Determination of River Water Level Exceedance Frequency Curves

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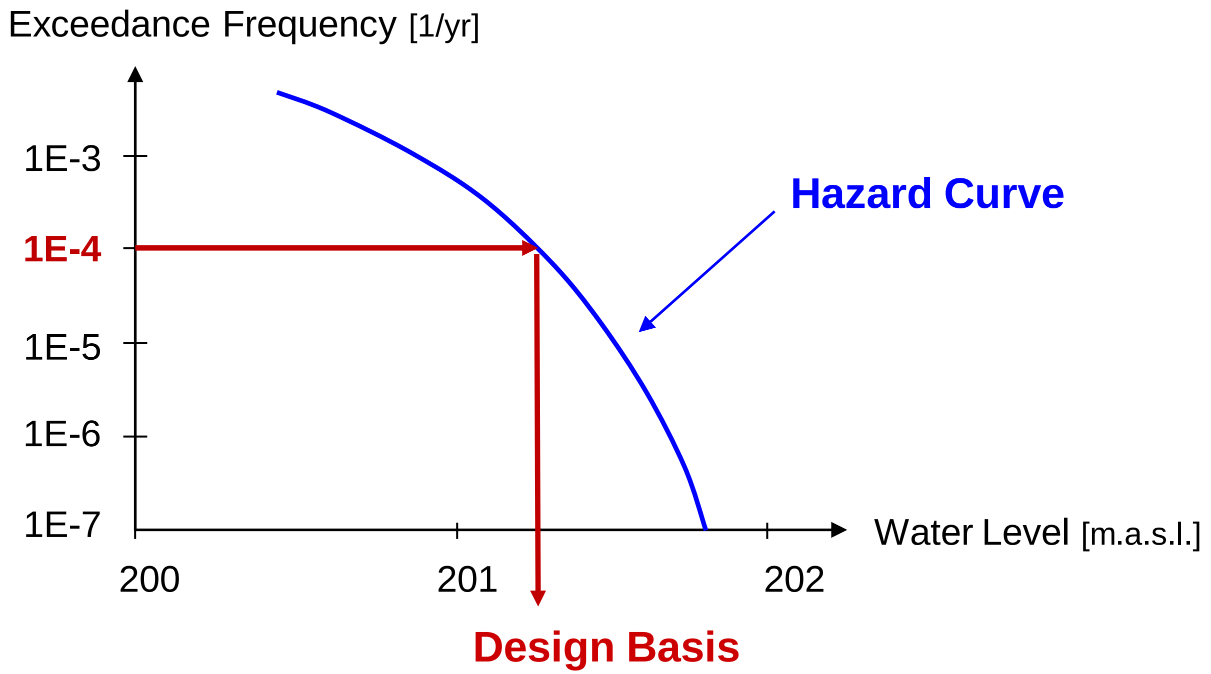
Introduction

Water level exceedance frequency curves are used as an input for

- **PSA**
- **Design Basis** or demonstration of acceptable safety



Introduction

A comprehensive assessment of the hazard curve requires the consideration of many attributes, like:

measured data

analysis of pre-instrumental flood events

weather scenarios

extreme value statistics

flood-induce failures of hydraulic facilities

log jam

deterministic hydraulic simulations

landslides

erosion, bed load

Introduction

How to integrate into the hazard assessment the various analyses (including their uncertainty) with available tools e.g.:

- Assessment of measured data and historical flood events
- Extreme value statistics
- Evaluation of (interacting) flood phenomena like partial or complete log jam of water control systems, landslide, flood-induced dam failures, sediment transport, …
- Deterministic hydraulic simulations of specific flood scenarios

➡ This paper presents an approach to integrate probabilistic and deterministic calculations and the relevant phenomena into the external flood hazard assessment.

