Improving accuracy, lead time and contingency in fluvial flood forecasts to enhance emergency management

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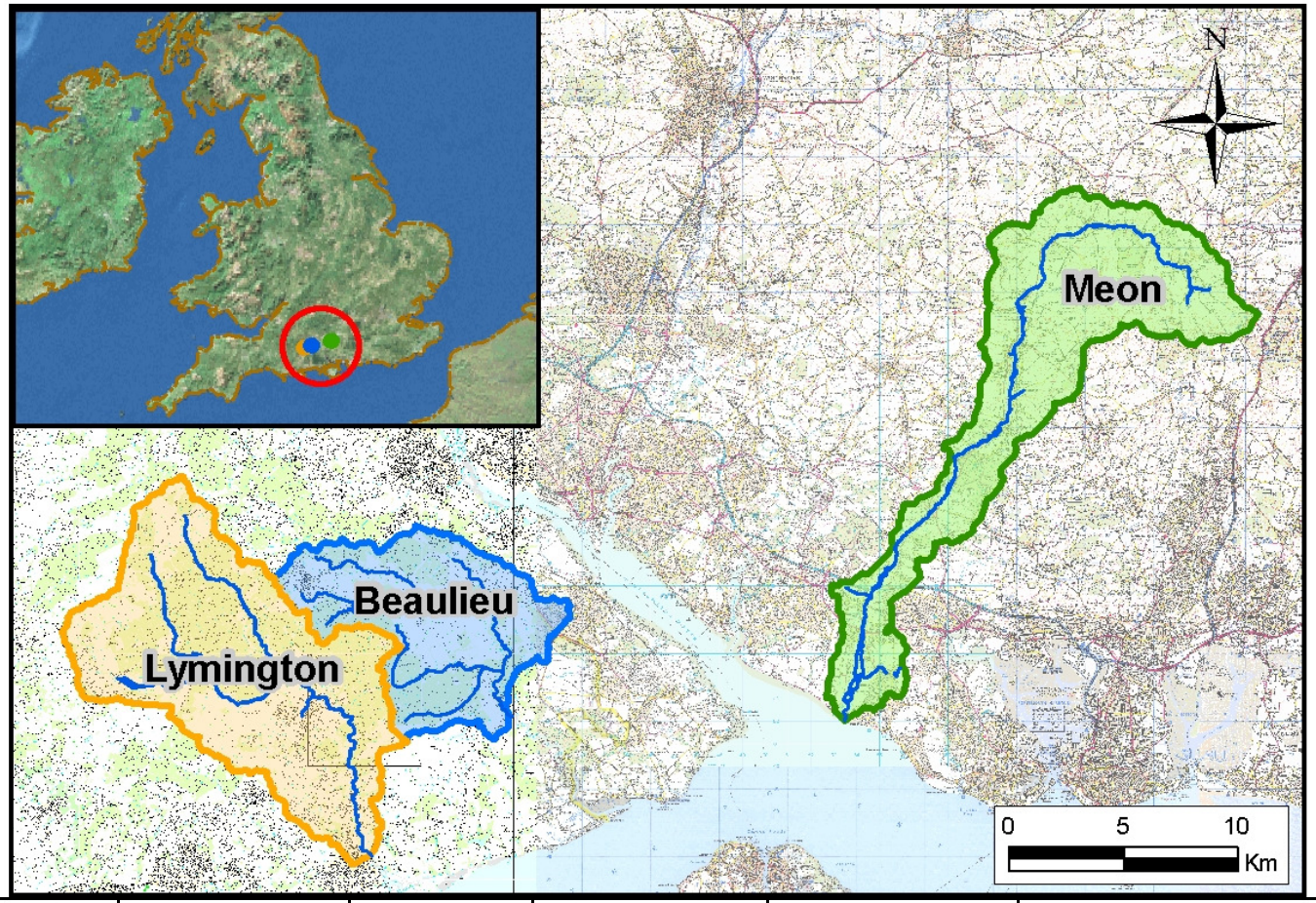
Flood Forecasting Models

- Rainfall-runoff + routing models (PDM+ISIS 1D) operated in real time with updating
- Data frequency: 15 minutes
- Models are calibrated against observed (raingauges) and forecasted (radar) rainfall

