Understanding spatial and temporal dependencies in flood risk exposure in the UK

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1 Introduction

In the UK flooding represents a major natural hazard that has resulted in £billions of insured losses over the past decade. Insurance companies need to be able to accurately model and understand flood risk exposure.

Insurance is priced as: *Premium = AAL + Risk Load + Expense Load*

The standard means of calculating Average Annual Loss (AAL) is through Catastrophe (Cat) Models. However, due to their complexity and commercial sensitivity, it is difficult to fully understand the underlying processes in the models and hence to price the risk component.

Using a Source-Pathway-Receptor-Consequence model to explicitly address each stage in the system, this project aims to increase understanding of the main contributing risk factors. Particular attention is paid to temporal and spatial dependencies at a national and local scale.

2 Sources - Fluvial and coastal

Fluvial and coastal extremes are modelled statistically using the conditional dependence model of Heffenan and Tawn (2004). The model describes the distribution of Y | X given that X is above a suitably large threshold, and is able to represent a variety of spatial and temporal dependence properties in the extremes. It is a multivariate, semi parametric regression model of the form:

$$y = a(x) + b(x)\, z$$

Where *a* describes the overall strength of the dependence, *b* the change in dependence as an event gets more extreme, and *z* is the residual term allowing inclusion of multiple dimensions. The model is fitted to daily mean flow (DMF) data for fluvial gauges and skew surge for tidal gauges.

The model can be used to characterize the dependence properties and to simulate data (Figure 1). The event peak is not experienced at the same time at all gauges. The temporal dependence structure is addressed either on an event basis by fitting the model to the largest events within a specified time window or by considering continuous data (Figure 2), for example to investigate the importance of loading sequences on defences.

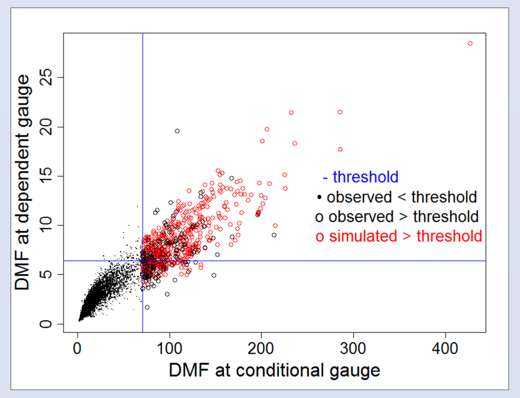

Figure 1 - Simulated DMF

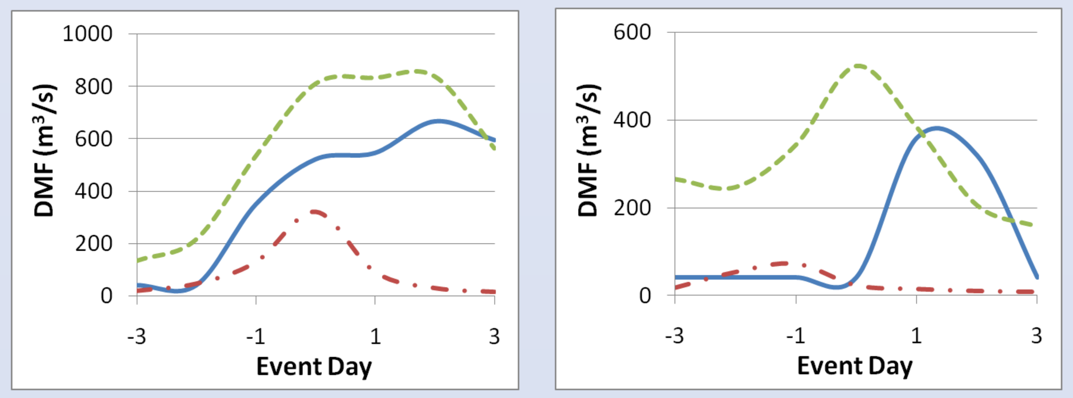

Figure 2 - Simulated continuous events

Heffernan and Tawn (2004) A conditional approach to multivariate extreme values, *JRSS Series B*, **66**: 497-530

3 Pathways - Defence systems

The reliability of defences is normally modelled using fragility curves (Figure 3). In reality the crest height and defence strength is not consistent along the defence section and this assumption could lead to under estimating flood risk as shown in Figure 4.