Method

measured data

analysis of pre-instrumental flood events

extreme value statistics

discharge

weather scenarios

flood-induce failures of hydraulic facilities

deterministic hydraulic simulations

landslides

partial log jam

water level

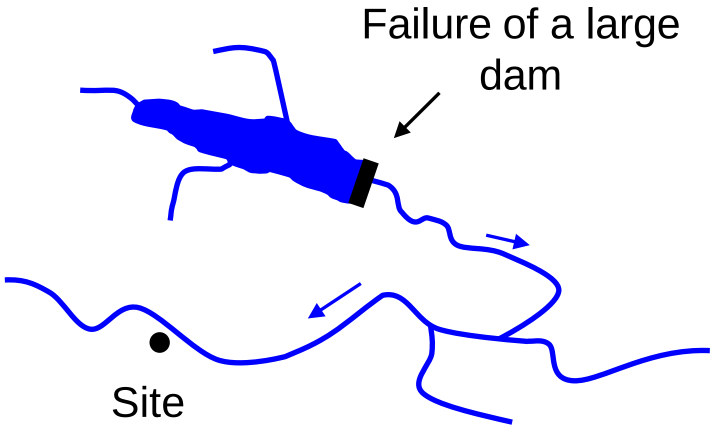
erosion, bed load

calculation flow

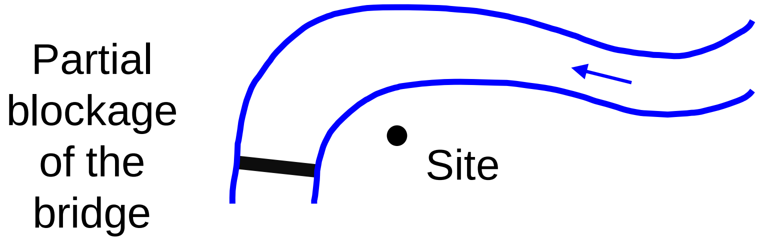
Method

Assumption: The phenomena can be delineated between

- system-relevant phenomena affecting to the discharge over a large part of the river, and
- local phenomena impact the water level at the considered site but have a negligible impact on the discharge of the system.



system-relevant phenomena



local phenomena

Method

Consideration of system-relevant phenomena:

Given a site-specific discharge exceedance frequency curve P_D valid for the discharge range $[r_1, r_2)$:

$$P_D(X \geq x) \quad \text{for} \quad x > 0$$

A numerical approach is used to include system-relevant phenomena into P_D. Based on P_D n initiating event frequency denoted as $H_D(y_i)$ are derived:

