EGU General Assembly 2020

A methodology for the bivariate hydrological characterisation of the overtopping failure for river levees

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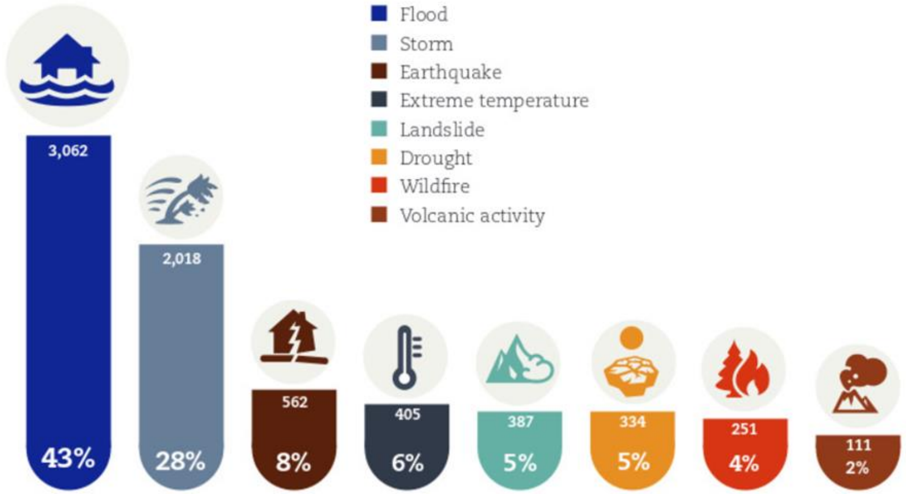
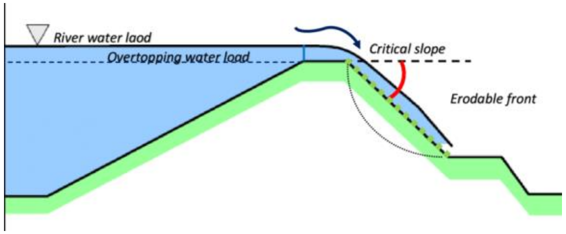
FRAMEWORK



Percentage of occurrences of natural disasters by disasters type (1995-2015)

AIM

Improve the current practice of the overtopping risk analysis for a river levee



Several from the most **flood disaster** are caused by **Levee Failure**

OVERTOPPING IS THE MAIN CAUSE OF LEVEE FAILURE

(Vorogushyn et al. 2010)

Arkansans – USA (2019)

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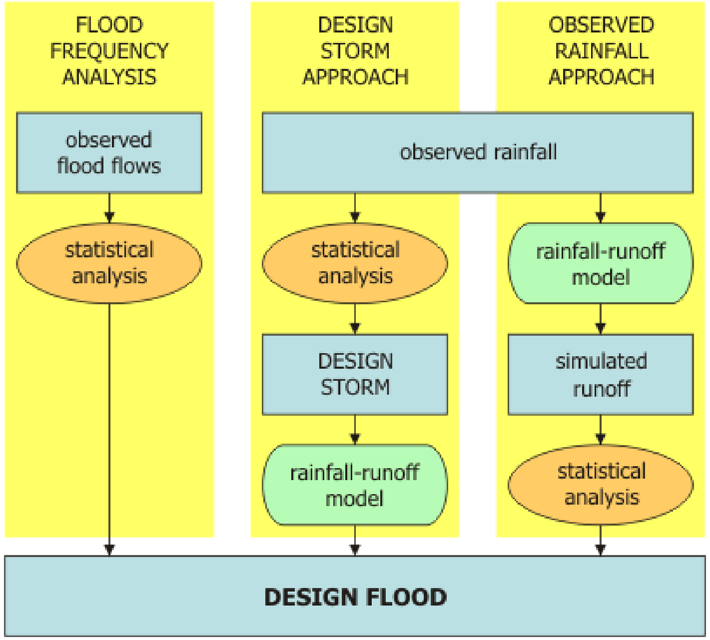
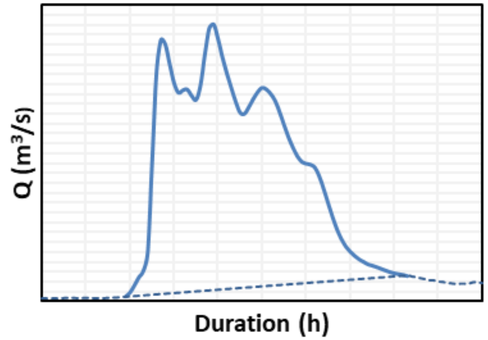
River Flood Risk analysis: Current Approach