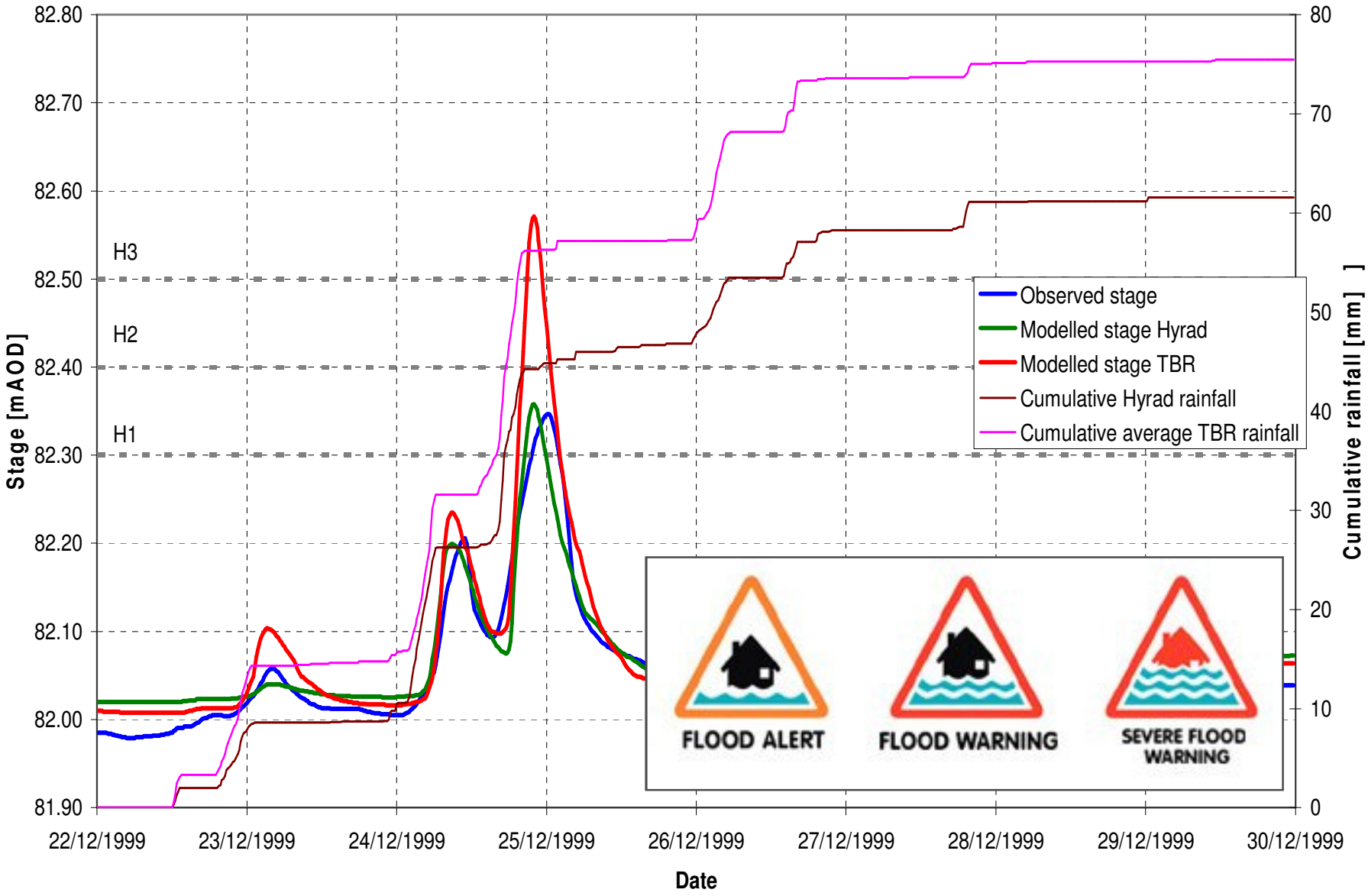
Practical cases



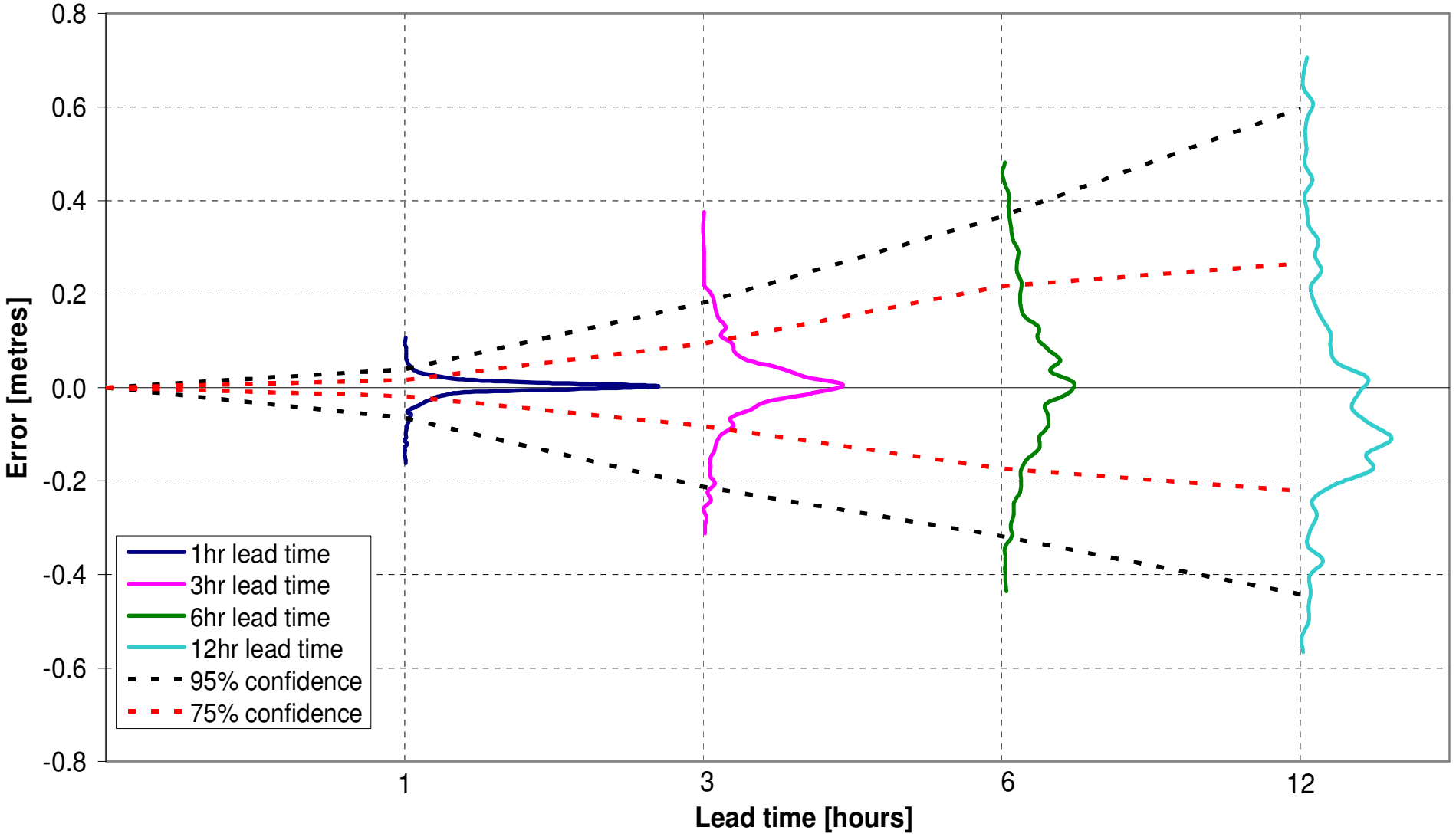
Catchment	Area [km^2]	Mean terrain slope [%]	Urban area [%]	# gauging stations	Mean flow [m^3/s]	Max recorded flow [m^3/s]	Data series length [ys]
Beaulieu	65	2.5	0.7	2	0.86	20.4	7.5
Meon	108	7.0	1.5	5	1.11	8.6	9
Lymington	121	3.8	0.6	3	1.37	68.8	10