$$H_D(y_i) = P_D(X \geq x_i) - P_D(X \geq x_{i+1})$$

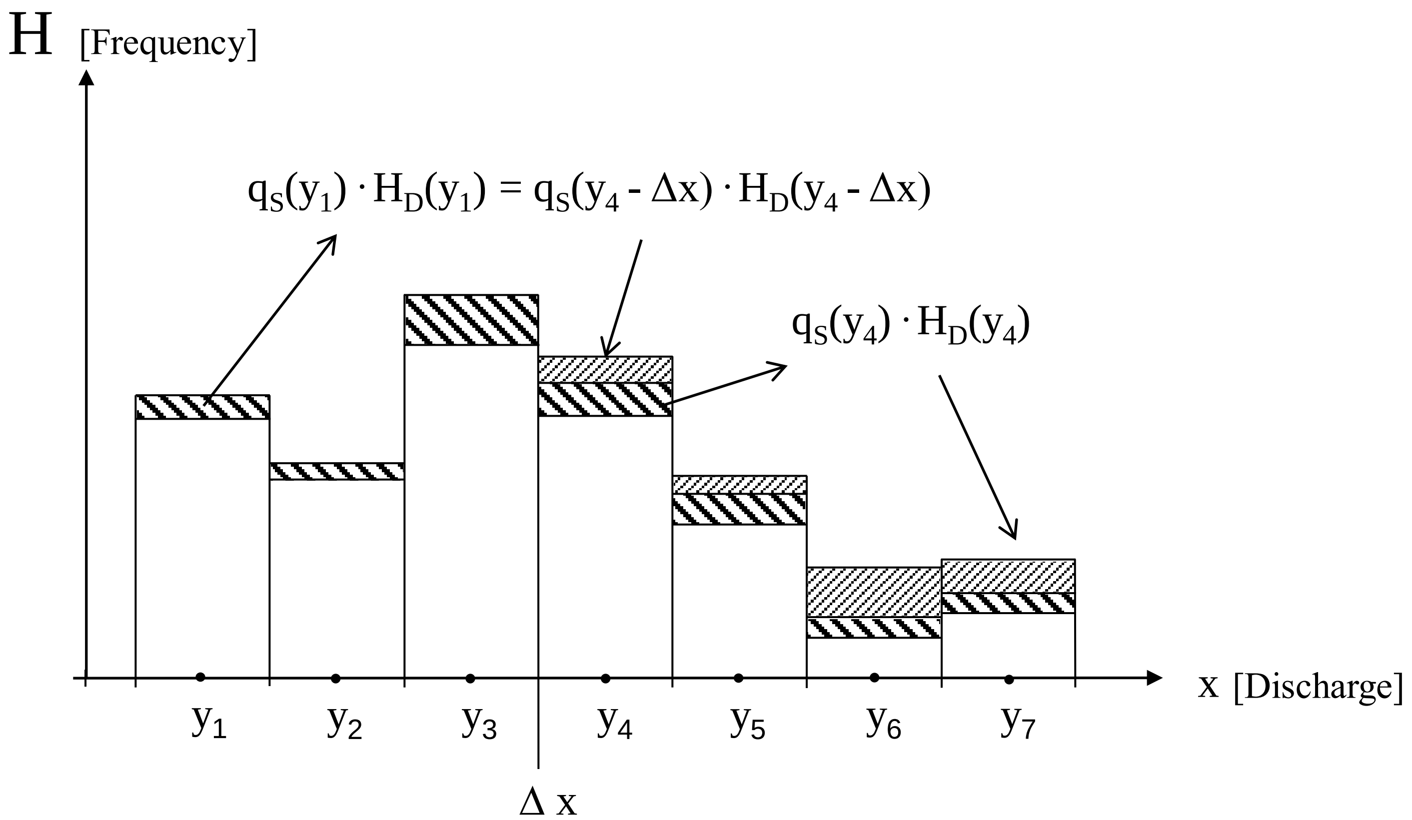
Let

$$q_S(x) \in [0, \ldots, 1]$$

be the discharge-dependent probability that a system-relevant phenomenon increases the discharge by Δx.

Method

Example of the reshuffling of the initiating event frequencies $H_D(y_i)$ given a hazard increasing phenomenon such that $y_{i+3} - y_i = \Delta x$



Method

For a hazard increasing phenomenon the reshuffled frequency $H_{DR}(y_i)$ is:

$$H_{DR}(y_i) = \begin{cases} [1 - q_S(y_i)]H_D(y_i) & \text{for } y_i \leq \Delta x \\ [1 - q_S(y_i)]H_D(y_i) + q_S(y_i - \Delta x)H_D(y_i - \Delta x) & \text{for } y_i > \Delta x \end{cases}$$

For a hazard decreasing phenomenon the reshuffled frequency $H_{DR}(y_i)$ is:

