4.19 Flood excess volume (FEV)

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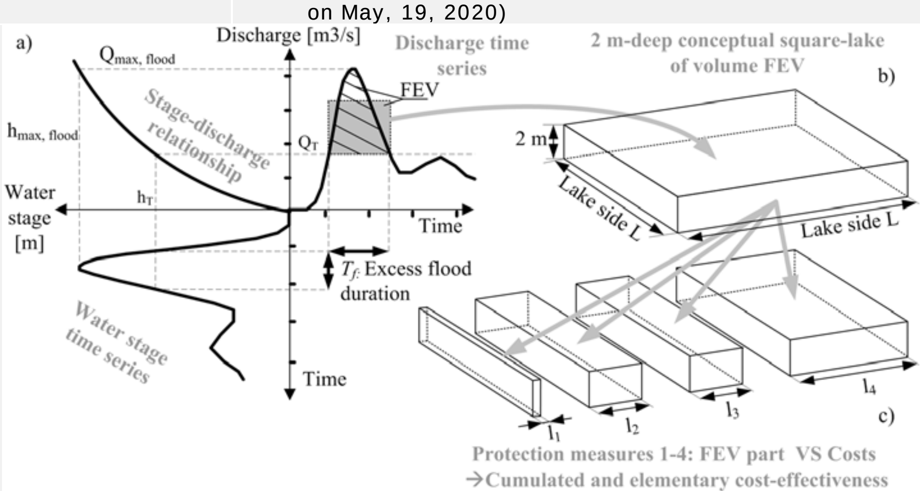
Author/s and affiliations: Guillaume Piton[1], Jean-Marc Tacnet[1]

[1] *Univ. Grenoble Alpes, INRAE, ETNA, Grenoble, France*

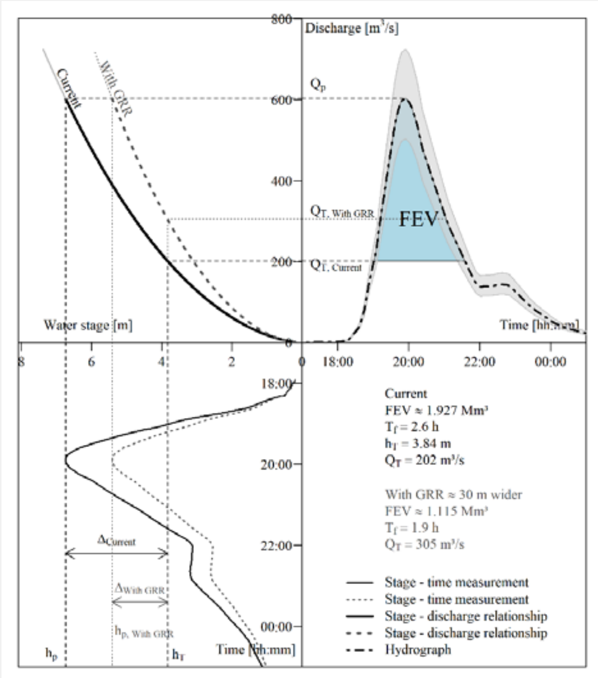
Flood-Excess Volume (FEV)	Natural and Climate Hazards Water Management
Description and justification	Flooding adverse consequences occur when flow levels exceed channel banks and reach areas with assets. Knowing the whole volume of the flood hydrograph is interesting but insufficient to determine whether the flood will trigger adverse consequences or not: it is also necessary to know the discharge times series (i.e., the hydrograph), the flow level over which flooding starts and to know the stage – discharge relationship to determine which fraction of the total volume can actually be harmful. The FEV is a computation of this hydrograph fraction: the hydrograph volume in excess compared to the channel capacity. In essence, when implementing water retention measures for flood protection, one does not want to buffer the whole hydrograph volume, just the FEV. The FEV method enables first to compute this water excess volume. In a second step, it is possible to compute how much of the FEV several protection measures can handle. If costs of each measures are available, it is finally possible to compute the cost-efficacy ratio of the whole strategy as well as of each measure (Cost per percentage of FEV). Overall, the FEV framework enables fast and straightforward computation of the amount of water causing problems, the design of the number and size of a panel of measures required to mitigate the associated problems and a fast assessment of the measure and strategy cost-efficacy ratio.
Definition	The FEV of a given flood event at a certain location is defined as (Bokhove et al., 2019): the water volume causing flood damage due to river levels h exceeding a relevant threshold h_T such that, some or major flooding issues occur for $h > h_T$. The data required to compute it are: (i) event hydrograph, i.e., discharge time series Q(t), (ii) water stage – discharge relationship, i.e., channel conveyance capacity h(Q) and (iii) the threshold value for flooding in term of discharge Q_T or of flow level $h_T=h(Q_T)$.
Strengths and weaknesses	+ The FEV framework is fast and simple to implement, has great educational potential and was tried and tested with success on several sites across Europe (Brague River FR, Aire and Calder Rivers UK, Glinščica River SLO). + Flood mitigation strategies usually relies on both water retention measures and works on the channel to increase its conveyance capacity. Usual indicators focus on one

