Using 'flood-excess volume' to assess and communicate flood-mitigation schemes

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1. Flood-excess volume: definition and use

Flood-Excess Volume (FEV): the volume V_e of water in a flood-peak at a river gauge location due to river levels exceeding a relevant threshold h_T, chosen such that, for any river level $\bar{h}$ above h_T, flooding occurs.

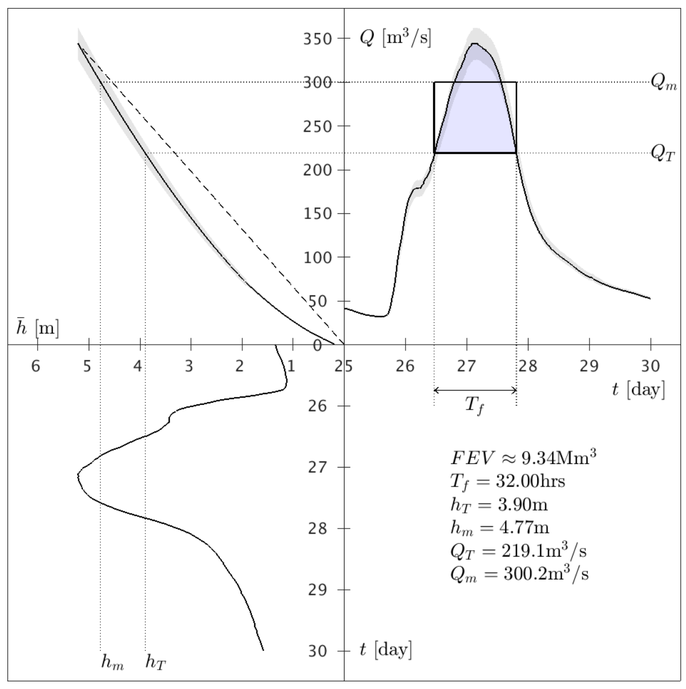
Best approximation:

$$V_e \approx \sum_{k=1}^{N_m} \left(Q(\bar{h}_k) - Q_T\right) \Delta t.$$

- $\bar{h}$: water level [m]
- Q: discharge [m^3/s]
- $Q_T = Q(h_T)$: threshold discharge
- $T_f = N_m \Delta t$: flood duration

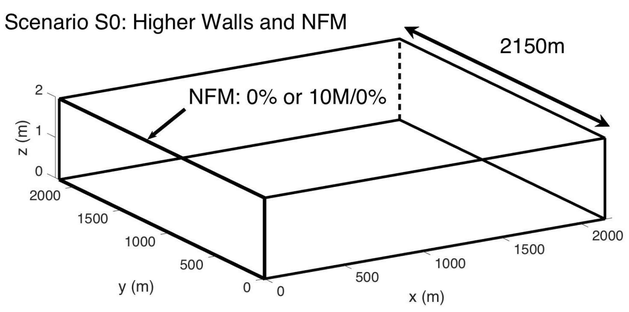
- **GOAL**: to quantify and communicate the efficacy of various flood-mitigation measures in a straightforward and concise manner.
- **IDEA**: calculate the FEV for a flood event of interest and express as the capacity of a 2m-deep square 'flood-excess lake' with side-lengths $\mathcal{O}$(1km).
- **OUTCOME**: a graphical tool that (i) contextualises the magnitude of the flood relative to the river valley and (ii) facilitates quick and direct assessment of the contribution and value of various mitigation measures.

2a. Case study I: River Aire, Boxing Day 2015



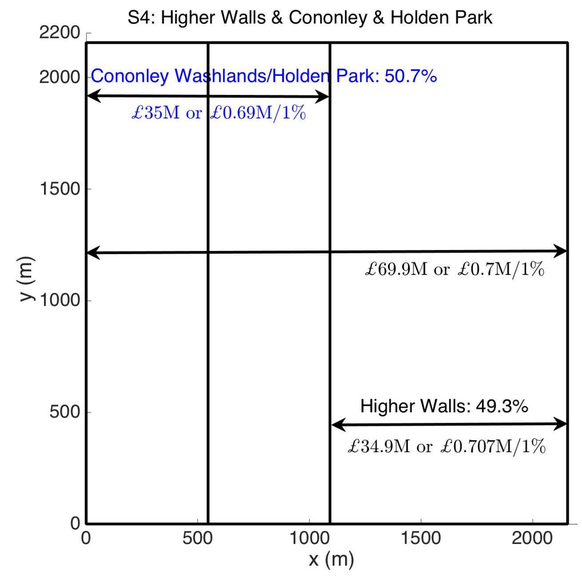
Q: what fraction of the FEV is reduced, and at what cost, by a suite of mitigation measures?