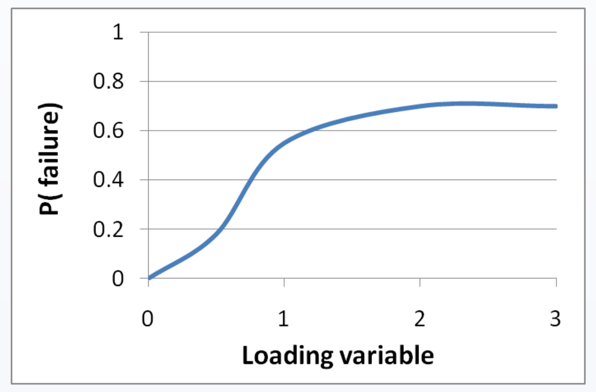

Figure 3 - Fragility curve

Using a Markov Chain process, realisations of crest heights are generated for different defence types based on variation properties observed from 59km of defence along the East Coast. Variation is generated based on the blockiness, probability of change and presence of low points (Figure 5). A similar approach can be taken for varying defence strength due to the gradual variation in soil properties or point weaknesses.

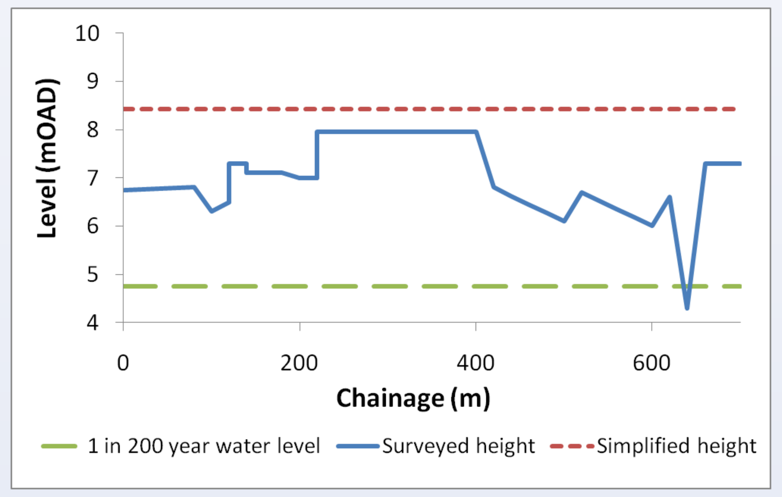

Figure 4 - Defence crest height, Mablethorpe (Source: Environment Agency)

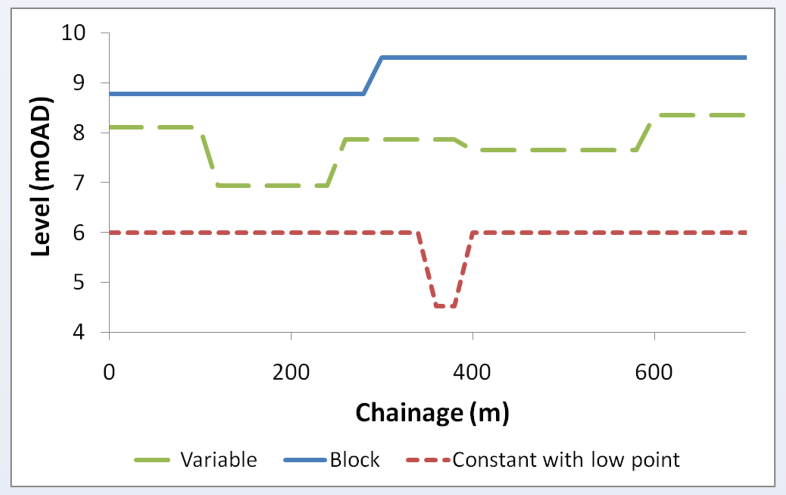

Figure 5 - Types of simulated crest variation

4 Receptors

This project considers risk to static caravans which are often located in flood risk areas. Using data from Catlin, the insured value of the caravans considered is over £2bn.

A nested multisite model is used allowing greater detail to be included for areas of interest (Figure 6) while maintaining a national structure.

The methodology could also be applied to any spatially distributed receptor.

