Real-time modelling of surface water flooding hazard and impact at countrywide scales

Steven Cole[1], Robert Moore[1], Paul Mattingley[1],Timothy Aldridge[2], Jon Millard[3,4] and Stefan Laeger[5]

BHS National Symposium, University of Birmingham, 4 September 2014

1 Centre for Ecology & Hydrology, Natural Environment Research Council
2 Health & Safety Laboratory
3 Flood Forecasting Centre, a working partnership between Environment Agency and Met Office
4 Met Office
5 Environment Agency

What is the Natural Hazards Partnership?

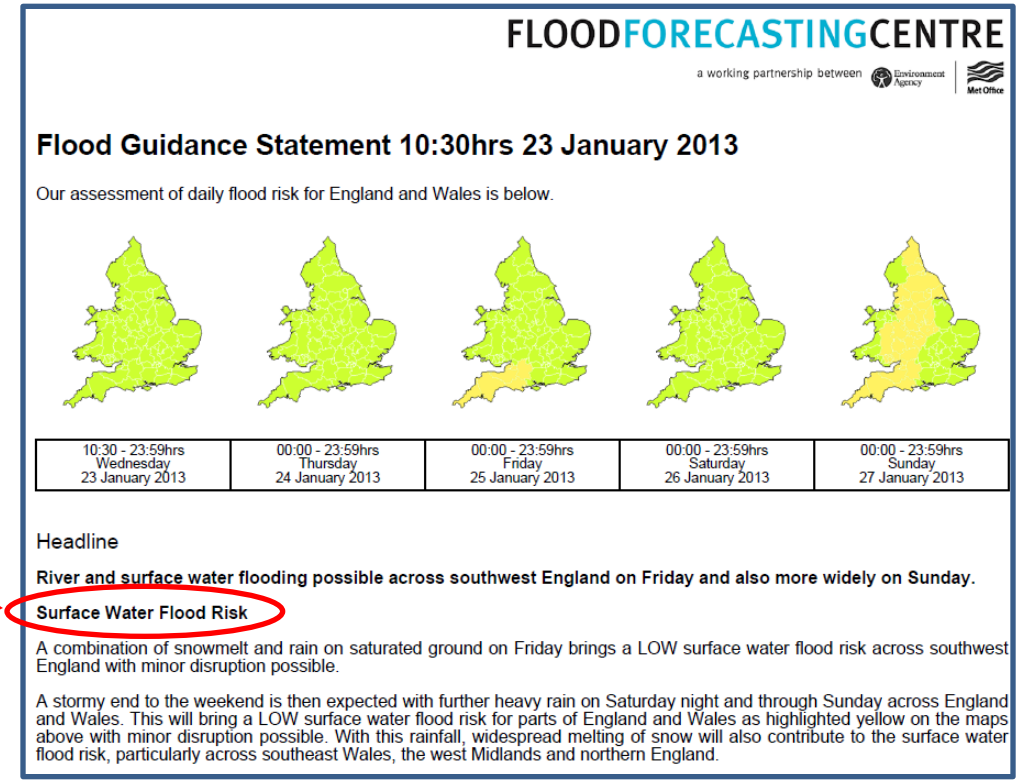
Real-time **Hazard Impact Model:** Surface Water Flooding

Surface Water Flooding

- Surface Water Flooding (SWF)
  - Major hazard with ~4 million properties at risk in England alone (EA, 2009)
- Summer 2007 floods
  - £3 billion insurance payouts
  - 55,000 properties flooded, ~36,000 due to SWF
  - National infrastructure impacts
    - 140,000 homes without clean water for 17 days
    - 42,000 homes without power for 24 hours
    - 10,000 people trapped on M5
  - Pitt Review commissioned
  - Flood Forecasting Centre & Scottish Flood Forecasting Service formed

Surface Water Flooding Alerts: Approaches

- Rainfall-based alerts (current practice)
  - Uses national rainfall-thresholds and broad soil moisture & urban effects
  - Supports FFC Surface Water Decision Support Tool (Spreadsheet)
  - Feeds in to FFC daily Flood Guidance Statement



FLOODFORECASTINGCENTRE

a working partnership between Environment Agency | Met Office

Flood Guidance Statement 10:30hrs 23 January 2013

Our assessment of daily flood risk for England and Wales is below.

10:30 - 23:59hrs Wednesday 23 January 2013	00:00 - 23:59hrs Thursday 24 January 2013	00:00 - 23:59hrs Friday 25 January 2013	00:00 - 23:59hrs Saturday 26 January 2013	00:00 - 23:59hrs Sunday 27 January 2013

Headline

River and surface water flooding possible across southwest England on Friday and also more widely on Sunday.

Surface Water Flood Risk

A combination of snowmelt and rain on saturated ground on Friday brings a LOW surface water flood risk across southwest England with minor disruption possible.

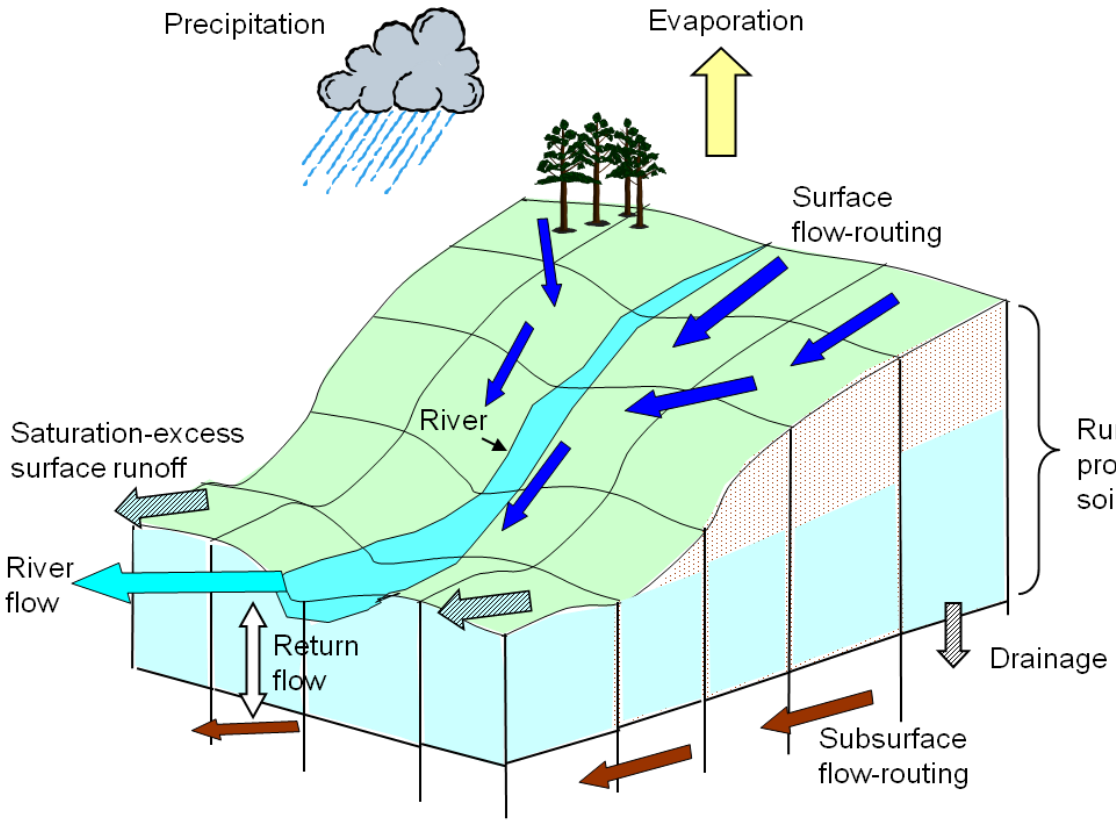
A stormy end to the weekend is then expected with further heavy rain on Saturday night and through Sunday across England and Wales. This will bring a LOW surface water flood risk for parts of England and Wales as highlighted yellow on the maps above with minor disruption possible. With this rainfall, widespread melting of snow will also contribute to the surface water flood risk, particularly across southeast Wales, the west Midlands and northern England.

