Reconstruction and quantification of “extreme” and detection of “normal” pre-instrumental flood events of major Swiss Rivers

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Goals of the project

The reconstruction of extreme hydrological events of the period before the onset of national hydrological gauge measurements (pre-instrumental period) is one of the main goals of this research project. This will include an emphasis on the long-term series of reconstructed peak discharges of pre-instrumental flood events of main Swiss rivers (Aare, Limmatt, Rhone, Sihl and Thurt Rivers). The occurrence of so-called "normal" floods of the Aare and Rhine Rivers will be reconstructed, from which a better understanding about flood risk assessment and/or flood protection measures. The aim is on the one hand to facilitate the access to raw data which generally is needed for further historical hydrological reconstruction and quantification, so that further research will be achieved in significantly shorter time. On the other hand, new historical hydrological research results shall be continuously included in order to establish this database as a useful tool for the assessment of flood risk by including the long-term experience of reconstructed pre-instrumental floods.

Methodology

The methodology developed by Wetter et al. (2011) combines different documentary and instrumental sources, relating reconstruction of the reconstruction of extreme pre-instrumental flood events. The methodology includes hydrological measurements (gauges), historic river profiles (cross sections and longitudinal profiles), flood marks, historic city maps, city maps, historical flood reports, and archival sources (Fig. A). It has been shown that extreme Rhine River flood events of the pre-instrumental period can be reconstructed in terms of peak discharges for the last 750 years by applying this methodology to the site of Basel. Further archival sources showed that conditions for completing similar historic hydraulic and hydrological extreme flood reconstructions to those in Basel are most appropriate for the Swiss cities of Aarau, Bern, Brugg, Lucerne, Schaffhausen, Solothurn and Zurich, and for the nearby German cities of Constance and Lindau. The main steps of this methodology are described below.

M1 Qualitative calibration

The principle of the comparative “qualitative calibration” approach is shown in figure A. Qualitative calibration basically works with overlapping periods of different flood “information systems” like daily water level readings, flood marks and narrative flood reports, which allows to calibrate the pre-instrumental flood information systems (flood marks, reports etc.) with instrumental measurements.

M2 Reconstruction of flood reference points and peak water levels

Flood reference points (FRP) are included in chronicler - and/or newspaper flood reports. A FRP may be e.g. the level of a bridge or the level of a window. The levels of these FRP need to be reconstructed in meters above sea levels (asl) and need to be distinguished from peak water levels (PWLs). Once FRP are reconstructed it sometimes may be necessary to assess the water depth at the site (Fig. B).

M3 Stability check of FRP levels over time

As we are dealing with long-term study periods, it is necessary to check whether the FRP were stable over time. If there is no stability of the levels, it is necessary to reconstruct the alteration of the FRP levels.

M4 Reconstruction of changes of run-off conditions due to river engineering measures over time

In a next step the changes of run-off conditions of the river under investigation need to be reconstructed. This is necessary to build homogenous groups of flood events and the attribution of representative river profiles to those flood groups to calculate the peak discharges (based on the reconstructed PWL) with hydraulic models. It furthermore helps to understand the changes of PWL over time and thus may help to quantify the difference in peak discharge of actual and pre-instrumental flood events (Fig. C).

References:


Fig. A: Qualitative calibration scheme of pre-instrumental flood events using overlapping periods of different flood information systems

Fig. B: Reconstruction of flood reference points and peak water levels based on narrative flood information and documentary sources

Fig. C: Changes of peak water levels over time. Qualitative assessment of river engineering measures influences to runoff conditions

M5 Calculation of peak discharges of pre-instrumental flood events

At this point of the project peak discharges of pre-instrumental flood events have only been calculated for Rhine River at Basel. Quantification of the runoff obtained from the evidence available for the pre-instrumental and instrumental periods was done by applying the one-dimensional (1D) hydraulic model FLUX/FLORIS2000, which is a flood routing software that calculates the 1D flow in river systems based on the de-Saint Venant equations (Ven Te Chow, 1973), being the Navier-Stokes equations for flow, integrated over the cross-sections of the river. The 1D flow equations are solved with a finite volume method. Measured cross-sections are used to discretize the river branches. The program package includes options for automatic calibration and flow regulation. The model can be used with a prescribed inflow and the results are the water levels for every cross-section. To quantify the peak flow for each historical flood mark, the inflow in the model of the runoff increased until the historical water level is reached. Thus, for every observed water level and corresponding flow can be calculated. The calculated peak discharges for Rhine River in Basel are displayed in figure D (figure D).

Fig. D: Reconstructed discharge series of extreme Rhine River flood events at the site of Basel based upon Flux/Floris2000 software

In the long run (starting with this research project) it is the aim to set-up a new tool for the Euro-Climhist database which will be specially designed for the needs and desires of historical hydrological research and public or private institutions that have a common interest in flood risk and flood protection topics. The integration of this tool in the Euro-Climhist database will offer the advantage that the historical flood events may be identified in climatological and hydrological water level conditions, through the access of only not flood related but also to climatological and geographical meteorological data (Fig. E).

Fig. E: Printout of the Historical Hydrological Database of Switzerland showing the reconstruction of the historical inundation area and the peak discharge of the pre-instrumental flood event of 1480 (on the bottom) homogenised to the actual hydrological regime and present day topographical conditions in Basel.