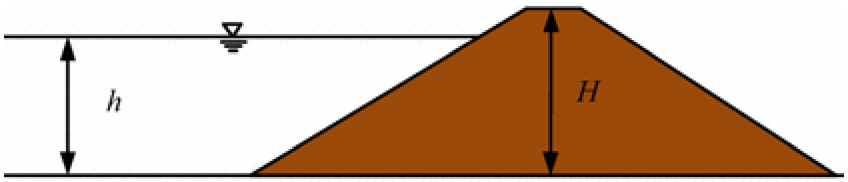
Standard Approach

The Design Flood is commonly based on the quantile of the probability distribution of the flood peak Q_{max} with adeguate length



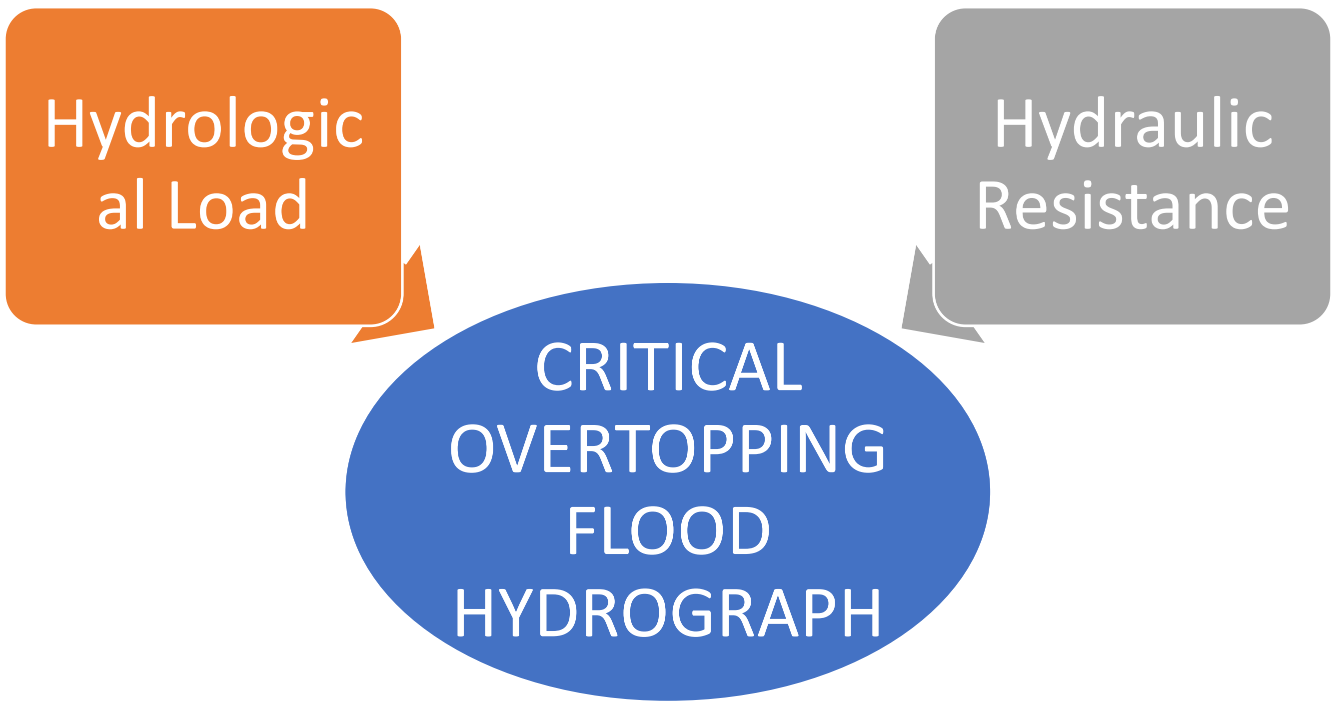
One Design Flood for return period

