A ‘blue print’ for local system-based probabilistic flood modelling

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Introduction

This paper summarises the outcomes of a study [Environment Agency, 2010] to investigate strategies for exploiting detailed flood models to improve the confidence of risk management agencies in broader-scale information about the probability and economic risk of flooding.

The study was carried from the perspective of risk management agencies in England and Wales, where a national, system-based approach to modelling flood risk has been used for some time now [Hall et al., 2003].

1. System-based flood risk model

Risk is defined as a product of probability and consequence. Flood risk assessment is therefore inherently probabilistic. models used for investment planning and other applications [such as the National Flood Risk Assessment in England and Wales, NaFRA, Environment Agency, 2009, Gouldby *et al.* 2008] include analysis of events that combine a range of extreme river flow or sea level conditions with possible failures of flood defences. Very often the goal is to model the risk in terms of the expected economic damages:

$$\bar{D} = \int_L \sum_S D(L = l, \mathbf{S} = s) \Pr(\mathbf{S} = s | L = l) f_L(l) dl \, , \qquad (1)$$

where L is a random variable representing the hydraulic load (typically river or sea water level) on the flood defence system with probability density function $f_L(l)$ and *Dbar* is a damage function, usually involving a deterministic hydraulic model of the system to compute flood depths.

The state of the defence system is characterised by the random vector $\boldsymbol{S}$, such that for a system of n defence assets, $\boldsymbol{s} = \{s_1, s_2, \ldots, s_n\}$ represents a system state, where s_i is a discrete variable indicating whether the ith defence asset is in a “failed” or “not-failed” state. The defence system state is modelled by the failure probability conditional on the load level, known as the fragility curve.

2. Level of detail

National or broad scale risk assessments

The need to carry out large numbers of simulations has led to the use of simplified water level projection or “flood spreading” models in the calculation of $D(L,\mathbf{S})$ in order to avoid excessive computer run times [e.g. Hall et al., 2003, Lhomme et al., 2008]. Simplified models also allow for a systematic analysis at national or regional scales, where the human time needed to configure, calibrate and run more detailed hydraulic system models could be too expensive.

Detailed local flood models

However, requirements for detailed flood mapping (e.g. the European Floods Directive 2007/60/EC), development planning and engineering design have often driven the investment in detailed flood models. Increasingly these are based on linked 1D and 2D hydraulic modelling software with high resolution (~1m horizontal resolution) ground elevation data on the floodplain and dynamic representation of flood defence assets and other structures.

There is therefore an interest for risk management agencies in re-using local detailed models within probabilistic flood risk assessments. This would seek to optimise the benefits, and get a better return on investment, from different classes of existing model as appropriate to the application.

3. What do users need?

We asked flood risk managers, specialist consultants and other professionals to clarify the requirements of any approach used to exploit detailed hydraulic models within system-based risk assessments.

The main findings of this consultation were:

- Users need to see a consistent approach, but value flexibility to benefit from local information.
- Users want to be able to assess the quality of the results, and, at a minimum, give a broad estimate of the level of uncertainty.
- Methods for incorporating detailed local models should be transparent and repeatable.
- In order to be used to assist in investment decisions it must be possible to assess probability of economic damage, to attribute risk to defence assets, and for tools to be suitable for use in scenario planning.
- Methods must be capable of being used to assess risk now and in the future.
- Methods should be open and allow the user to input results from different types of models. For instance there should not be a restriction to one particular type of hydraulic model or software package.

3. Development of a ‘blueprint’

We proposed a ‘blueprint’ for the use of detailed local models in a probabilistic system-based risk assessment. The blueprint consists of a set of basic principles to guide method choices and a generic process chart *(see box at right)*.

4. Basic principles

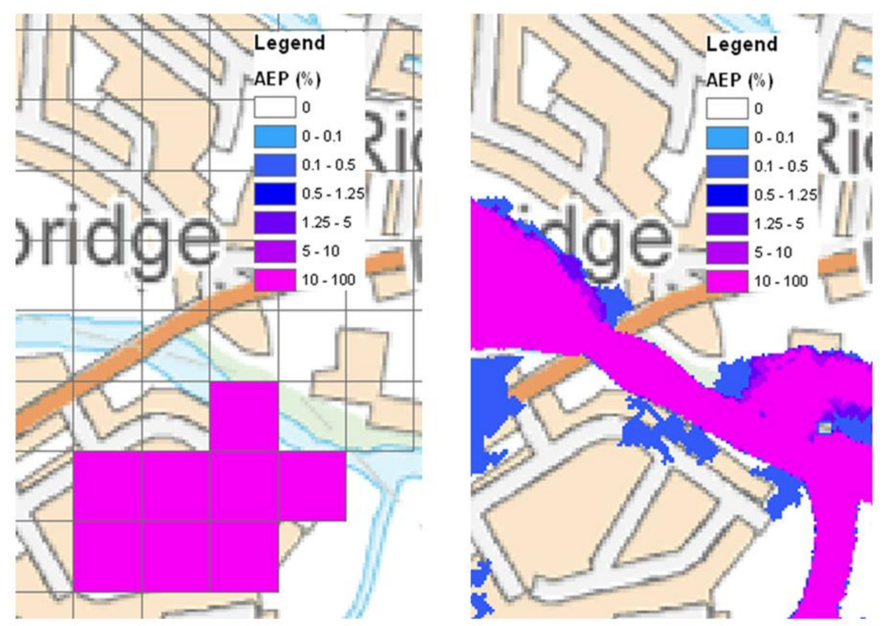
1. The additional modelling effort and expense required in applying detailed models, should be proportionate to the decision being supported.
2. Local detailed modelling should only be applied in locations where broader scale flood risk models lack accuracy or do not enjoy the confidence of users.