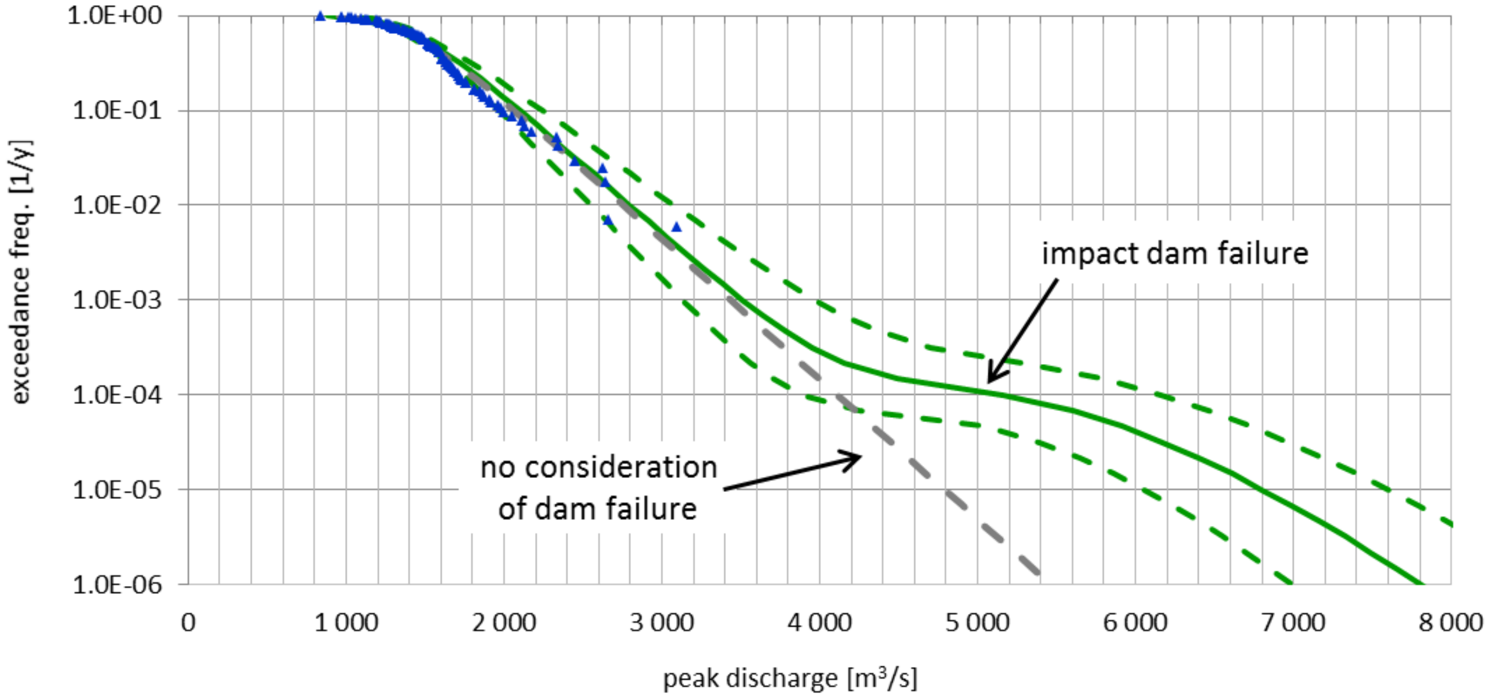
$$H_{DR}(y_i) = \begin{cases} H_D(y_i) + q_S(y_i + \Delta x)H_D(y_i + \Delta x) & \text{for } y_i \leq \Delta x \\ [1 - q_S(y_i)]H_D(y_i) + q_S(y_i + \Delta x)H_D(y_i + \Delta x) & \text{for } y_i > \Delta x \end{cases}$$

Given $H_{DR}(y_i)$, the reshuffled discharge exceedance frequency curve is

$$P_{DR}(X \geq y_i) = \sum_{t=i}^{n} H_{DR}(y_t) \quad \text{for } t = i, \ldots, n$$