Stage in the river depends by the entire hydrograph



BIVARIATE ANALYSIS
OF PEAK DISCHARGE **(Q)** AND VOLUME OF HYDROGRAPH **(V)**

METHODOLOGY



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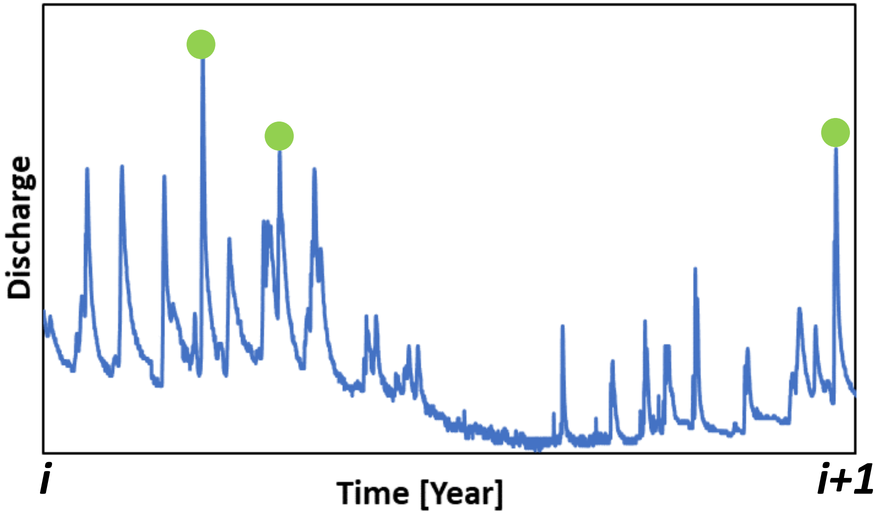
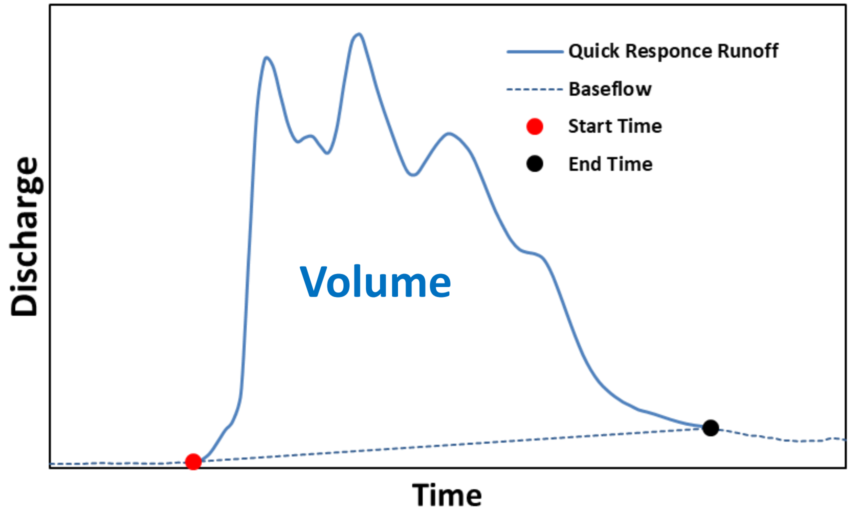
METHODOLOGY