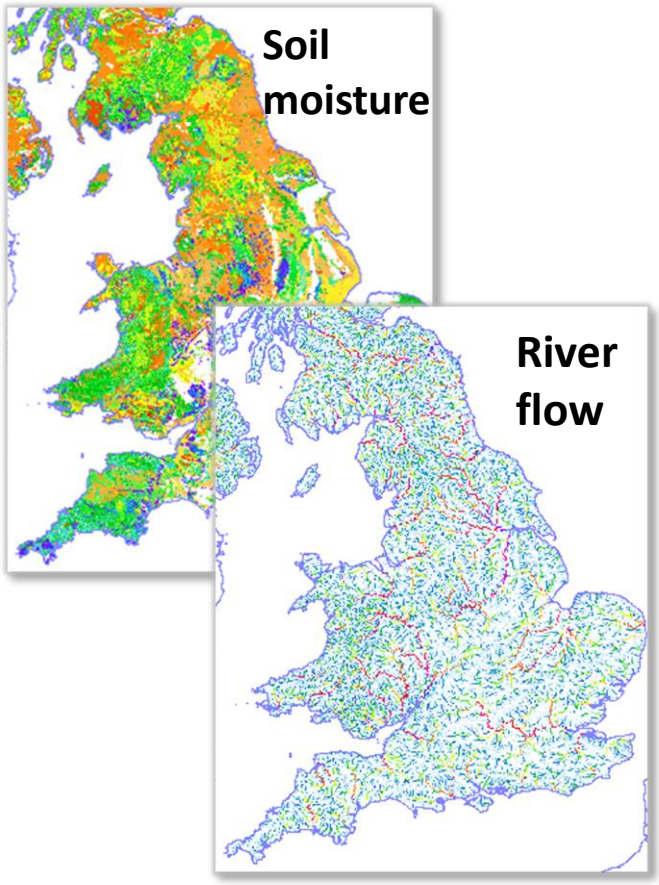
Surface Water Flooding Alerts: Approaches

- Rainfall-based alerts (current practice)
  - Uses national rainfall-thresholds and broad soil moisture & urban effects
  - Supports FFC Surface Water Decision Support Tool (Spreadsheet)
  - Feeds in to FFC daily Flood Guidance Statement
- Localised runoff thresholds (ongoing NHP developments)
  - G2G distributed hydrological model converts rainfall to runoff
  - G2G soil moisture conditions influence surface runoff production
  - Scientific advances to improve national SWF hazard footprint
  - G2G already used by FFC & SFFS so "quick win" potential
- New impact assessments (ongoing NHP developments)
  - Use existing national datasets on property, infrastructure & population
  - Case studies show potential for real-time hazard and impact forecasts

HEALTH & SAFETY LABORATORY

Grid-to-Grid (G2G) Distributed Model



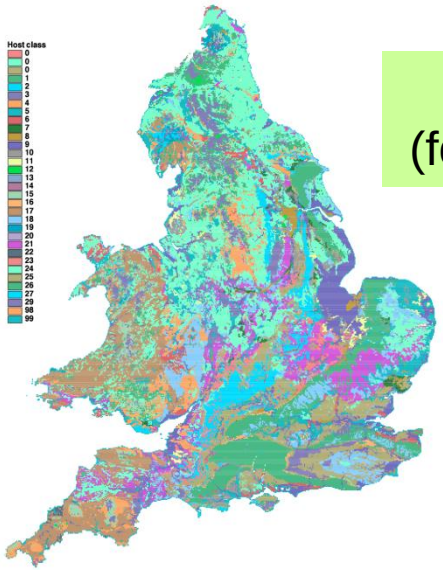


- Uses spatial datasets on terrain, soil/geology, land-cover
- Responds to spatial variation of rainfall input
- Used operationally across Britain at a 1km 15 min resolution

Moore *et al.*, IAHS Publ. 305 (2006)

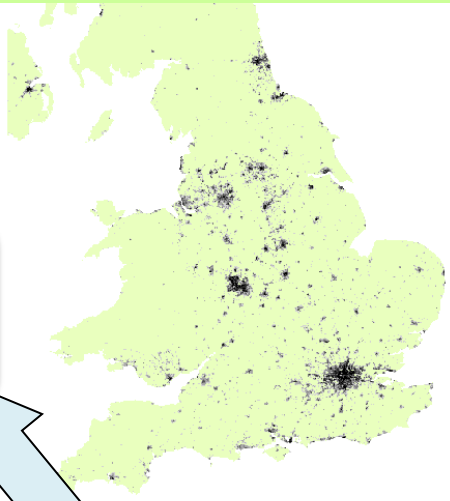
Price *et al.*; Cranston & Tavendale, Water Management (2012)

Factors affecting G2G runoff production



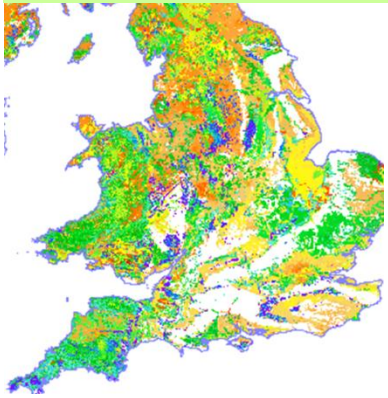
Soil properties
(for each HOST class)

Urban/Suburban coverage
- Increase runoff (by decreasing soil depth)



G2G Runoff Production

Soil Moisture Deficit
(modelled)