Evaluation of results

- Six to eight events between calibration and verification, focusing only in the rising limb and peak
- Peak magnitude and timing, but also threshold level crossing
- Forecasting accuracy assessment


82.80
82.70
82.60
82.50
82.40
82.30
82.20
82.10
82.00
81.90
Stage [mAOD]
H3
H2
H1
80
70
60
50
40
30
20
10
0
Cumulative rainfall [mm]
22/12/1999
23/12/1999
24/12/1999
25/12/1999
26/12/1999
27/12/1999
28/12/1999
29/12/1999
30/12/1999
Date
Observed stage
Modelled stage Hyrad
Modelled stage TBR
Cumulative Hyrad rainfall
Cumulative average TBR rainfall
FLOOD ALERT
FLOOD WARNING
SEVERE FLOOD WARNING

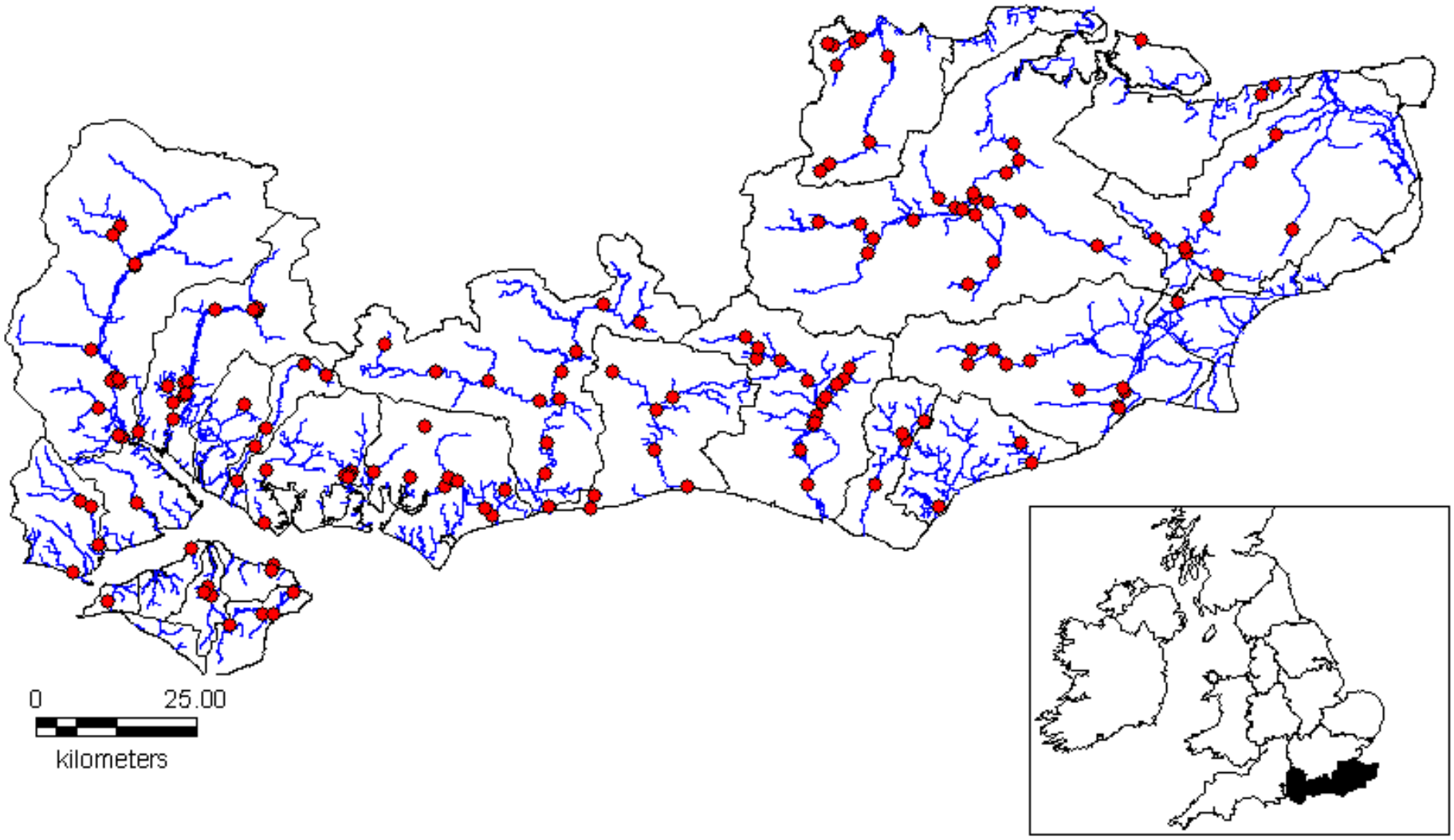
Example of forecasting accuracy assessment Lymington@Brockenhurst