Method

Illustration by an artificial example:



Phenomena absent in data will not be captured solely by extrapolation.

Method

Consideration of local phenomena:

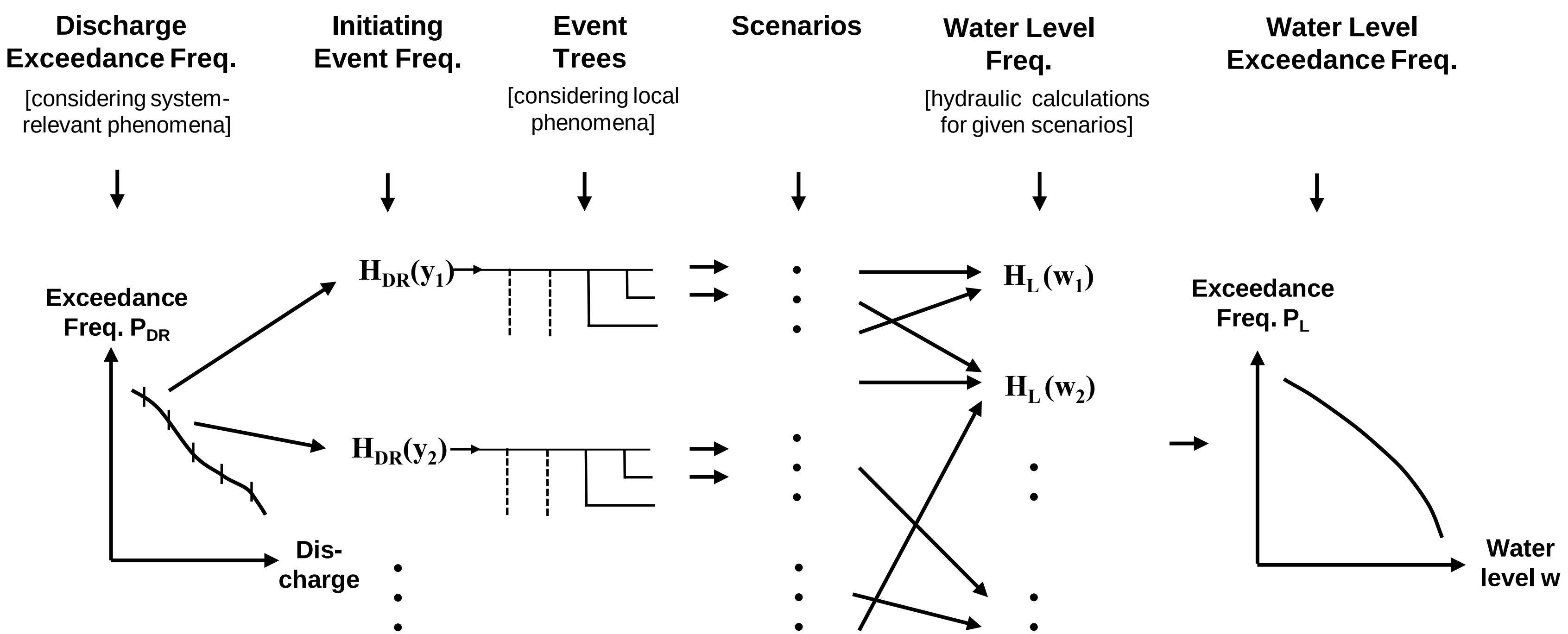
- The discharge at the site is given by P_{DR}
- Event trees are used to consider local phenomena.
- The initiating events of the event trees are derived by P_{DR}