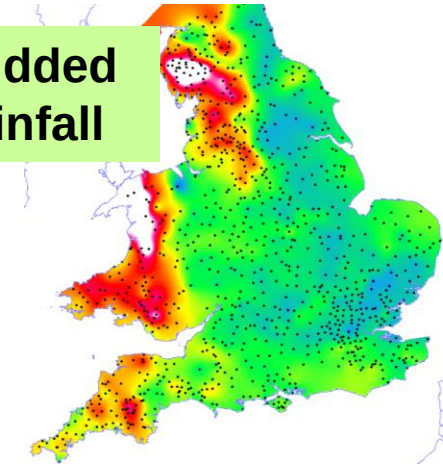


Terrain/slope

Steep slopes → Shallow storage

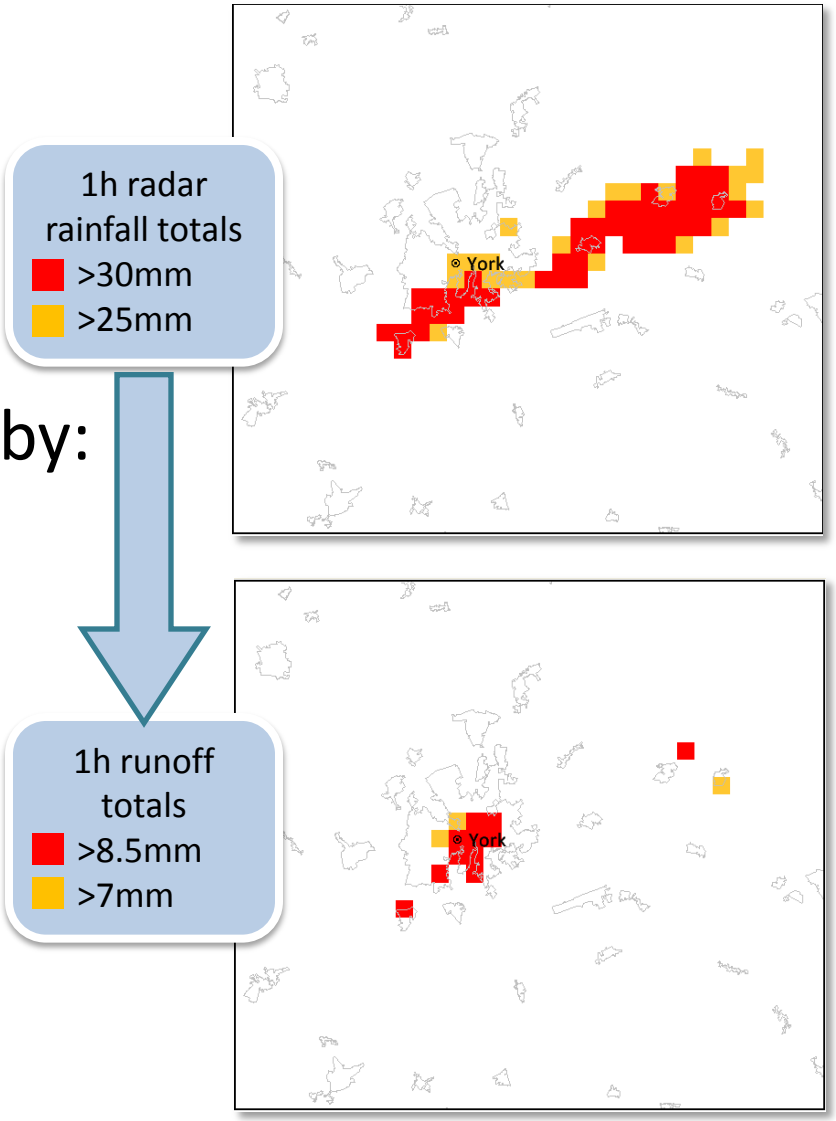
Shallow slopes → Deep storage

Gridded rainfall



G2G runoff alerts for surface flooding

- National rainfall-thresholds
  - Based on Extreme Rainfall Alert method
  - Uses FEH 30 year return period rainfalls "averaged" across 8 UK cities
- G2G runoff production affected by:
  - Rainfall amount **plus**
  - Urban/suburban coverage
  - Soil and geology properties
  - Antecedent soil moisture conditions
- Prototype runoff threshold exceedances seem **more targeted**



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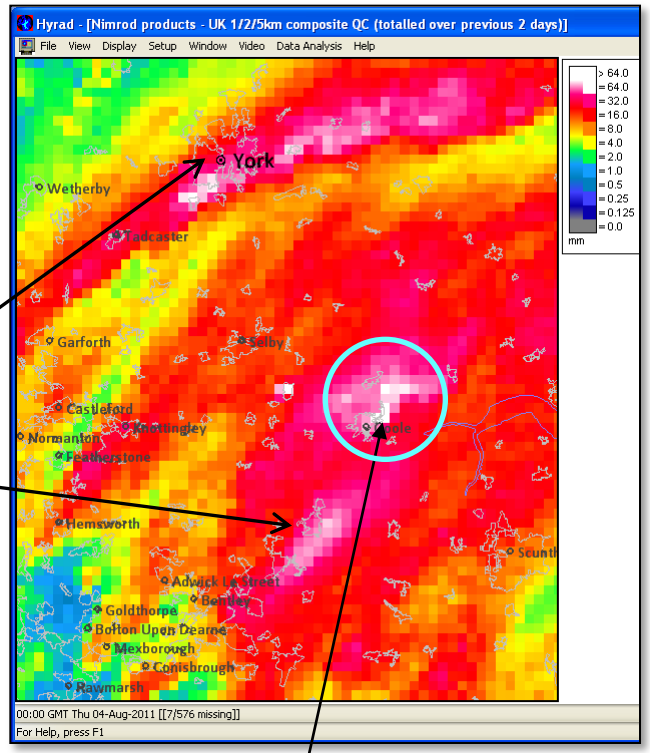
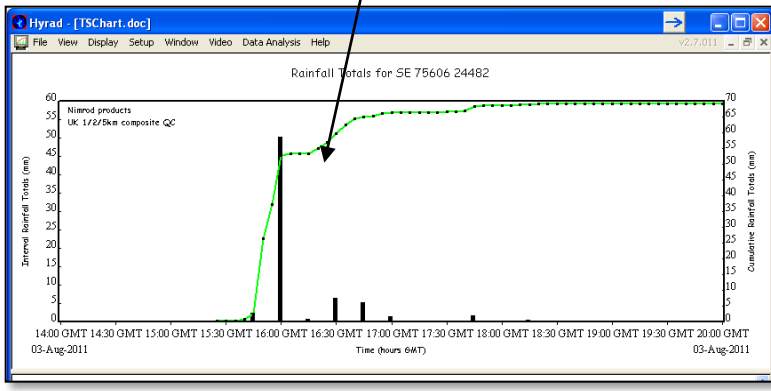
SWF Case Study: 2-3 August 2011

- 2-3 August 2011 event
  - FFC identified event with SWF impacts
  - Peak radar accumulations of 40-60mm near York and Goole
  - Reports of flooding at Thorne and York
  - Goole badly affected including a residential home
- End-to-end case study to produce first SWF impact maps
  - Note uses radar-rainfall and not forecasts
  - Good first step guiding future development