Contingency Flood Forecasting techniques

- Back-up system to be used in case of failure of the primary forecasting methods
- Simple forecast tools (tables and charts) to predict the magnitude and timing of an event's peak
- 15-min stage, flow and rainfall data used
- Developed for 126 gauges in South-East England (Client: Environment Agency. Antecedent Pilot study)

Study area

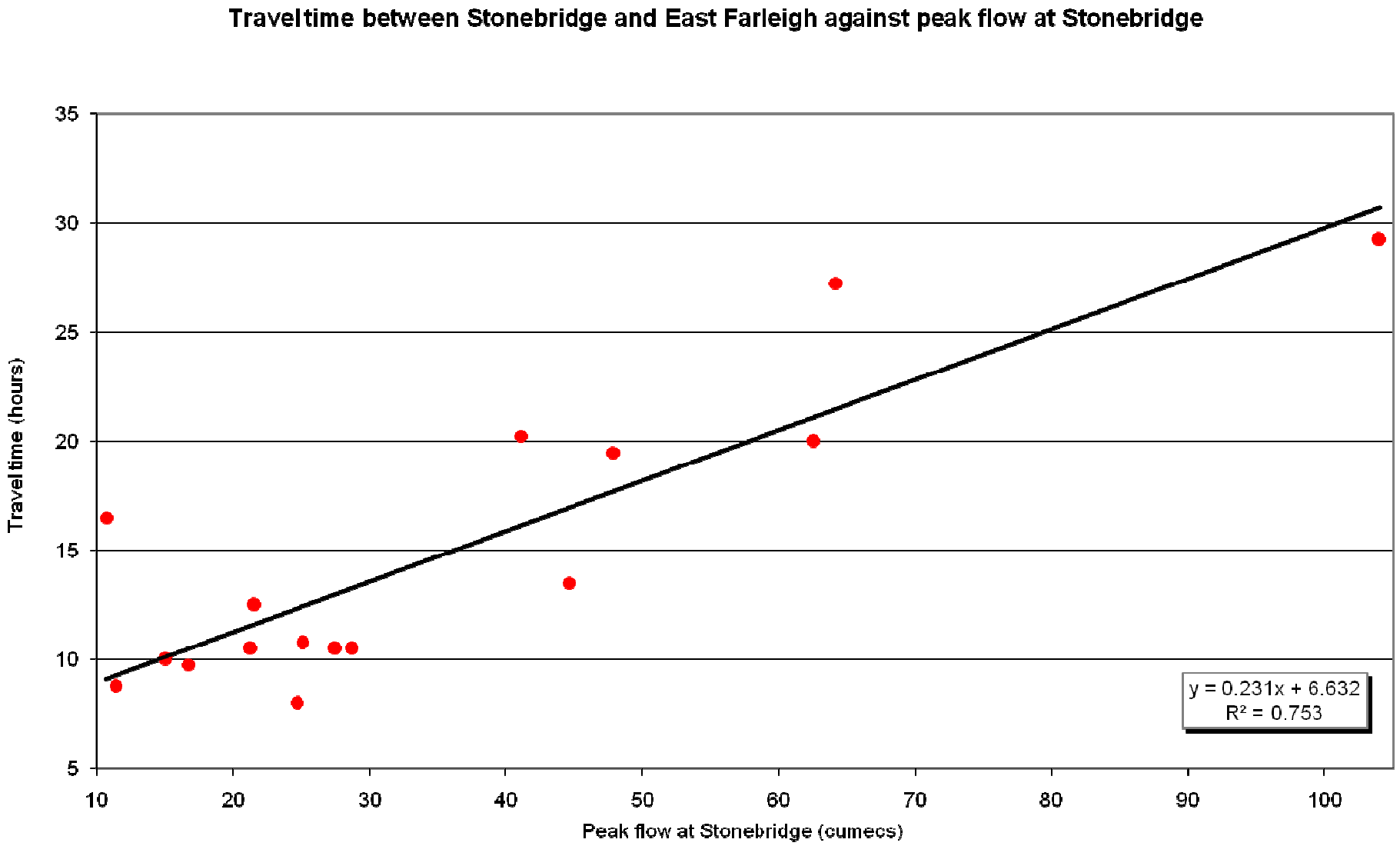


Contingency Flood Forecasting techniques

- Peak time: Catchment lag and travel time
- Peak magnitude: Rate-of-rise, rainfall correlations and peak-to-peak
- Peak relative magnitude: Event rarity analysis and Historical event data