	aspect or the other while the FEV encapsulates both. The example provided as attached figure shows how giving room to the river (GRR) enables changing the channel capacity and then decrease the remaining FEV nearly by half. - Fast and straightforward methods necessarily rely on several simplification hypothesis and thus provide imperfect assessments. Among limitations of FEV discussed by Bokhove et al. (2020) (i) Three-dimensional flood dynamics is reduced to the analysis of FEV at or near the most critical point along a river where flooding starts. Generally, river hydraulics are modelled in a one- or two-dimensional manner: it is therefore best to consider FEV-analysis as a diagnostic at the worst spot. (ii) Only the averaged and cumulative effects of retention measures upstream of the point of FEV-analysis are considered. Spatio-temporal considerations en route to the most critical point of flooding are thus ignored. (iii) Only effectiveness is considered here but not benefits, which would require a full economic analysis of damages saved and/or costs incurred.
Measurement procedure and tool	Given an in situ hydrograph Q(t) explicitly as function of time t, or implicitly as a function Q = Q(h) of the in situ river level h = h(t), discretized in time step of duration Δt, and knowing the threshold discharge for flooding $Q_T=Q(h_T)$, the approximation of FEV is: $$FEV = \sum_{flood} \big(Q(t) - Q(h_T)\big)\Delta t = \sum_{flood} \big(Q(h(t)) - Q(h_T)\big)\Delta t$$ For data-scarce contexts, Bokhove et al. (2020) provides simplified equations.
Scale of measurement	m3
Data source	
Required data	Hydrograph, water stage – discharge curve, threshold depth for flooding.
Data input type	Quantitative
Data collection frequency	Possibly hourly measurement of discharge or flow stage on the duration of the flood event (if possible more frequent for flash floods)
Level of expertise required	Intermediate
Synergies with other indicators	Complementary with Height Of Flood Peak/Time To Flood Peak, Peak Flow, Peak Volume, Flood Peak Reduction, Reduction Of Inundation Risk For Critical Urban Infrastructures.
Connection with SDGs	13