Site-specific flood level exceedance frequency curve:

- For each sequence of an event tree the frequency, discharge and considered local phenomena are known.
- Flood levels are determined for the sequences based on deterministic hydraulic calculations.
- Given a flood level and the frequency for each sequence the desired flood level exceedance frequency curve can be computed.

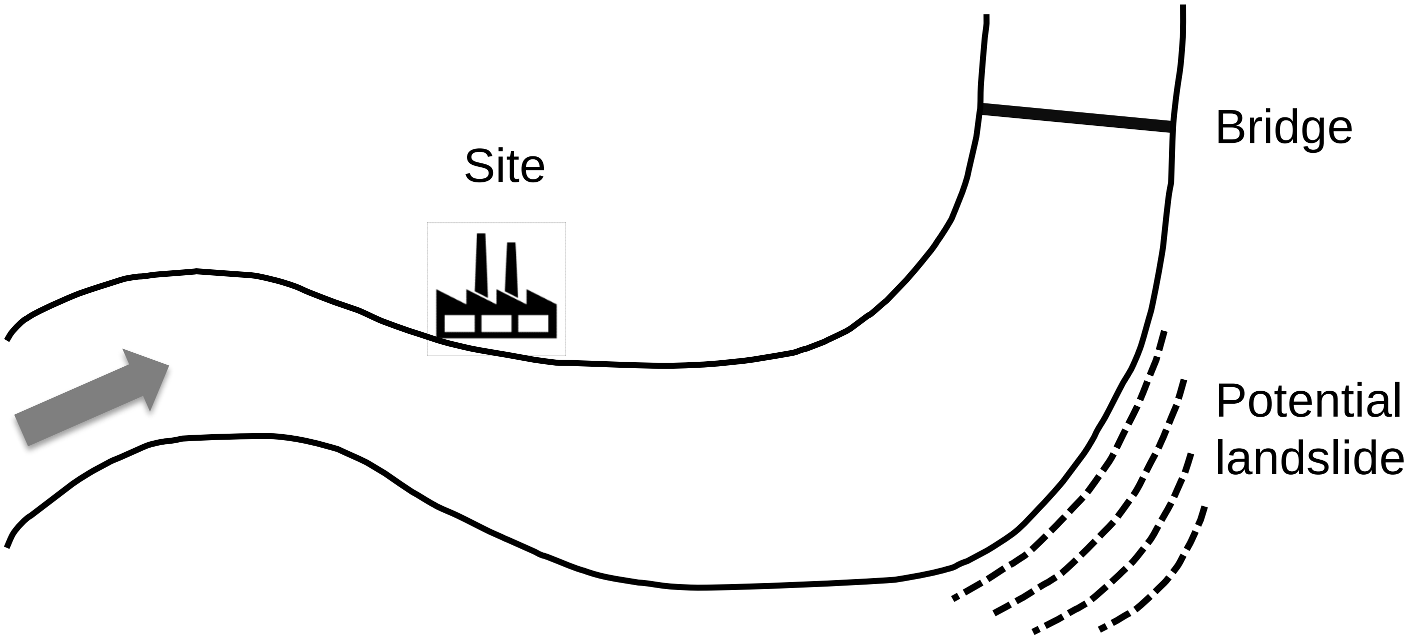
Method

Overview on the suggested concept



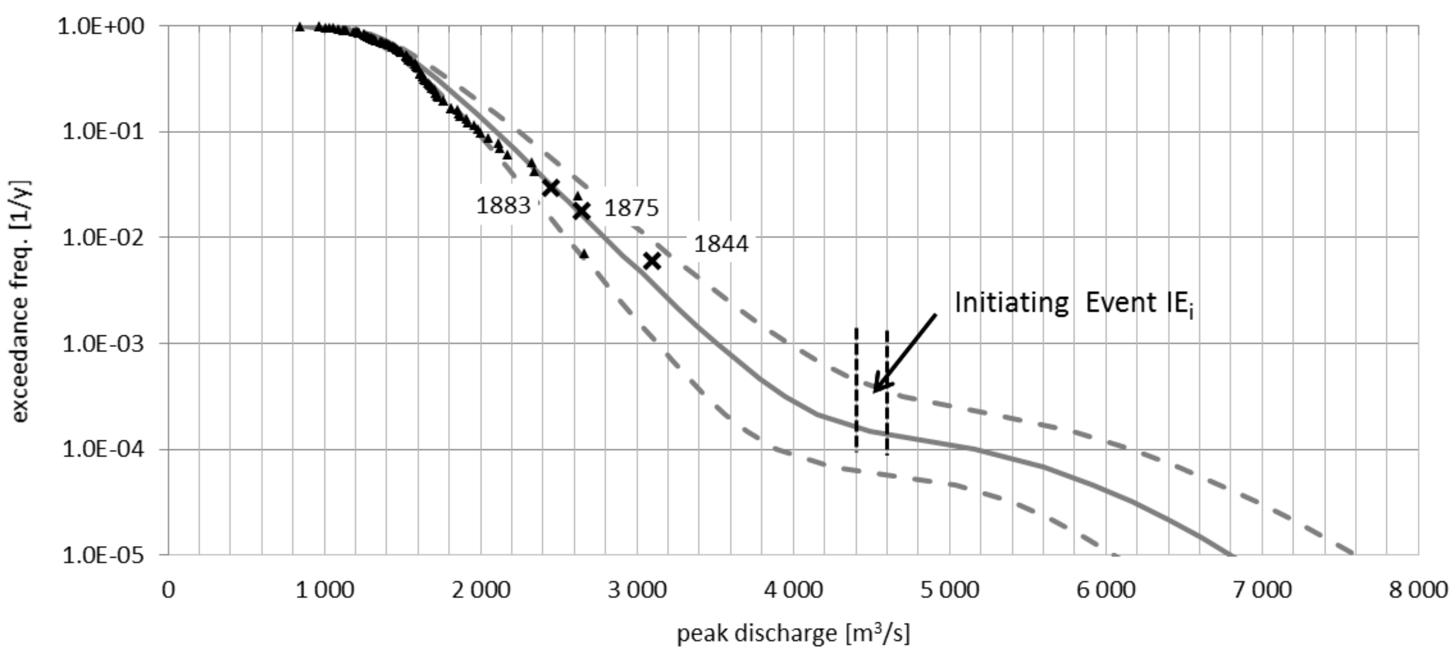
Example

Illustration of the concept by an artificial example:



Example

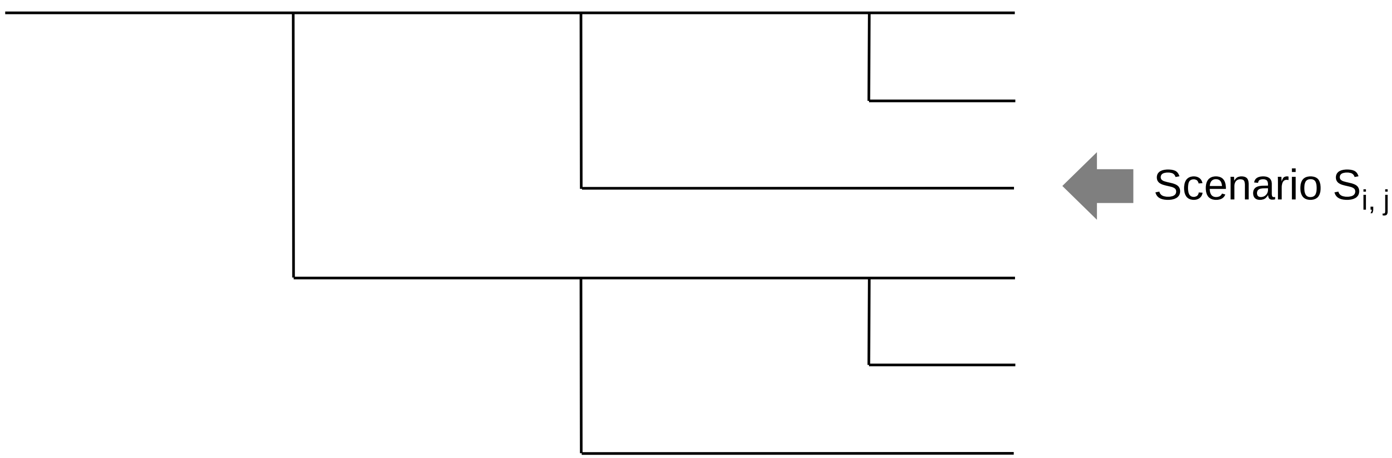
Site-specific discharge exceedance frequency curve (including a system-relevant phenomenon):



Example

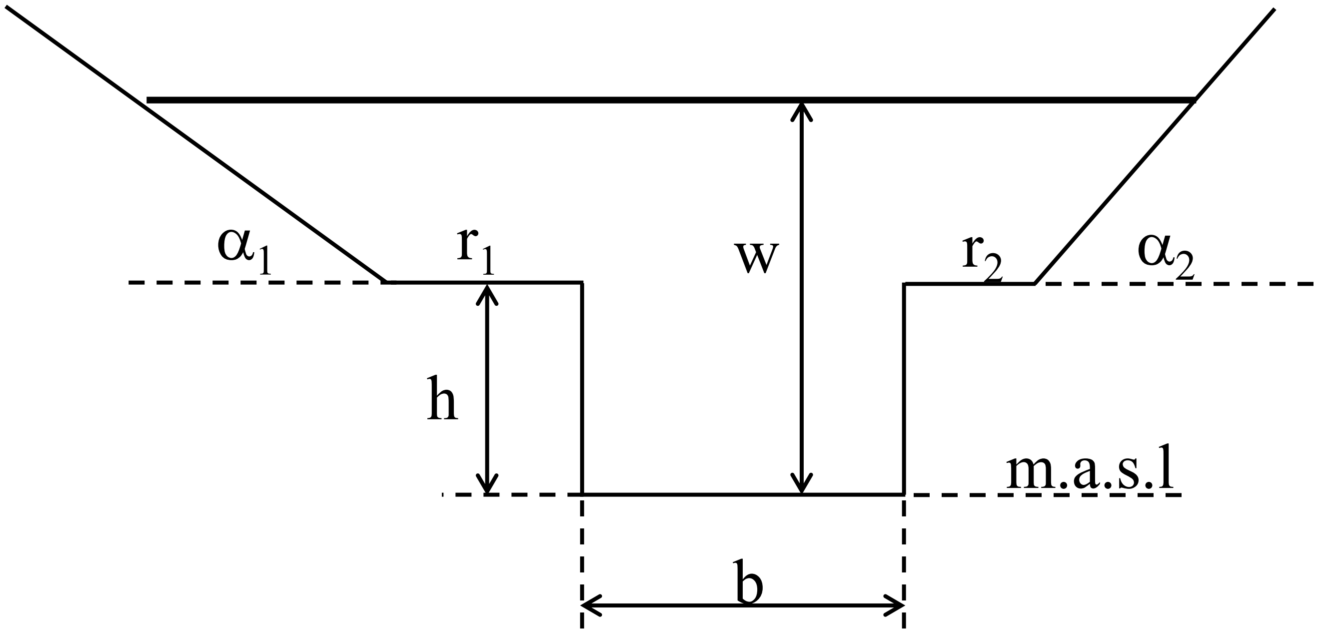
Event tree structure:

Initiating Event $[\ H_{DR}(y_i)\ ]$	No landslide	No total blockage of the bridge	No partial blockage of the bridge