Peak time: Travel time analyses

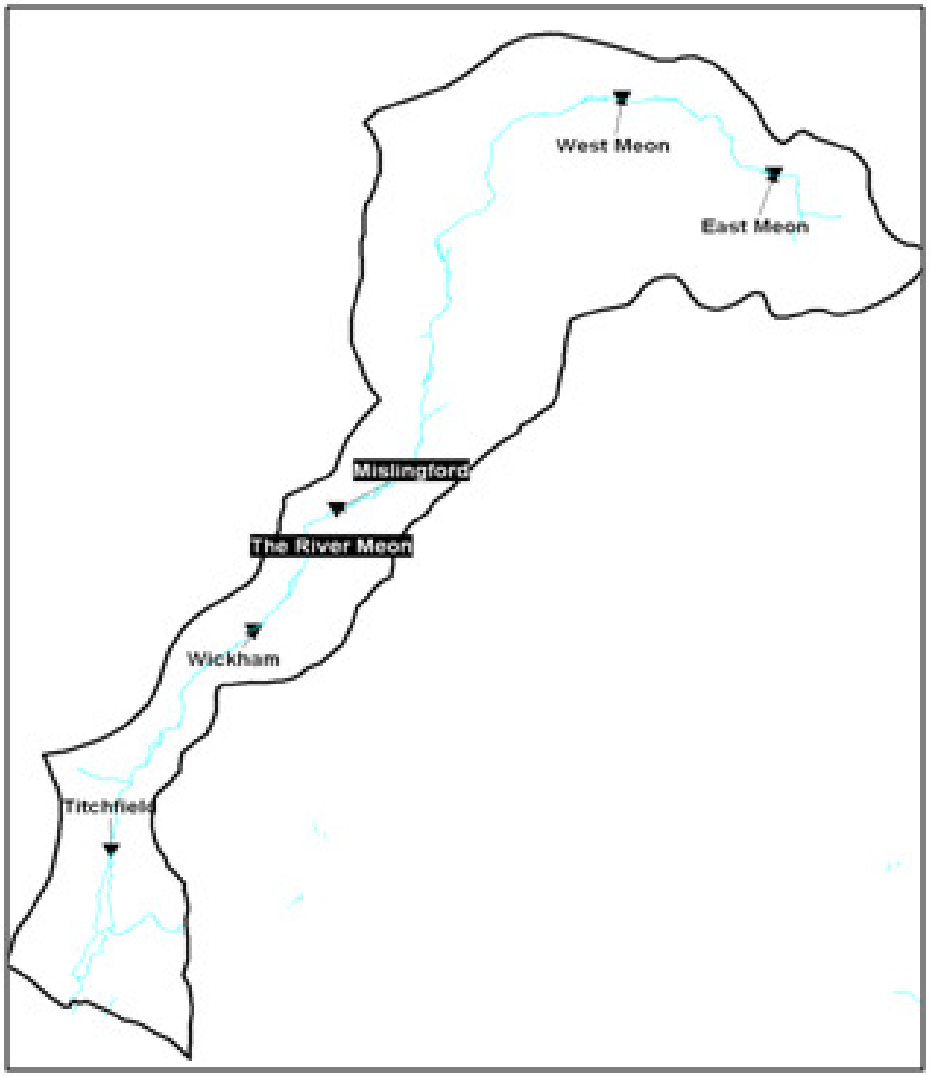
- The travel time between two gauges was calculated based on observed data from a sample of events (no modelling was used)
- Plotting the travel time against the peak flow (or level) at the upstream forecasting point resulted the most useful format to derive conclusions
- With the observed peak at the upstream location it is possible to estimate the peak time at a downstream location


Traveltime between Stonebridge and East Farleigh against peak flow at Stonebridge
Travel time (hours)
35
30
25
20
15
10
5
10
20
30
40
50
60
70
80
90
100
Peak flow at Stonebridge (cumecs)
y = 0.231x + 6.632
R² = 0.753

Peak time: Catchment lag

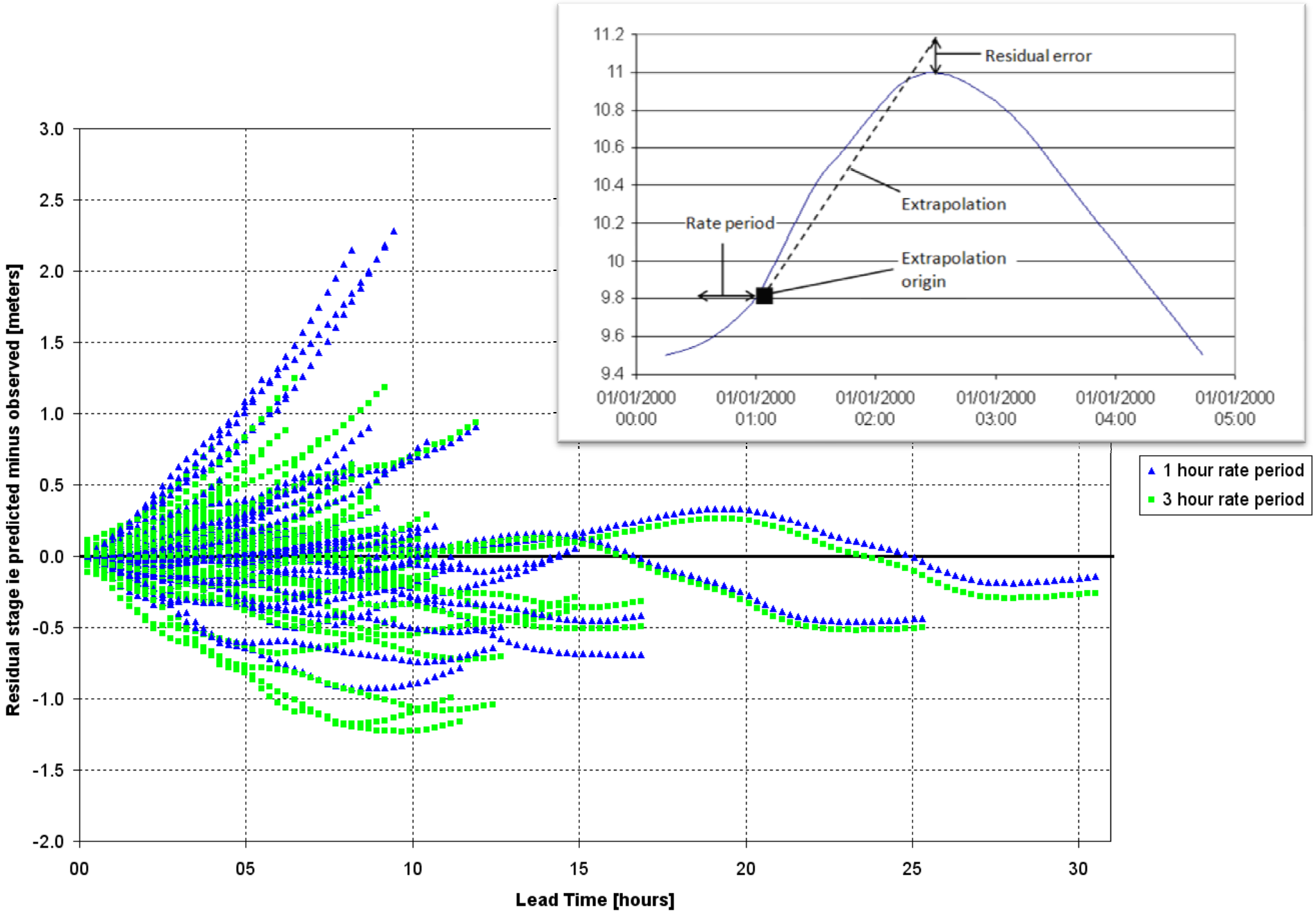
- The time between the centroid of the hyetograph and the resultant peak flow in the river
- As the catchment response depends on the antecedent conditions, the events were separated in different SMD categories.
- With the forecasted rainfall hyetograph it is possible to estimate the likely timing of the peak flow (or level)