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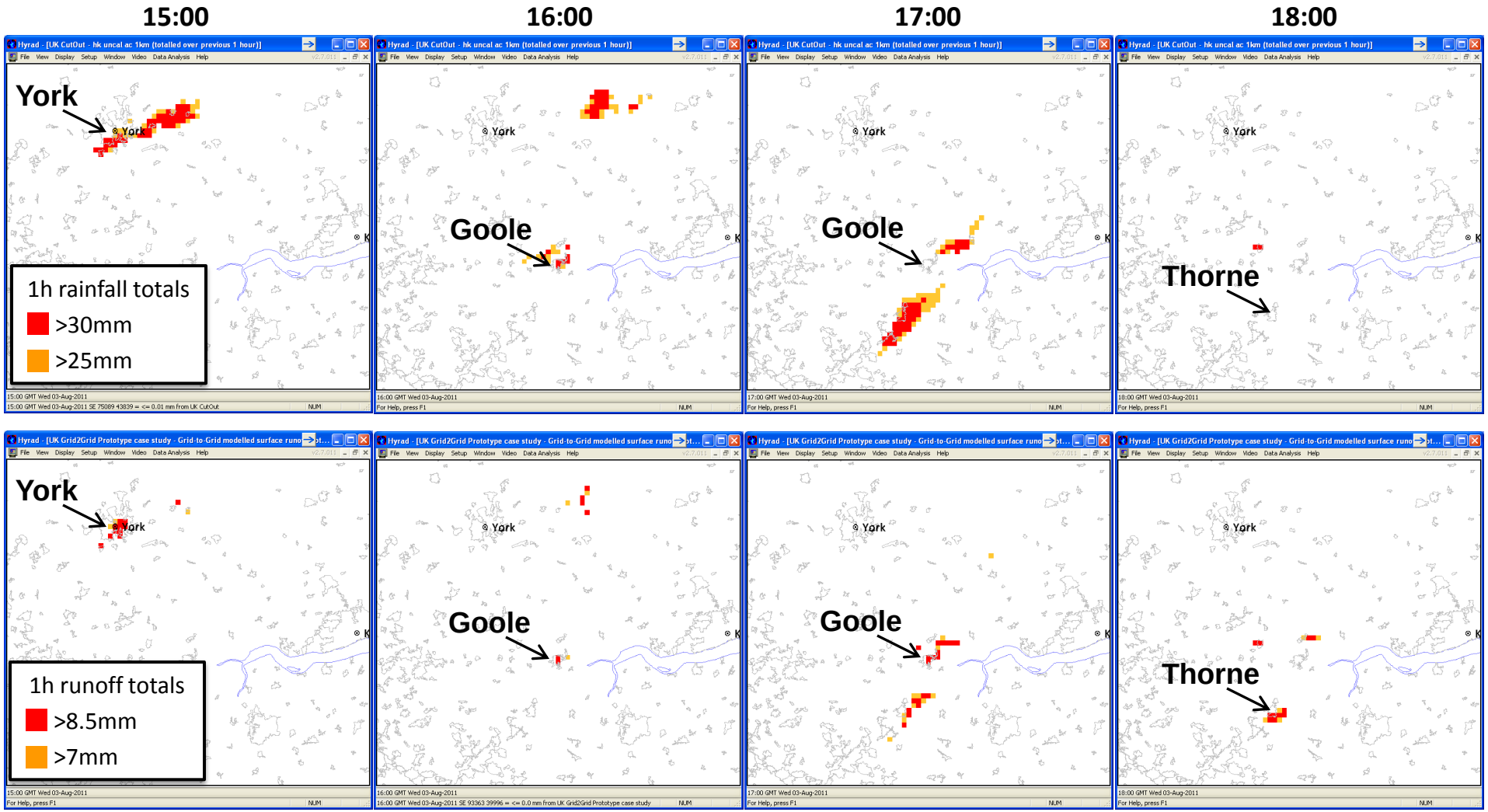
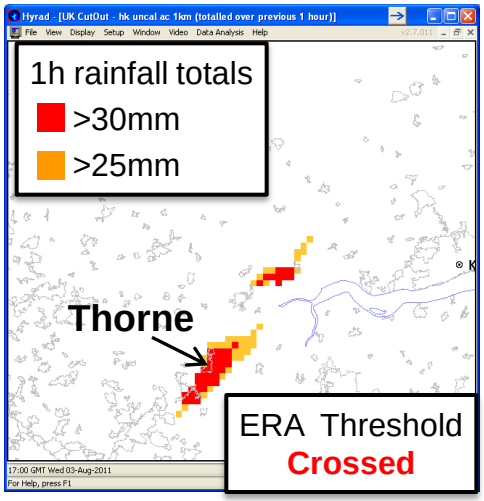
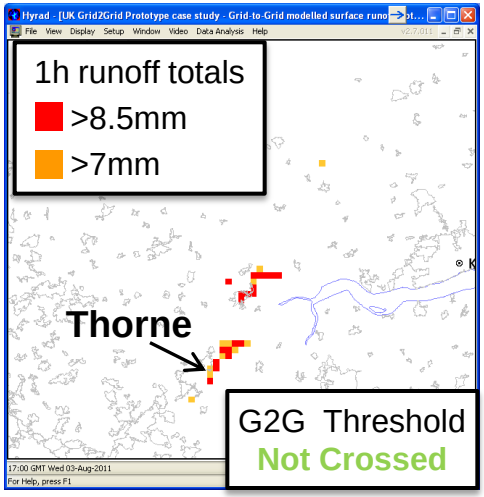
SWF Case Study: 2-3 August 2011

- Evolution of rainfall and surface-runoff accumulation maps
- Reported flood locations highlighted (FFC data)



SWF Case Study: rainfall vs surface-runoff

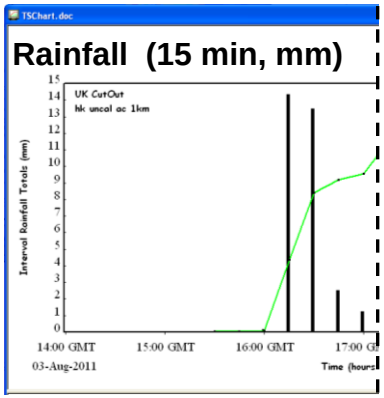


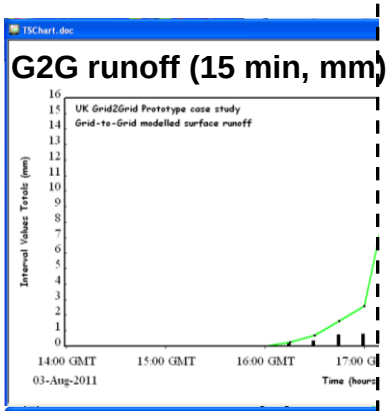


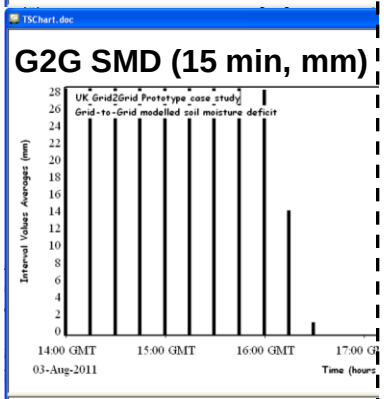
17:00

Heavy rain
Low runoff %
Pixel becomes saturated

17:00 **18:00**







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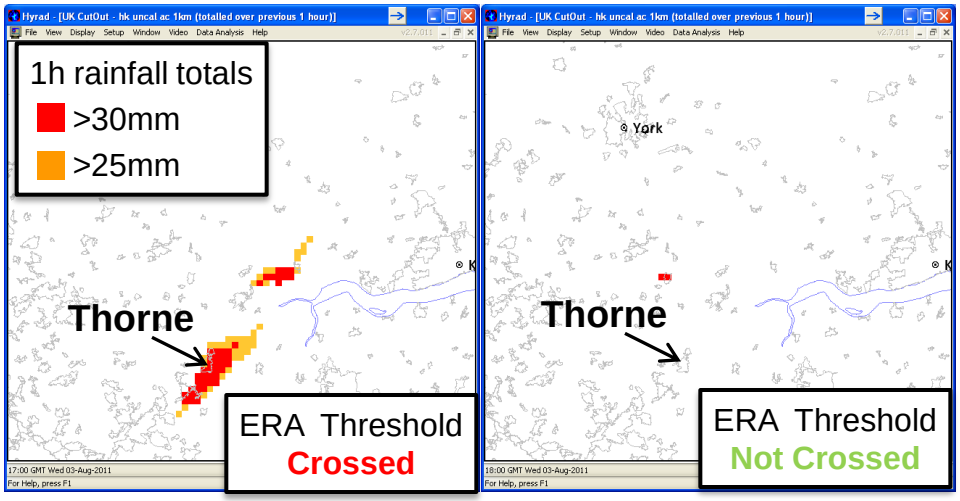