- express the FEV as a 2m-deep 'flood-excess lake' of side-length 2.15km: FEV$\approx 9.34\text{Mm}^3 \approx (2150^2 \times 2)\text{m}^3$.

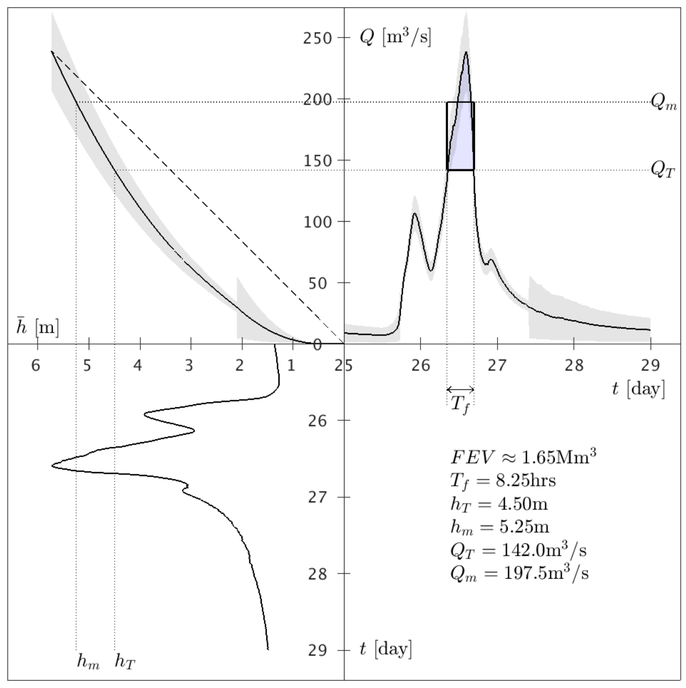


- given a calculation (or estimate) of potential flood storage volume and associated cost of each mitigation measure, the 'flood-excess lake' can be partitioned accordingly and overlaid with a cost per 1% of FEV mitigated

Hypothetical scenario for Leeds' flood alleviation scheme II (FASII+), comprising flood walls and flood-storage sites:



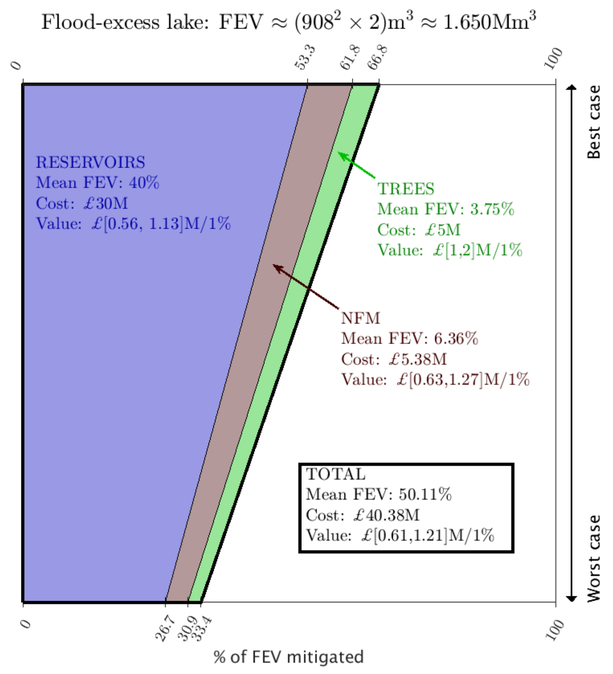
2b. Case study II: River Calder, Boxing Day 2015



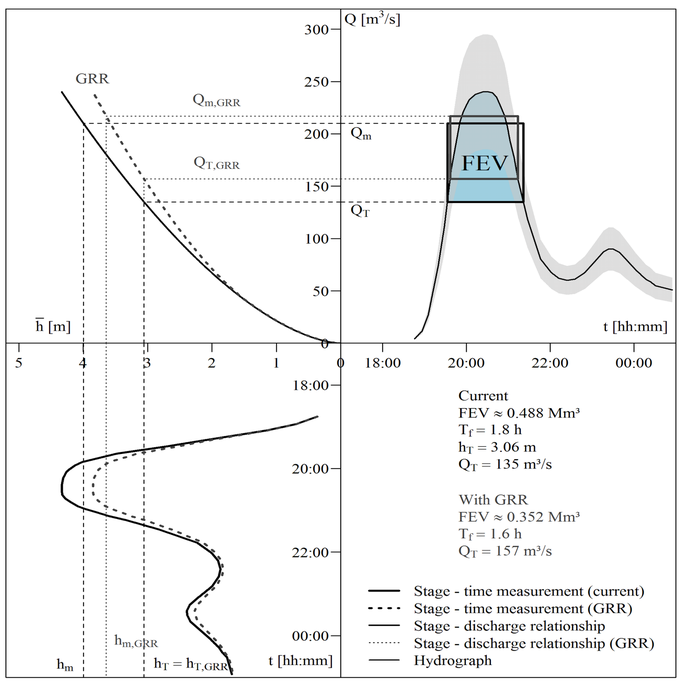
Exploratory flood-alleviation scheme comprising (i) temporary storage in reservoirs, (ii) upscaled 'leaky' debris dams, and (iii) tree planting:

- takes into account uncertainty in storage capacity;
- draw-down and control of reservoirs has great potential;
- major upscaling of leaky dams can have a significant and cost-effective impact;
- mean FEV mitigated is 50%: more measures (e.g., flood walls) required to offer full protection.

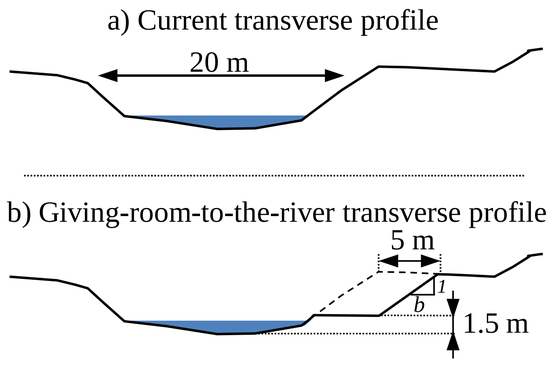
Right: woody-debris 'leaky' dams, an example of Natural Flood Management (NFM), are being installed in tributaries of the River Calder. Photo courtesy Robin Gray (Pennine Prospects).



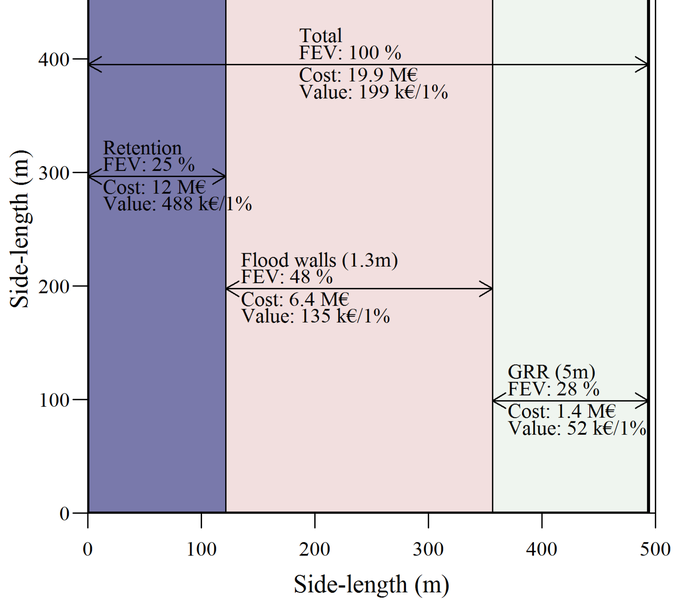
2b. Case study III: River Brague, October 2015



An alternative to raising flood walls: **giving room to the river (GRR)** increases the river width in order to increase the discharge capacity for a similar water depth.



- New 'GRR' rating curve reduces FEV for same h_T (left)
- GRR is assessed favourably alongside flood walls and retention measures in an exploratory flood-mitigation analysis for the River Brague (right)



3. Highlights

- a complementary way of classifying flood events, to be used either prior to or in tandem with more detailed hydrodynamic numerical modelling
- a new protocol to optimise assessment of mitigation scenarios, including cost-effectiveness analyses, for the benefit of policy makers
- encourages evidence-based decision-making for flood-mitigation schemes

References and acknowledgements

Three accessible articles on FEV:

1 OB, MK, TK (2018a): *Under review PRSA.* See also: `https://eartharxiv.org/stc7r/`

2 OB, MK, TK, GP, J-MT (2018b): *In prep.* Prelim. ver.: `https://eartharxiv.org/87z6w/`

3 OB, MK, TK (2018c): *Under review PRSA.* See also: `https://eartharxiv.org/w9evx/`

We thank the Environment Agency for providing data and reports for the UK cases, and SIAQUEBA and DDTM06 for the Brague case. Work funded by EPSRC [grant nos. EP/M008525/1 and EP/P002331/1] and the EU H2020 project NAIAD [grant no. 730497].