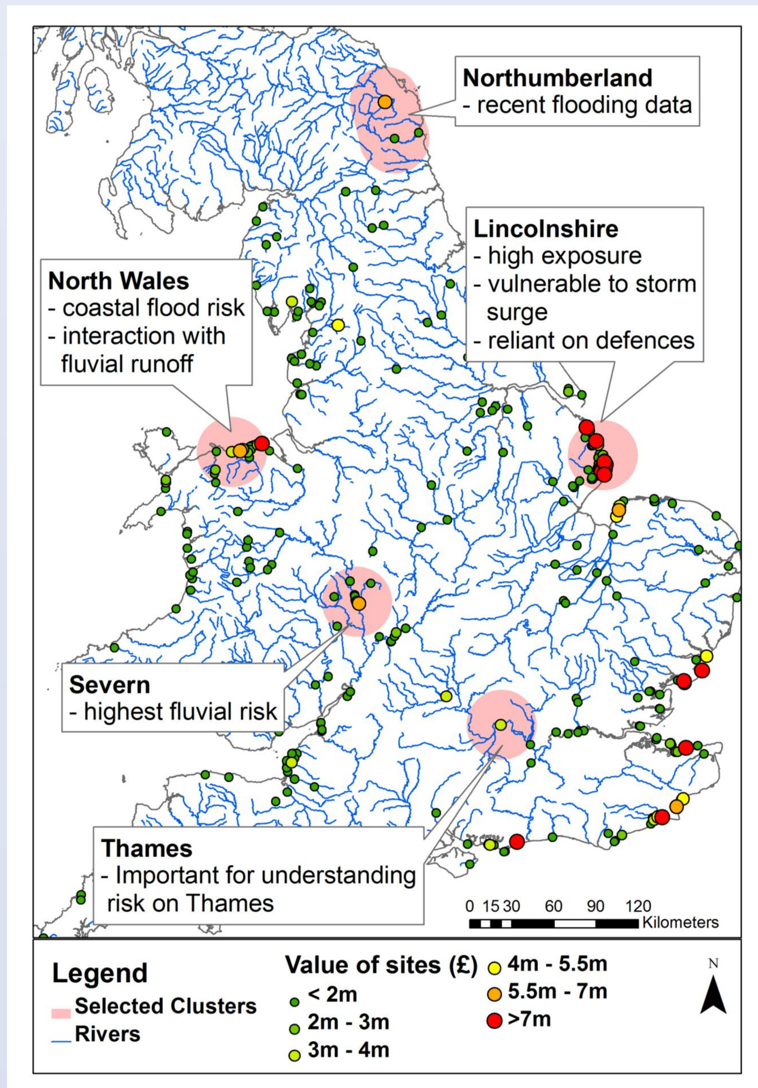

Figure 6 - Selected risk clusters

5 Consequences

Water depth on the floodplain is simulated using deterministic inundation modelling. Damage is estimated from standard depth-damage curves. (Figure 8). The curves can be modified to investigate uncertainty in the curves and the potential risk reduction of introducing mitigation measures.

Figure 7 - Damaged caravans (source: BBC News)

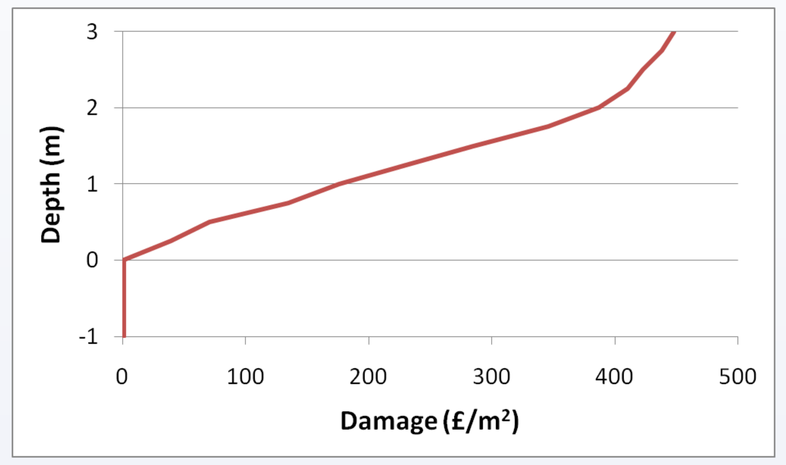

Figure 8 - Depth-damage curve (Source: FHRC Multi Coloured Manual)

6 Practicalities

Using statistical models in practical applications creates a number of issues which have been addressed as part of this project:

Issue	Solution
• DMF data does not provide flood peaks	→ Produced DMF to peak flow conversion method
• Concurrent data is required for long time periods	→ Use simplified pairwise dependence model to infill gaps
• Data is required at sites not gauges	→ Produced interpolation routines and route through hydraulic model
• Dependence model may not preserve physical consistency	→ Physical checks on sampling method at connected gauges
• Insurance window is 7 days – longer than most UK events	→ Make use of declustering and event based analysis

7 Increased understanding of risk

The model is run multiple times using Importance Sampling to estimate flood risk and answer the key insurance question "**What is the risk of a large spatial event affecting all stock?"** In addition the systems based approach increases understanding of the risk driving forces central to many decision makers and can be used to:

→ Identify areas of potential over exposure
→ Investigate significance of temporal and spatial dependencies
→ Identify areas where risk is sensitive to defence failure
→ Investigate the potential of mitigation to reduce losses

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