SMD Range A	Mean catchment lag (hours from centroid of contributing		
Forecast Point	SMD ≤ 10	10 < SMD ≤ 100	SMD > 100
East Meon	3.9	3.4	N/A
West Meon	6.9	9.5	N/A
Mislingford	7.9	4.5	N/A
Wickham	6.1	5.8	N/A
Titchfield	10.5	15.5	N/A



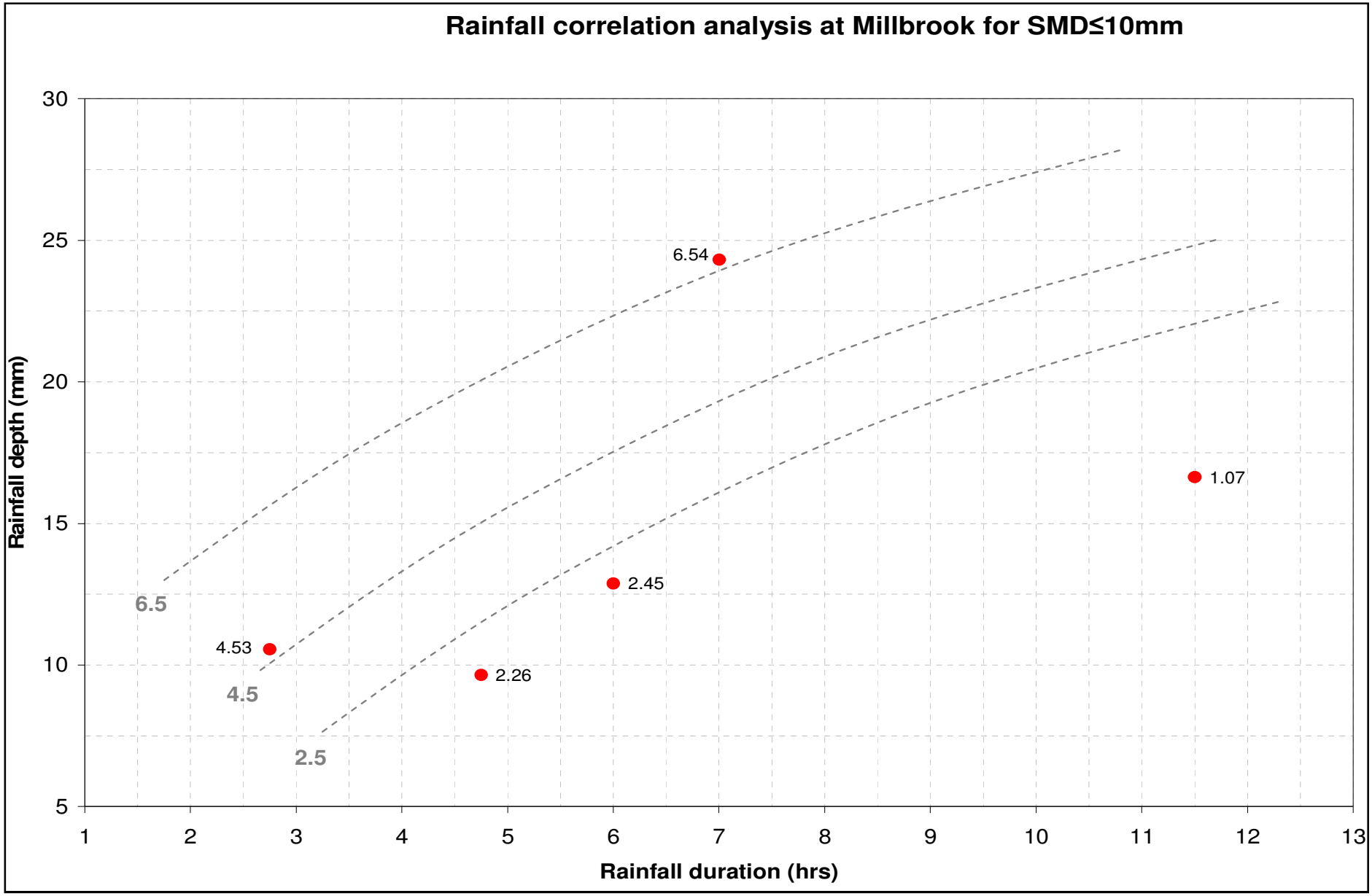
Peak magnitude: Rate of rise extrapolation