HYDROLOGICAL LOAD

1. Detection of observed Peak Discharges and Volumes series (Peak Over Threshold)





Start Time (Mediero et al. 2010):

$$\left(\frac{Q_i - Q_{i-1}}{Q_i}\right) \geq 0.2$$

End Time (Aksoy et al. 2007):

$$Q_r = Q_0\left(1 + \frac{(1-b)\cdot {Q_0}^{(1-b)}}{\varepsilon \cdot b}\right)^{\frac{1}{1-b}}$$

2. Generation of Synthetic Peak (Q) through inverse **of Generalized Pareto Distribution (GPD)** and parameters estimation through L-moments method.

$$\text{GPD } (x|u,\beta,\gamma,\mu) = P(X > x|X > u)1 - \left[1 + \frac{\gamma\cdot(x-\mu)}{\beta}\right]^{-1/\gamma}$$

β = scale, γ=shape and μ= location

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METHODOLOGY

HYDROLOGICAL LOAD

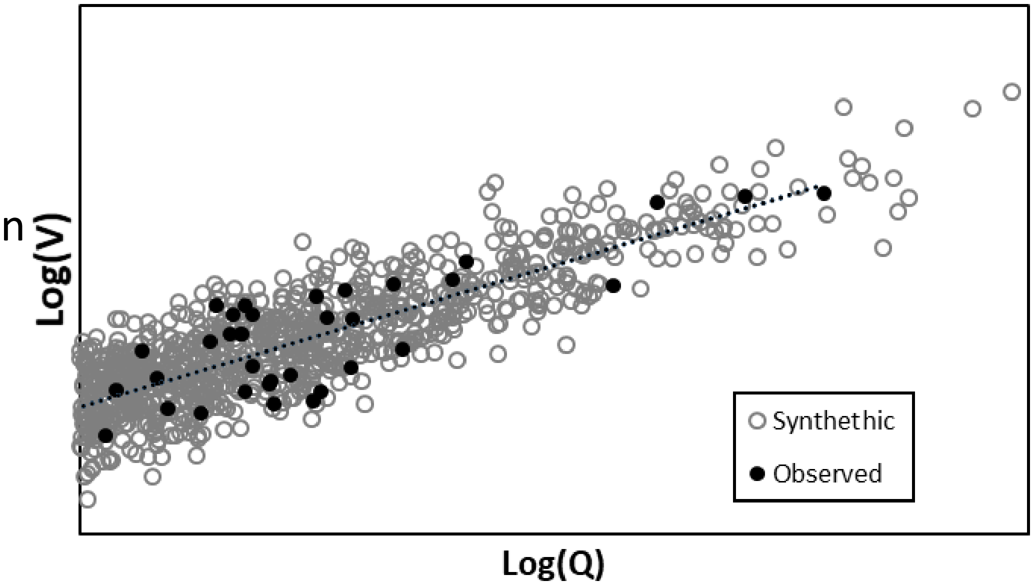
Normal Randomization to generate synthetic Volume (V)

$$\boldsymbol{V = \frac{1}{\sigma\sqrt{2\pi}} e^{-0.5\left(\frac{x-\mu}{\sigma}\right)}}$$

With Mean ($\boldsymbol{\mu}$) equal the Regression Equation between **Q_{obs} and V_{obs}**

$$\mu = k \cdot Q_{synth}{}^{\alpha}$$

With Standard deviation ($\boldsymbol{\sigma}$) equal Residual Variance of the Regression



$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(\log(V_{obs}) - \log(log(k \cdot Q_{obs}{}^{\alpha})\right)^2}{n-1}}$$