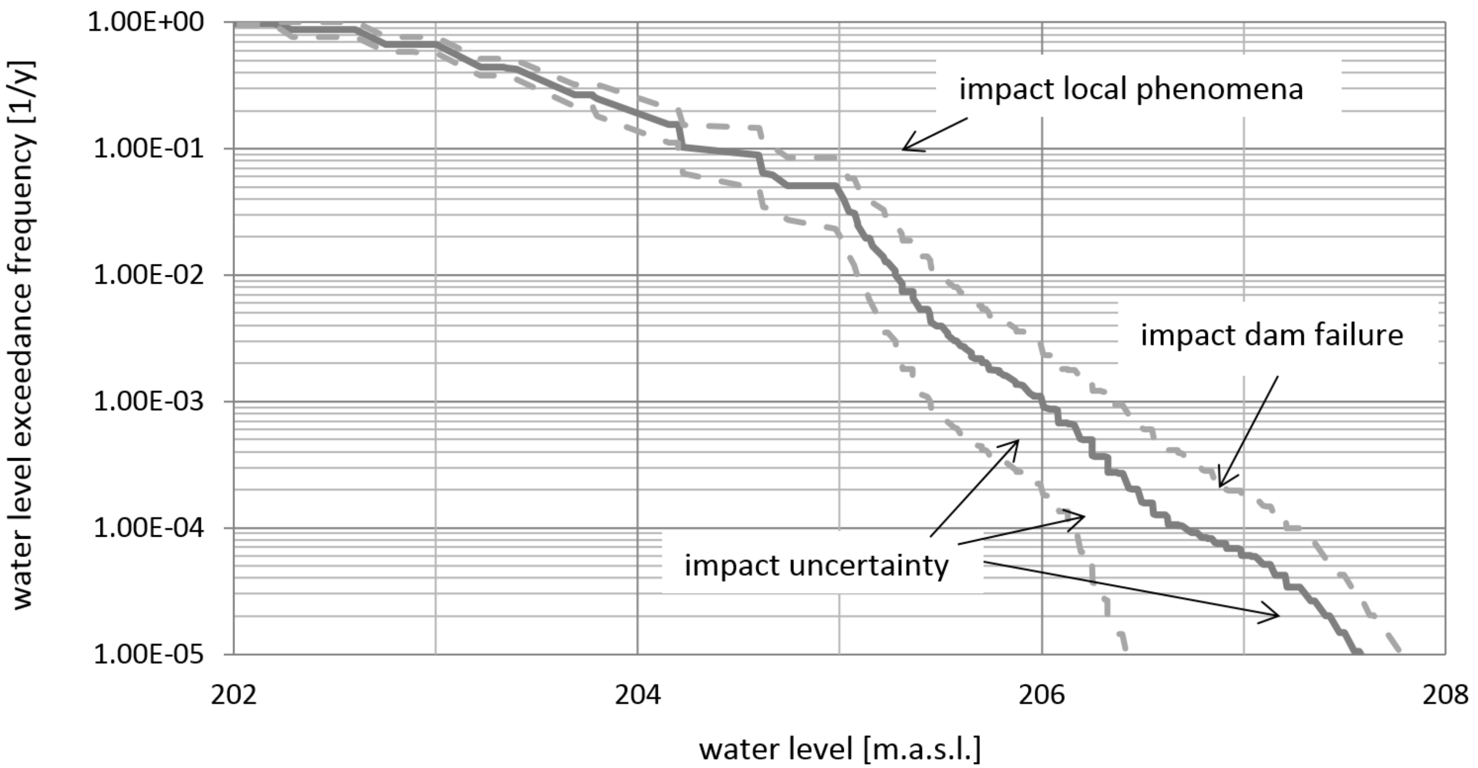
Example

Assumed river profile:



Example

Water level exceedance frequency curve:



Conclusions

- The presented approach allows to systematically consider the various data on flood events, the relevant phenomena, and to integrate the results of deterministic estimation of water level with probabilistic assessments.
- A key element of the approach is to distinguish between phenomena, relevant for a large part of the river concerning discharge – the so-called system-relevant phenomena – and local phenomena which are less relevant for the overall discharge but important for the flood level at a specific site.
- A way to incorporate system-relevant phenomena into a given discharge exceedance frequency curve was presented.
- The described approach can be extended to include the impact of uncertainties in the expert judgement in a systematic and integrated manner.