- The rate of rise of the rising limb of the hydrograph is used to estimate the peak value, using a linear extrapolation
- A key challenge is to decide when to stop extrapolating; this is estimated by other techniques
- Various extrapolation origins are used for each event; each of them has a different lead time associated
- The results are shown in terms of “residuals” against lead time
- When the water levels start to rise it is possible to estimate the peak magnitude and the error associated


Residual stage ie predicted minus observed [meters]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
00
05
10
15
20
25
30
Lead Time [hours]
1 hour rate period
3 hour rate period
11.2
11
10.8
10.6
10.4
10.2
10
9.8
9.6
9.4
Residual error
Extrapolation
Rate period
Extrapolation origin
01/01/2000 00:00
01/01/2000 01:00
01/01/2000 02:00
01/01/2000 03:00
01/01/2000 04:00
01/01/2000 05:00

Peak magnitude: Rainfall correlations

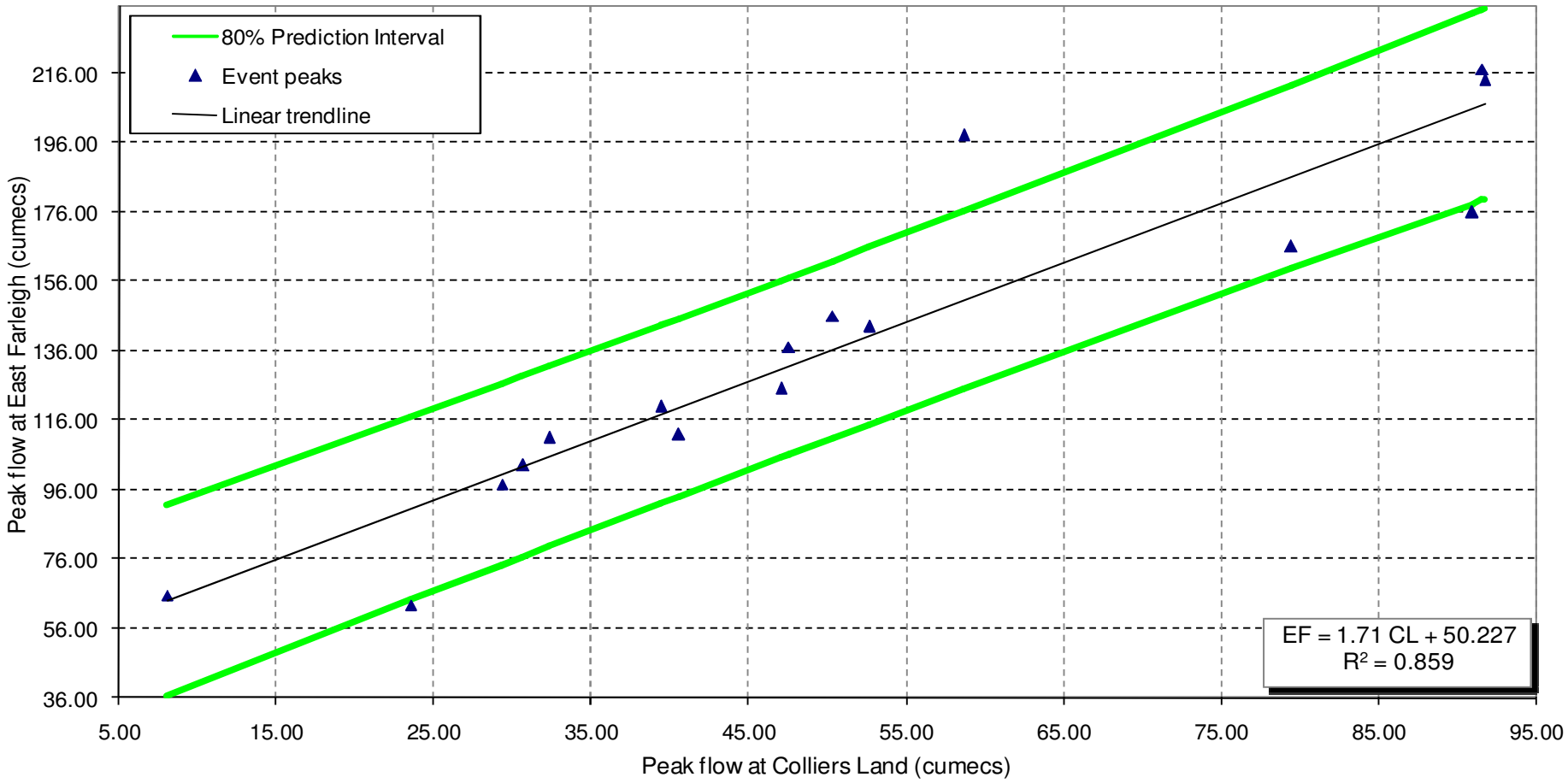
- Relates the rainfall depth and duration of an event with the resultant peak flow or level
- The better the correlation, the higher the confidence in the results, however poor correlations may also indicate that there are other factors that have an influence on the events
- The events are separated according the SMD categories to account for the catchment antecedent conditions
- This technique provides longer lead times than the others, since it can be run with forecasted rainfall


Rainfall correlation analysis at Millbrook for SMD≤10mm
Rainfall depth (mm)
Rainfall duration (hrs)
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
6.54
1.07
2.45
2.26
4.53
6.5
4.5
2.5

