JBA Trust Challenge: **A Risk-based Analysis of Small Scale, Distributed, "Nature-based" Flood Risk Management Measures Deployed on River Networks**

There is growing interest in the use of "nature-based" flood risk management measures, which include small-scale runoff attenuation features (RAFs), typically "leaky" dams or barriers made from wood that allow low flows to pass through, but that hold back high flows, thus providing temporary storage of flood water. The hope is that a large collection of such RAFs deployed in small stream channels may hold back enough flood water so as to mitigate flood risk downstream, where communities and people are at risk.

A typical "leaky" dam or runoff attenuation feature (RAF) made from natural materials.

The challenge is in understanding the performance and optimisation of a system comprising a collection of individual RAFs, distributed spatially throughout a connected stream network in a river catchment.

This is a difficult problem that JBA Trust has been involved in tackling in recent work (see, for example http://www.jbatrust.org/news/reducing-flood-risk-by-working-with-nature/).

Within a network analysis, we wish to generalise each RAF as an object that intercepts runoff within a flow pathway, and then releases the flow more slowly. Such features can be envisaged in hydrological models as conceptual storage elements or slow-pass filters (where the flood flow is a "signal" that is attenuated by the RAF).

The crux of our challenge lies in representing arbitrary collections of RAFs as a whole system, within a stream network analysis.

Ultimately, we wish to account for the performance and potential failure modes of a system of RAFs, including issues such as:

- propagation of flood "waves" (i.e. peaks in runoff) through the network;
- possible synchronisation or de-synchronisation of peak flows;
- cascade-like failure modes (i.e. a collapse of one RAF triggers further collapses downstream);
- dynamic utilisation of the potential storage created by RAFs (i.e. testing whether the system of RAFs operates optimally over the network, versus situations where only a few RAFs are effective and others are redundant).

A network analysis should prove useful in future to support optimisation of deployment and maintenance strategies.

We want to bring in some of the complexity of a real system – so although some level of abstraction may be required, the network should be characterised by realistic data such as variable stream slopes, flood wave speeds, friction and "inflow" boundaries.

We are seeking to explore whether there is a mathematical strategy to give insight (and basic rules) into assessing the effectiveness and resilience of many small-scale nature-based flood risk management interventions in complex river networks. This will help us to describe distinctive deployment and maintenance strategies, e.g. concentrated on headwaters, concentrated on lower reaches, maintain every 1/2/10/50 years etc. (leading to different performance profiles through time).

More detailed issues to be discussed during the workshop could include:

Optimising spatial distribution of nature based flood risk management interventions considering:

- Synchronisation issues (superposition of flood waves from different streams being made worse);
- Under-utilisation issues (storage uptake before flood peak);
- Failure of in-stream storage features such as leaky dams;
- Cascade failure of in-stream features;
- Spatially variable rainfall fields inputs (different inflow conditions);
- Can the model be generalised to a treatment of 2d surface runoff from a complex terrain, where blanket rainfall is used to expose network pathways?

Conditioning / catchment complexity

- Inflow boundary conditions. Spatially and temporally and variable;
- Slope of river reaches leading to different celerities (wave speeds). Minimum of 2 slope classes with corresponding wave speeds;
- Length of river reaches, leading to time of travel with above. 2 length classes;
- Friction of channel. Minimum of 2 classes;
- Failure of leaky barrier in relation to maintenance strategy.

Example Data:

- JBA Trust will provide example stream network data, (for example from Brompton, N Yorkshire, where RAFs are being trialed) and flood flow measurements/simulations.