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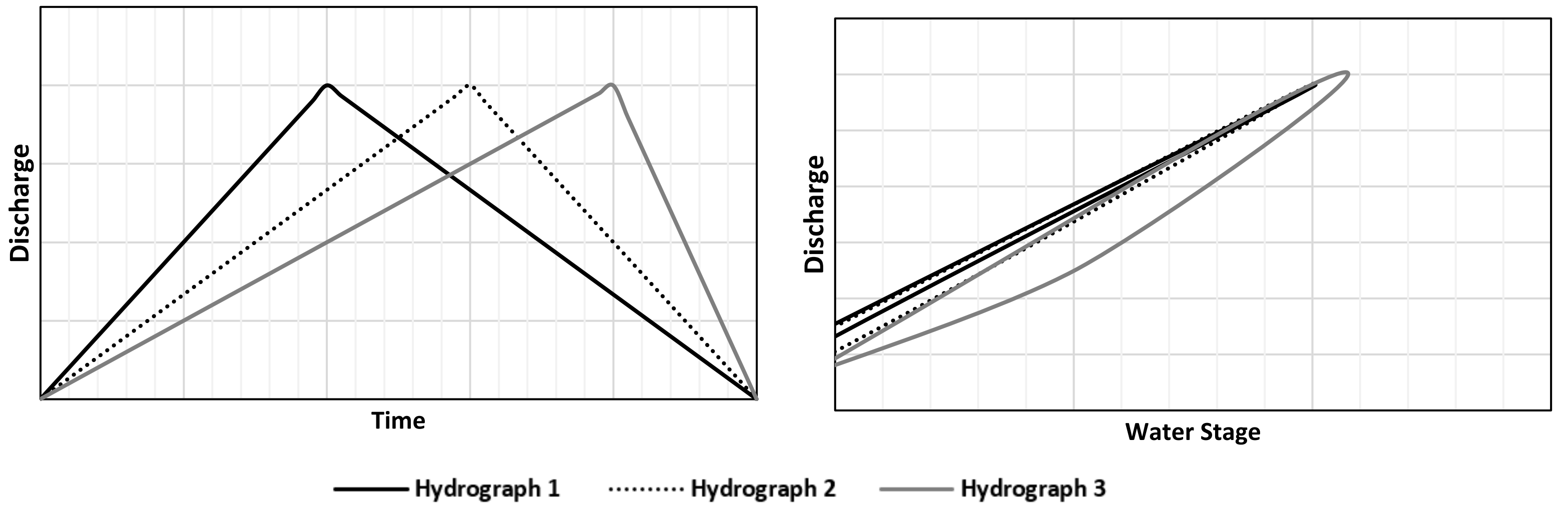
METHODOLOGY

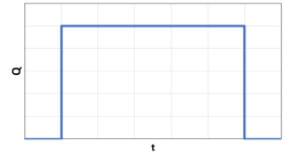
Hydrological Load

Shape



Shape Classification through Overtopping Hydrograph Shape Index (*OHSI*) *(Isola et al. 2020)*

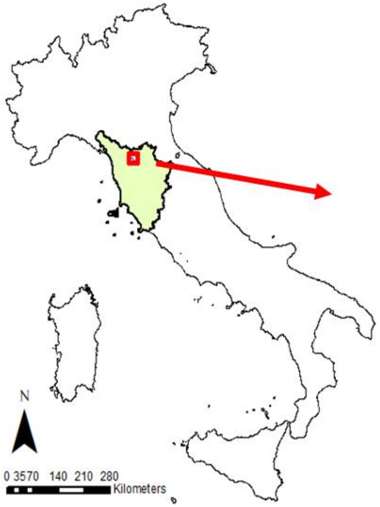
$$OHSI = \left(\frac{X_{rl,ad} \cdot D_r + X_{fl,ad} \cdot D_f}{D}\right) \cdot \left(\frac{Y_{rl,ad} \cdot \left(Q_p - Q_{min,rl}\right) + Y_{fl,ad} \cdot \left(Q_p - Q_{min,fl}\right)}{\left(Q_p - Q_{min,rl}\right) + \left(Q_p - Q_{min,fl}\right)}\right)$$

OHSI  tends → Ideal rectangular shape 

CASE STUDY

We tested the methodology **for two case studies** (ex. Ombrone river, Era River), here we show results about of Ombrone Pistoiese River located in the town of Poggio a Caiano.
The Ombrone Pistoiese river is a tributary of Arno River in Tuscany, central Italy.