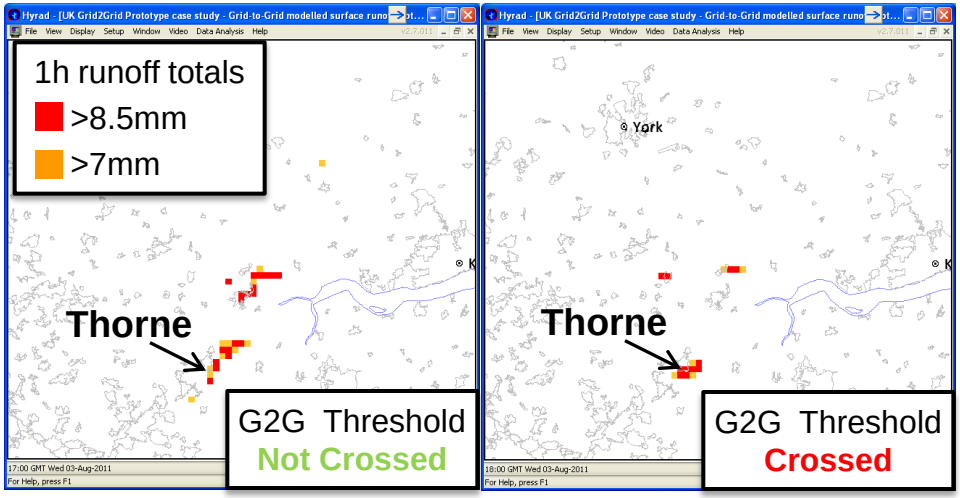

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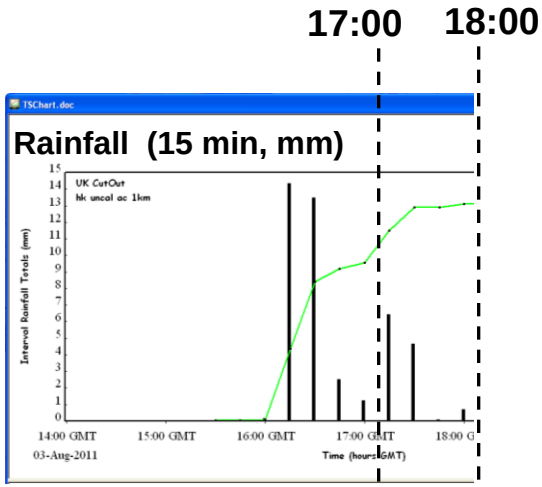
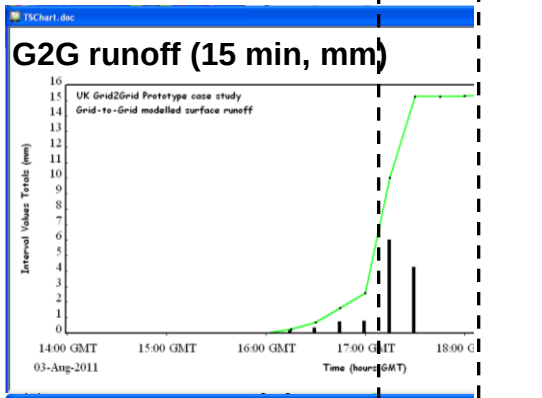
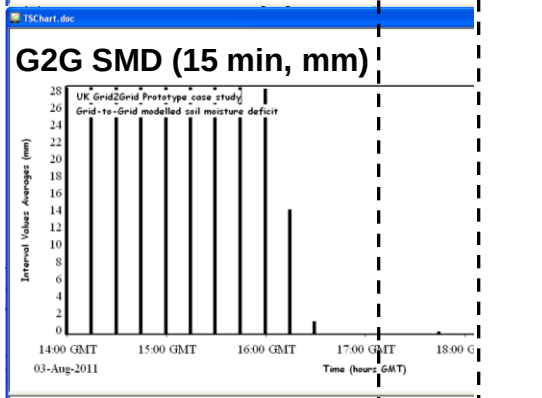
18:00

Moderate rain
High runoff %
Saturated







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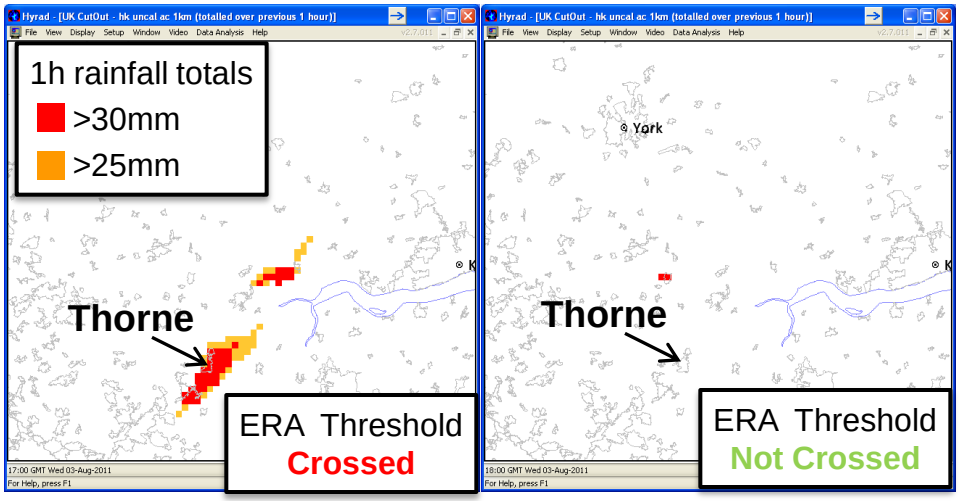

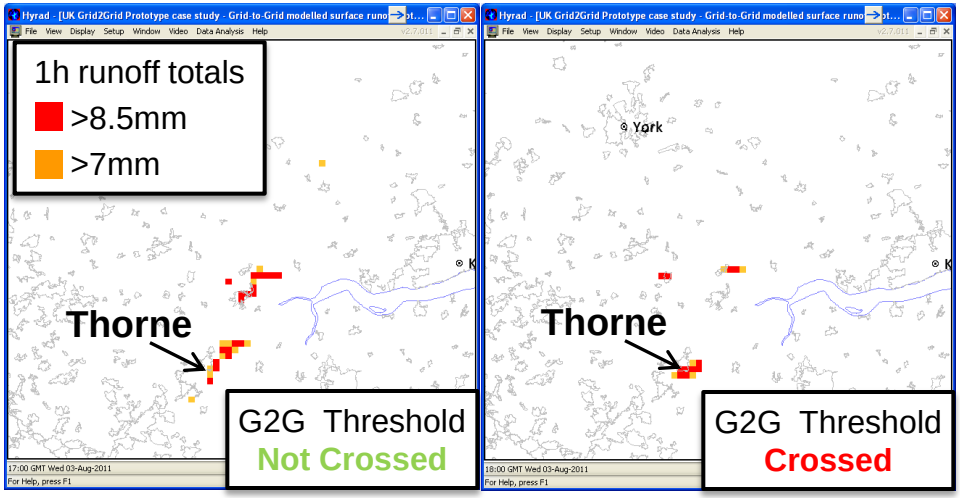

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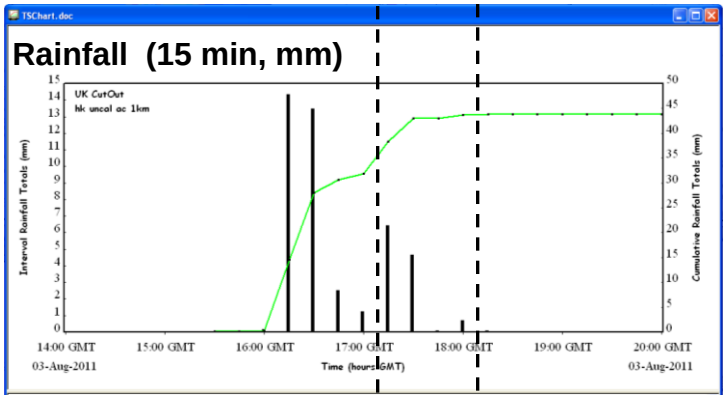