Peak magnitude: Peak to peak correlations

- Relates peak level or flow data at two gauges in the same watercourse and generates a correlation that allows estimating the peak value at the downstream gauge with the peak value at the upstream one
- The farther the gauges the longer the lead time, so if two correlations show similar R^2 values then the one using the furthest upstream donor will be preferable
- Prediction (or confidence) intervals can be statistically calculated for each correlation, which gives an estimation of the expected error in the forecasts

Peak-to-peak correlation at East Farleigh
Donor station = Colliers Land

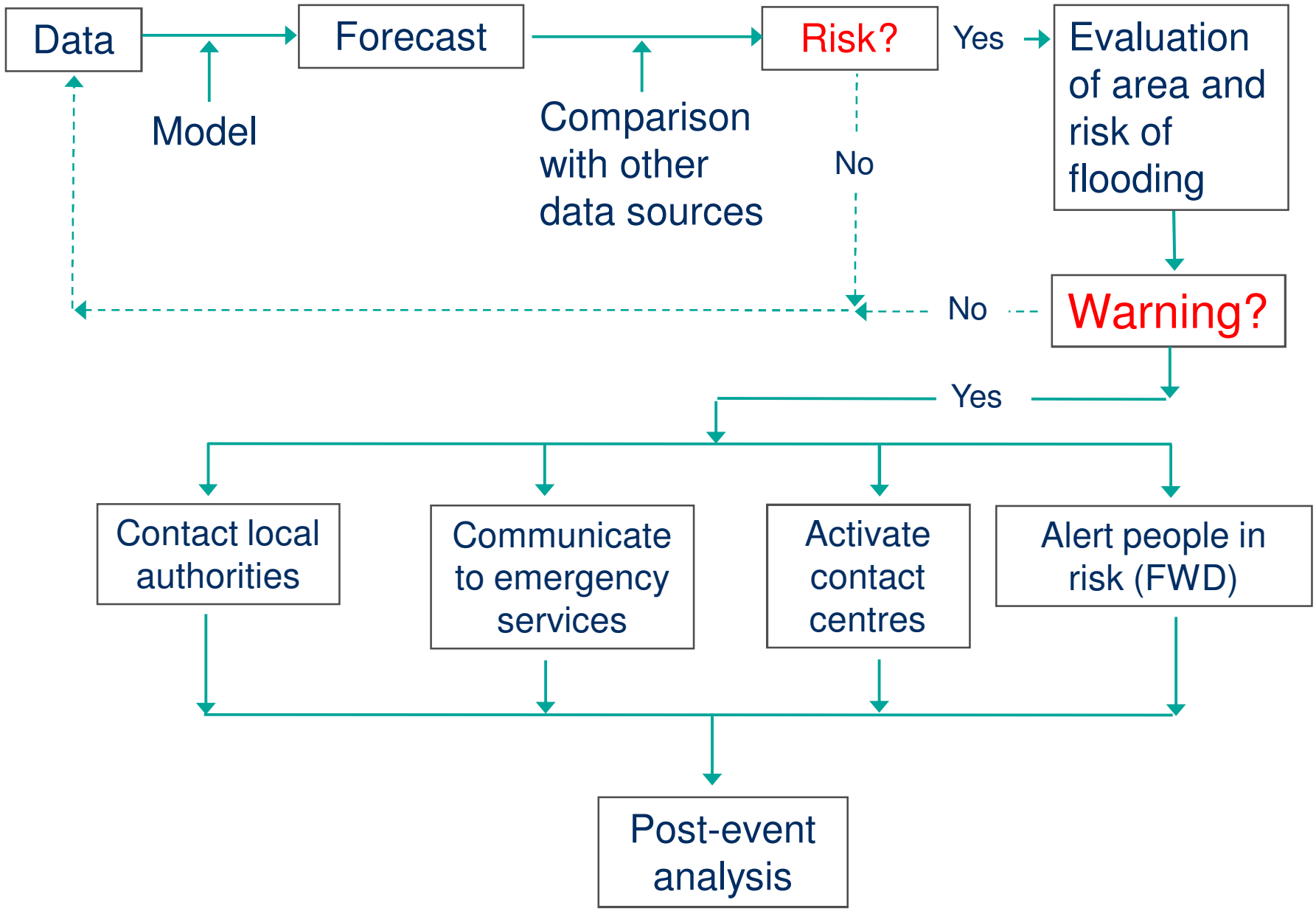


Peak relative magnitude

- Event rarity analysis: Provides information on the estimated rarity (Rp) of a range of historic flood (and rainfall) events at each forecasting point. It helps putting the forecasted event in context with the past observed events.

- Historical event data: Summarises the main characteristics (peak flow and level, rainfall depth and duration, number of flooded properties, etc.) of the highest events in the historical data series

Flood Warning Dissemination


Data
Model
Forecast
Comparison with other data sources
Risk?
Yes
Evaluation of area and risk of flooding
No
Warning?
No
Yes
Contact local authorities
Communicate to emergency services
Activate contact centres
Alert people in risk (FWD)
Post-event analysis

Conclusions

- Flood forecasting and warning became cost-effective methods of mitigating the impacts of flooding, to be used in conjunction with other mitigation measures (i.e. flood defences)
- Hydrodynamic flood forecasting modelling provides duty officers with the key evidence to inform the issue of warnings, especially when supported by information on the expected performance of the models at different lead times
- Should the primary forecasting sources fail for any reason, the contingency flood forecasting methods are simple but effective and ready-to-use tools for the forecasting duty officers

Thank you!

Questions?