- The catchment area: ≃450 km^2
- Hydrometric Gauge station named "Ponte all' Asse"
- Collection of hourly series of discharge data for the period 1992-2016



The river reach is completely banked

Test the methodology

OVERTOPPING FAILURE
&
FLOOD DAMAGE ESTIMATION

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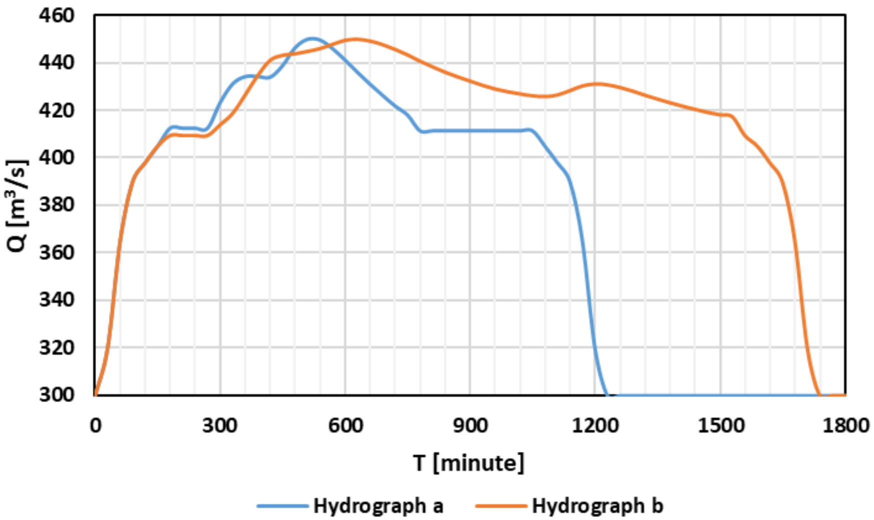
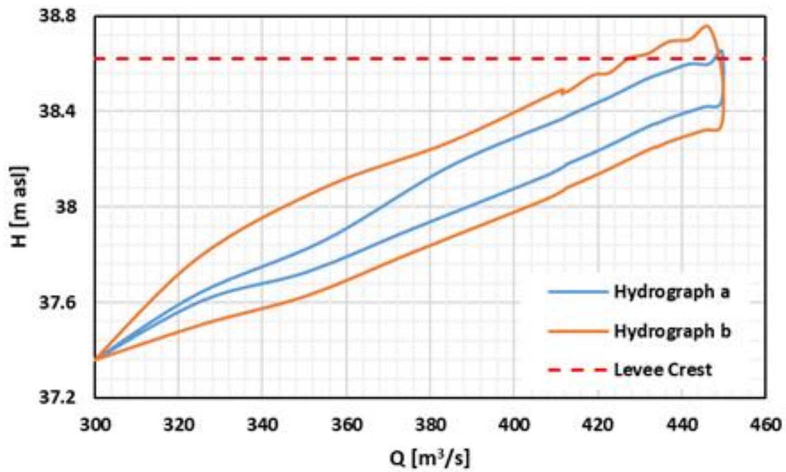
Evaluation of The Hydrographs

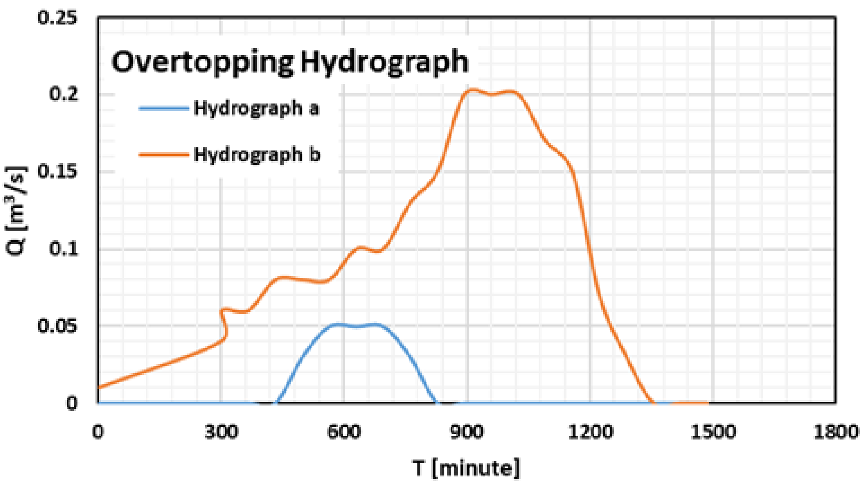
Peak discharge and Volume from approximated bivariate distribution
Shape: observed shape classified through OHSI and sensitivity analysis