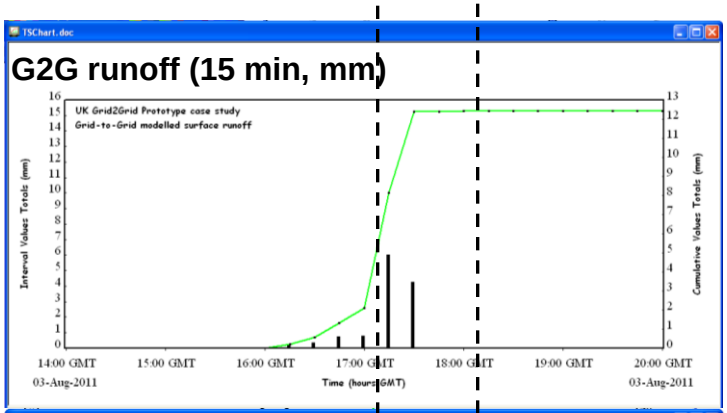

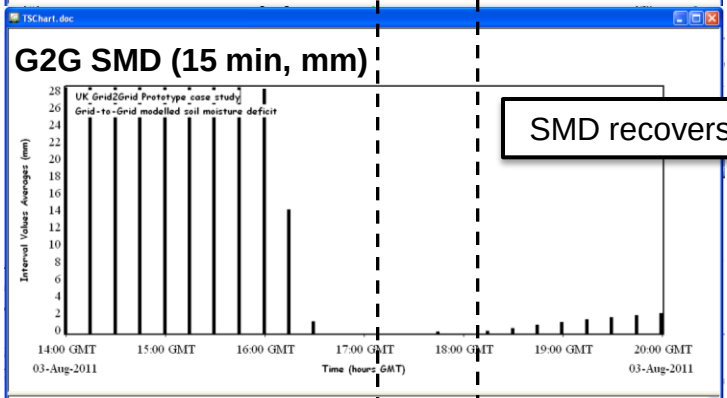

17:00

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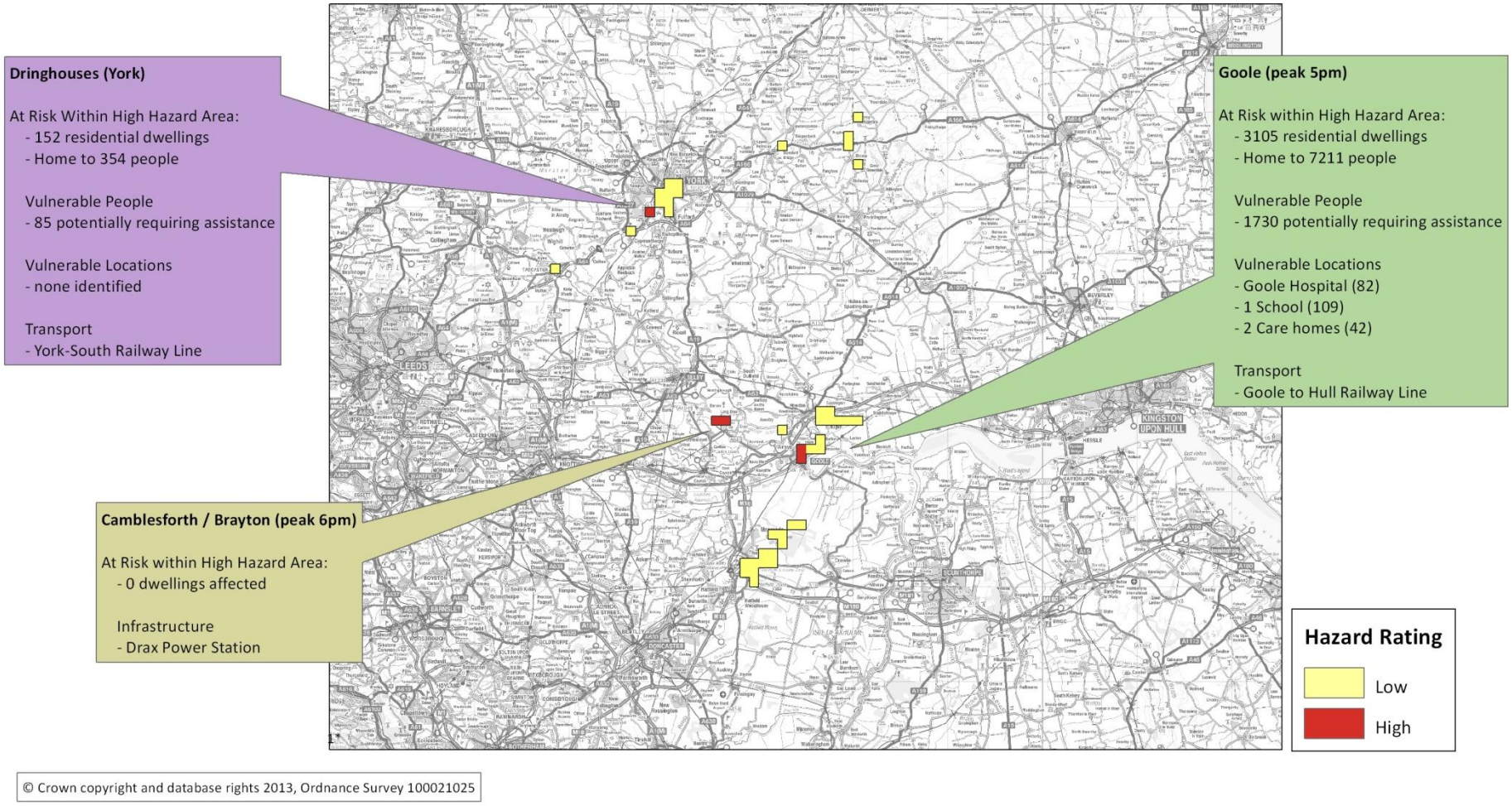
Example SWF impact output

- Impact Summary over time-frame of event



SWF Impact Modelling approach

Ensemble rainfall forecasts (MO)

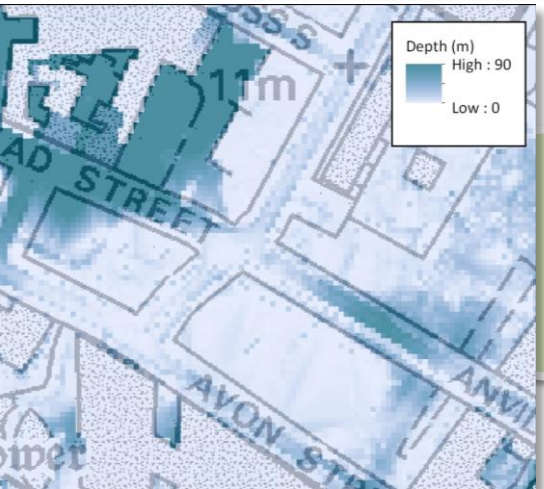
National Receptor Dataset (EA)