In addition, methods to allow the use of detailed local hydraulic models should:

3. be flexible such that the modeller can represent features that affect the local flood risk
4. provide primary (e.g. probability of depth above a certain threshold) and secondary (e.g. probability of number of properties flooded) outputs
5. enable confidence statements to be made about the outputs
6. supported by guidance on the choice of scenarios (which can cover the choice of range of hydrological event probabilities, defence failure scenarios etc.) to promote consistency.

Right: Comparison of level of detail in typical national-level system-based flood risk assessment with detailed local modelling.

AEP is annual exceedance probability of flooding.



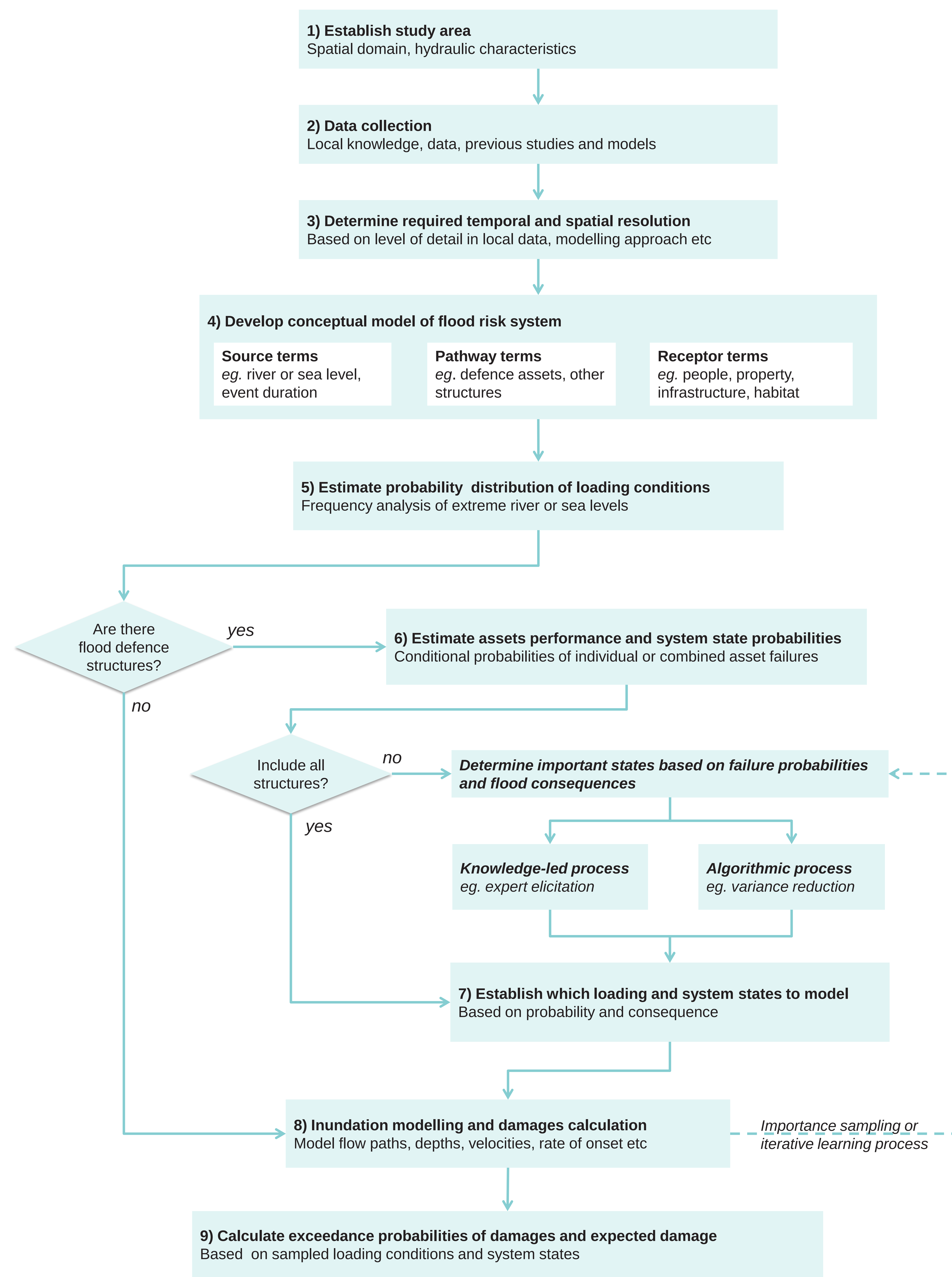
5. Next steps

In our paper we have attempted to summarise the issues relating to the practical use of detailed hydraulic models for system-based flood risk assessment. We identified critical trade-offs between the level of detail in hydraulic system modelling and the approximations required to carry out a probability integration such as equation (1).

Further work is needed to quantify the trade-offs and help risk managers understand the implications. We have suggested a synthetic system study to test sampling strategies and examine the robustness of approaches based on more limited numbers of detailed model runs. This should help to understand what is an acceptable trade-off between approximation of the hydraulic system, approximation of the probability integration and cost of the analysis for circumstances faced by risk managers in practice.

A generic process for using local system models in probabilistic, system-based risk assessment

The flow chart proposes a generic process for the use of detailed local models in a system-based risk assessment. It is not prescriptive about either the choice of hydraulic model or the approach taken to performing probability integration. The steps shown are common to methods that use detailed hydraulic models and to methods that use more general flood spreading techniques.



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