues at CEH past and present