Other impact datasets …

Hazard Footprint
Based on G2G surface runoff

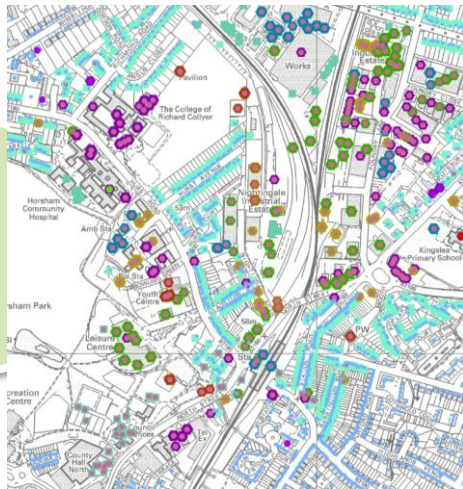
Impact Library
(HSL)

Hazard Impact Outputs



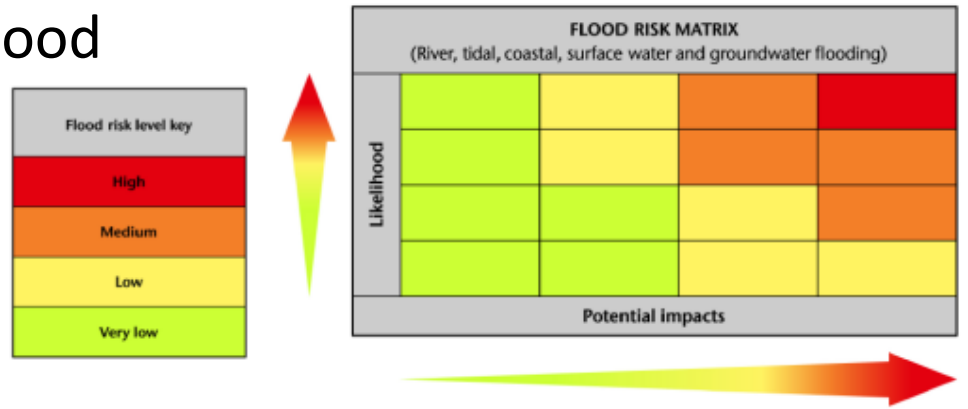
Updated Flood Map for Surface Water UFMfSW (EA)

National Population Database (HSL)



Impact Library

- Pre-calculate 1km Impact Library, using uFMfSW scenarios (e.g. 30yr, 1hr storm) and national datasets on population and receptors
- Criteria based on defined set of flood impacts
  1. Danger to life
  2. Damage to Buildings
  3. Disruption of Key Sites and Infrastructure
  4. Disruption of Transport
  5. Disruption of Communities
- Evidence-based approach for impact assessment methodology
- 1km impact output and regional summary
- Link impact and likelihood to Flood Risk Matrix used by EA/FFC



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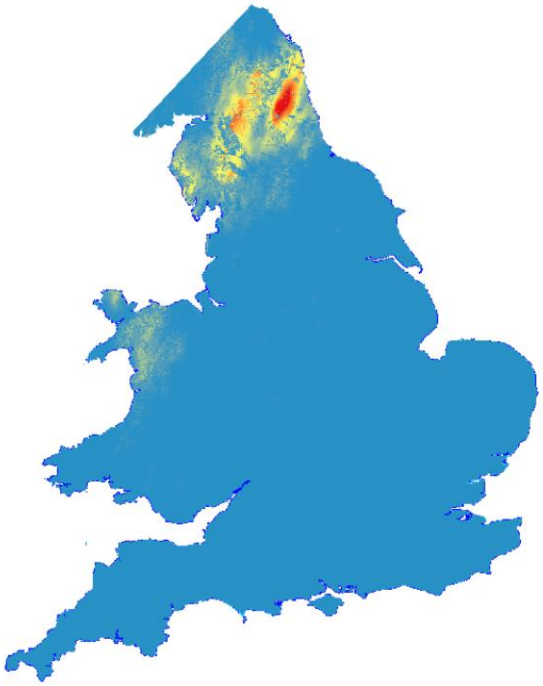
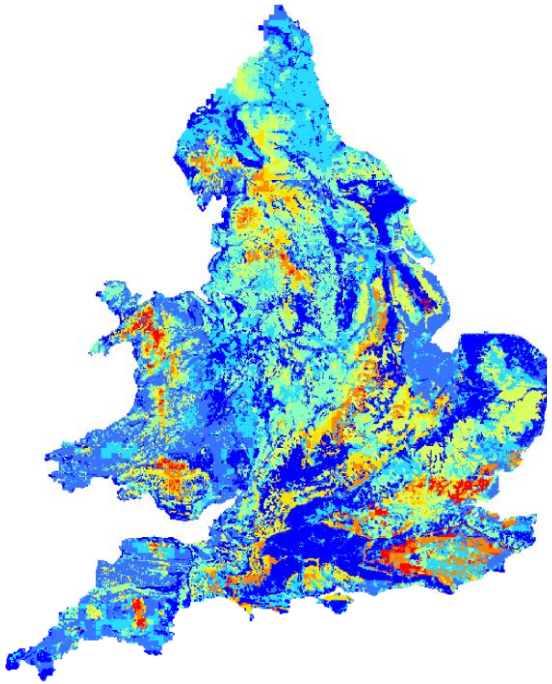
Link G2G Hazard Footprint to impact

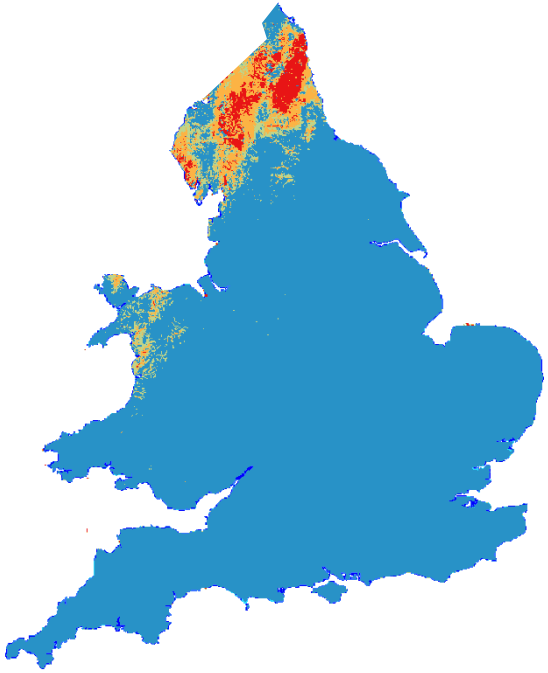
Calculate G2G surface runoff accumulations

Exceeds UFMfSW "net rainfall" scenario?