H-b exceeds the levee resistance criterion conditions and cause the overtopping failure.

Levee resistance criterion
$10000\ m^3$ per m for 2 hours
(Damme et al., 2016) .



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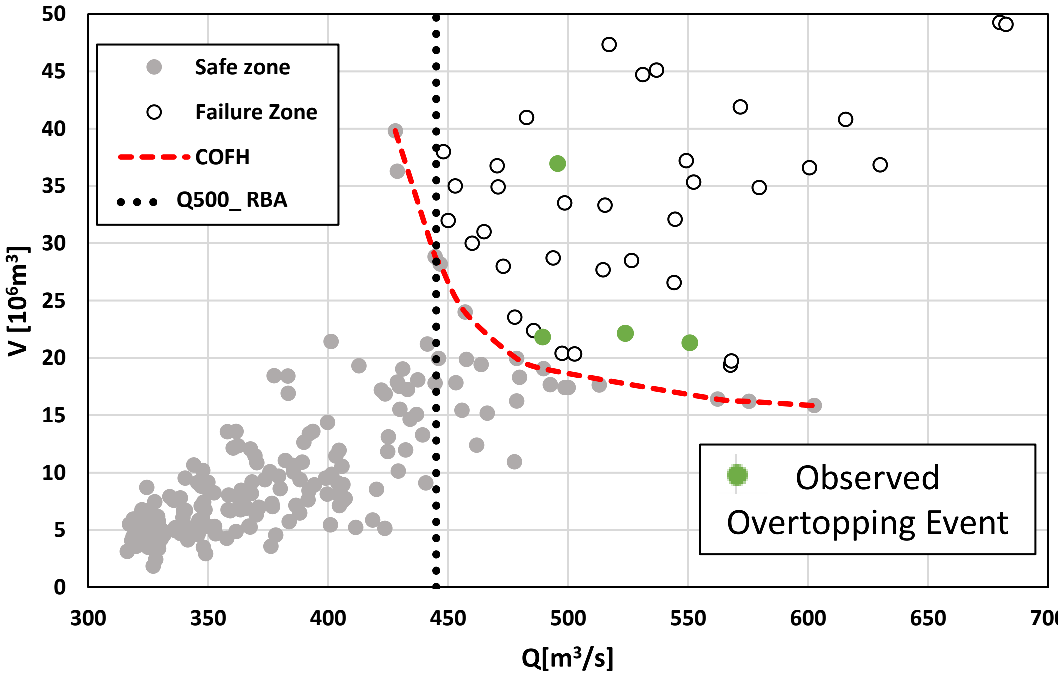
CRITICAL OVERTOPPING FLOOD HYDROGRAPH

The **Critical Overtopping Flood Hydrograph** is a curve in peak-volume space which contains every hydrograph that cause the **overtopping failure threshold condition**.

OVERTOPPING LEVEE RESISTANCE CONDITION

- The water level exceeds the levee crest in one or more cross-sections of the river.
- The overtopping volume exceeds 10000 m^3 per m for 2 hours (Damme et al., 2016) .



Poggio a Caiano 1992
Flood for levee overtopping

For further information about the work, please see the article:

ASCE LIBRARY Journal of Hydrologic Engineering

River Levee Overtopping: A Bivariate Methodology for Hydrological Characterization of Overtopping Failure

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https://doi.org/10.1061/(ASCE)HE.19435584.0001929

THANKS FOR YOUR READING