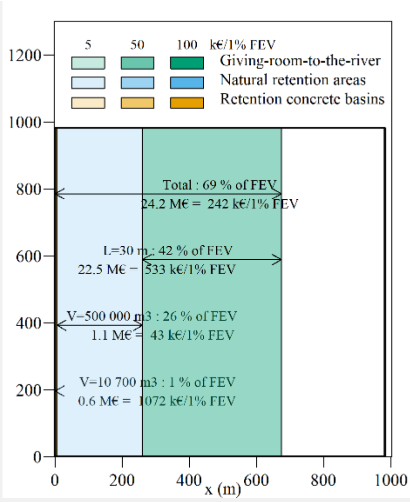
Opportunities for participatory data collection	Fine-tuning of the threshold level for flooding can benefit from local dweller knowledge. Proposition and sizing of protection measures can be performed with stakeholder participation (Arfaoui and Gnolonfin, 2020)
Additional information	
References	Arfaoui N, Gnonlonfin A. 2020. Supporting NBS restoration measures: A test of VBN theory in the Brague catchment. Economics Bulletin 40 : 1272–1280. [online] Available from: https://ideas.repec.org/a/ebl/ecbull/eb-20-00134.html (accessed on May, 19, 2020) Bokhove O., Kelmanson M.A., Kent T., Piton G., Tacnet JM. 2019. Communicating (nature-based) flood-mitigation schemes using flood-excess volume. River Research and Applications 35 : 1402–1414. DOI: 10.1002/rra.3507 Bokhove O., Kelmanson M.A., Kent T., Piton G., Tacnet JM. 2020. A Cost-Effectiveness Protocol for Flood-Mitigation Plans Based on Leeds' Boxing Day 2015 Floods. Water 12 : 1–30. DOI: 10.3390/w12030652 Piton G., Dupire S., Arnaud P., Mas A., Marchal R., Moncoulon D., Curt. T., Tacnet J. 2018. DELIVERABLE 6.2 From hazards to risk: models for the DEMOs - Part 3: France: Brague catchment DEMO . NAIAD H2020 project (Grant Agreement nº 730497) [online] Available from: http://naiad2020.eu/wp-content/uploads/2019/02/D6.2_REV_FINAL.pdf (accessed on May, 19, 2020)



Conceptual flood-excess volume (FEV) representations. (a) Three-panel graph highlighting FEV: (bottom-left) view of river-level time series around a flood event; (top-left) stage–discharge relationship arising from (top-right) discharge data, in which FEV is the hatched ''area'' between the discharge curve $Q(t) = Q(\check{h}) = Q(h(t))$, displayed vertically as function of time horizontally, and a chosen threshold discharge $Q_T = Q(h_T)$ with exceedance time T_f, involving in situ temporal river levels h = h(t). (b) FEV square-lake representation as a D = 2 m-deep square lake, with side-length $L = (FEV/D)^{0.5}$, to facilitate visualisation of FEV ‘‘size.’’ (c) FEV-effectiveness assessment computed for each measure as equivalent FEV fraction, represented as side L of the square lake (Bokhove et al., 2019)



Application example of the FEV at the Brague catchment scale on flood disaster of Oct. 2005 (time return of about 500 years). Current stage – discharge capacity (thick line, upper left panel) triggered flooding above discharge Q_T = 202 m^3/s generating 1,900,000 m^3 of FEV. In a NBS strategy giving room the river (30 m widening) this threshold discharge is increased to 305 m^3/s and the FEV became 1,100,000 m^3 that may be partially handled with complementary water retention measures.



Square lake representation at the Brague catchment scale on flood disaster of Oct. 2005: the full FEV of 1.9 Mm^3 is equivalent to a square lake of side nearly 1 km long and 2 m deep. The existing retention concrete basin of 10,700 m3 handle less than 1% of this total volume at high cost. Giving 30 m of width to the river would cope with 42% of the FEV while the natural retention areas would cope with 26% of the FEV at low cost. 31% of FEV remains and require other measures if one want to protect against the full event.z

4.20 Rainfall interception rate of NBS

Project Name: OPERANDUM (Grant Agreement no. 776848)

Author/s and affiliations: Slobodan B. Mickovski[1], Alejandro Gonzalez-Ollauri[1] , Karen Munro[1]

[1] *Built Environment Asset Management Centre, Glasgow Caledonian University, Glasgow, Scotland, UK*

Rainfall interception rate of NBS	Water Management
Description and justification	The aerial parts of vegetation established as part of the NBS can intercept precipitation and thus decrease and delay the amount of water reaching the soil which, in turn, will decrease the risk of erosion and landslides.
Definition	Interception rate refers to the proportion of precipitation that does not reach the soil, but is instead intercepted by the leaves, branches of plants and the forest floor.