Use Impact Library to assess impact







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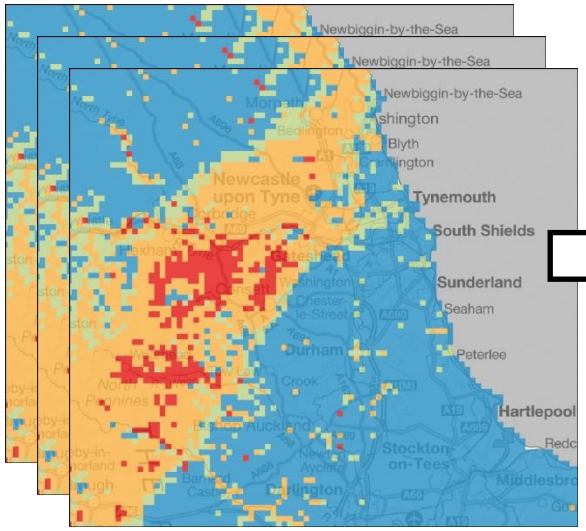
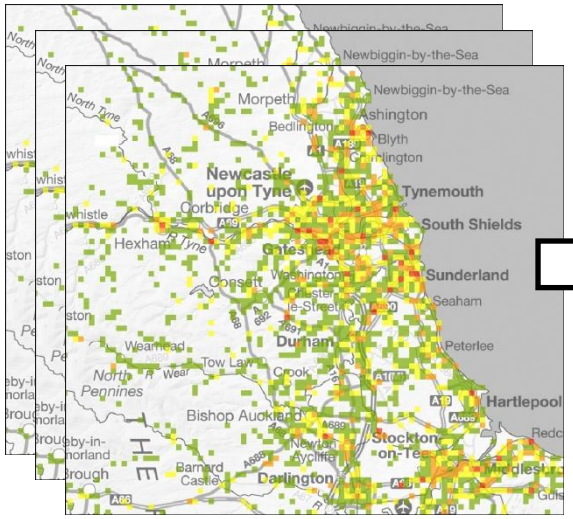
Probabilistic impact products

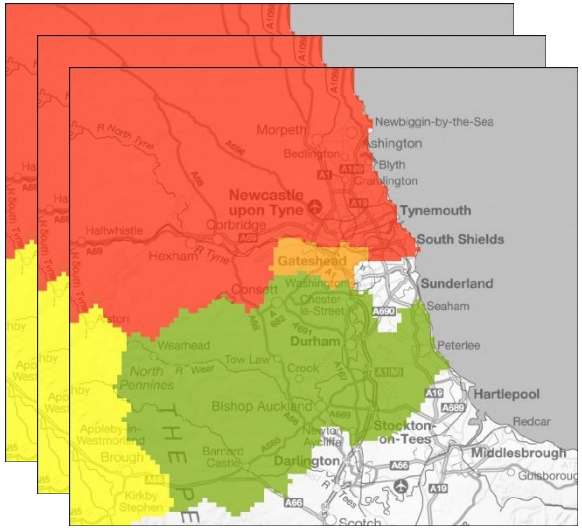
Proof-of-concept hazard impact forecast system:



Ensemble of SWF hazard footprint (G2G)

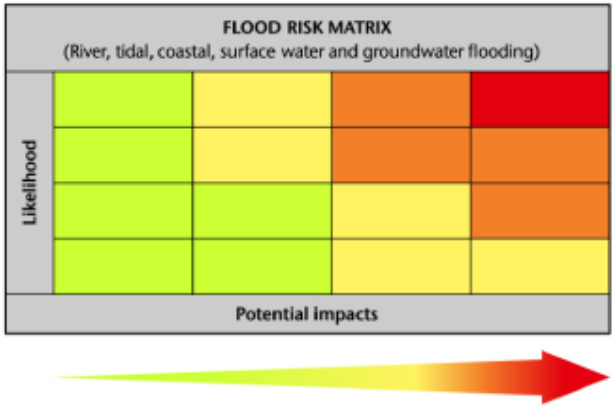


Impact Library for each UFMfSW scenario



Regional Summary of Forecast Flood Risk

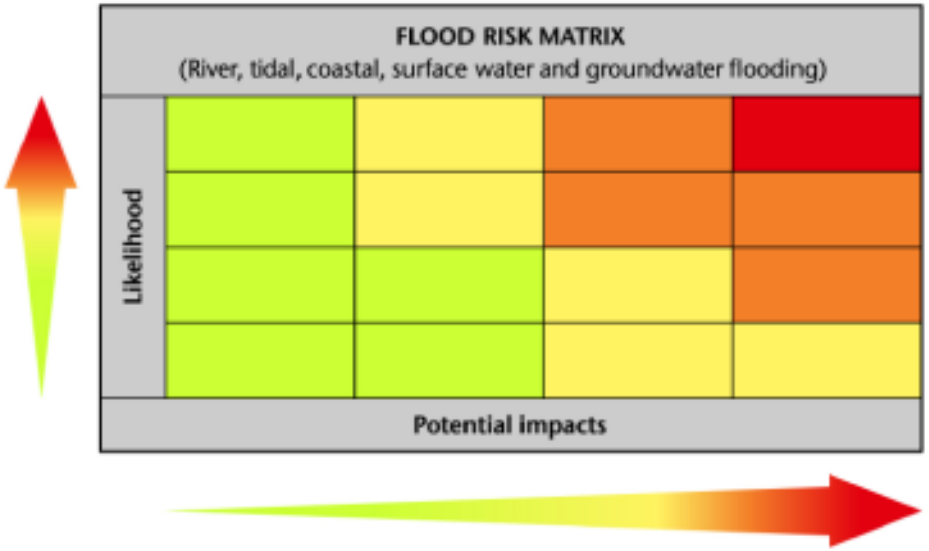
- Regional impact summary for *each* ensemble member
- Summarise for time, space & uncertainty
- Reporting by County/Authority
- Combine impact **and** likelihood to calculate risk



Case study

- Proof-of-concept outputs (26-28 June 2012)

	Darlington				Durham				Northumberland				Tyne and Wear			
Forecast Origin	Minimal	Minor	Significant	Severe	Minimal	Minor	Significant	Severe	Minimal	Minor	Significant	Severe	Minimal	Minor	Significant	Severe
26 0015	12	0	0	0	12	0	0	0	12	2	0	0	12	0	0	0



Case study

- Proof-of-concept outputs (26-28 June 2012)
- Compared to “actual” risk as assessed by FFC
- Impact forecasts show promise

	Darlington				Durham				Northumberland				Tyne and Wear			
Forecast Origin	Minimal	Minor	Significant	Severe	Minimal	Minor	Significant	Severe	Minimal	Minor	Significant	Severe	Minimal	Minor	Significant	Severe
26 0015	12	0	0	0	12	0	0	0	12	2	0	0	12	0	0	0
26 0435	12	0	0	0	12	0	0	0	12	1	0	0	12	0	0	0
26 0735	12	0	0	0	12	0	0	0	12	0	0	0	12	0	0	0
26 1155	12	0	0	0	12	0	0	0	12	1	0	0	12	1	1	0
27 0015	12	0	0	0	12	0	0	0	12	0	0	0	12	0	0	0
27 0435	12	0	0	0	12	0	0	0	12	0	0	0	12	0	0	0
27 0735	12	0	0	0	12	0	0	0	12	0	0	0	12	0	0	0
27 1155	12	6	**5**	0	12	8	**5**	0	12	10	3	0	12	5	3	0
28 0015	12	0	0	0	12	3	3	0	12	12	**10**	1	12	7	**6**	1
28 0435	12	4	2	0	12	8	4	0	12	10	**7**	0	12	8	**8**	1
28 0735	12	0	0	0	12	0	0	0	12	6	1	0	12	2	1	0
28 1155	12	0	0	0	12	0	0	0	12	0	0	0	12	0	0	0

Region	Post Event Impact Level	Forecast Likelihood	“Actual” risk
Northumberland	Significant	Medium	Amber
Tyne and Wear	Severe	Medium	Amber

Summary and Next Steps

- Proof-of-concept NHP Hazard Impact Model for SWF shows potential for nationwide application
  - Supported by positive feedback from SEPA of similar system trialled during Commonwealth Games (earlier talk 2-9S)
- Targeted improvements to methodology
  - Runoff-production, impact datasets, impact calculations, ...
  - Explore closer links to high-resolution inundation modelling
- Further case studies and validation
  - Historical SWF footprint and impact data scarce
- Presentation of outputs key for end-users
- Near-operational end-to-end trial by FFC in 2015