Reconstructing historic flood levels using a hydraulic model

Learnings towards contemporary risk assessment: City of Bath, UK

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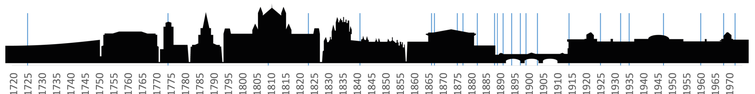
Why: To design long-term flood protection structures, considerable interpolation is required as the average recorded record is lower than the 30 years.

What: Can we reduce this uncertainty by extending the record back in time by reconstructing historical events using a numerical model?

Where: Our case study is the historical city of Bath, UK, but the methodology is applicable to other locations.

(1) Importance of utilizing historical datasets

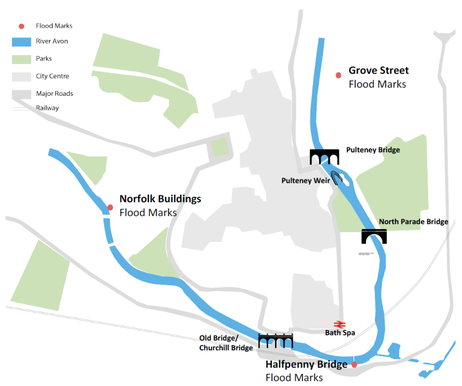
Chronology of past flood events in the city of Bath: 1720-1970



Flooding is a costly problem and estimating the risk of future flood events is of considerable interest. The average record length of annual maximum series (AMS) of peak flow in the UK is around 40 years but most infrastructure is designated to cope with design flood events of predefined return periods (e.g. 1 in 100 or 1 in 10,000 year events). It is clear that **considerable interpolation is necessary** in most cases, leading to high levels of uncertainty. One strategy for reducing this uncertainty is to try and **create a longer data series** by augmenting the flood series derived from observed flow series with **historical flood events reconstructed from historical evidence**.

The city of Bath has been chosen as a case study, but the **methodology will also be applicable to other locations**.

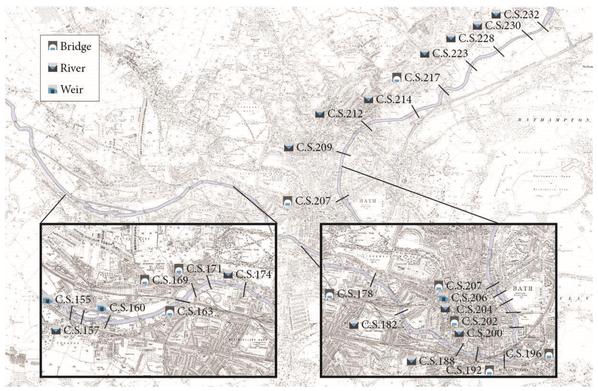
(2) The historical floods of Bath and the River Avon



As the city of Bath developed around the River Avon, communities in Bath have experienced the effects of flooding since the Roman times.

Bath has a particularly rich **record of historical evidence** which appear from the **19th century** with **flood marks** on buildings through-out the city (16 marks – earliest from **1823**).

(3) Reconstruction of peak flows using numerical modelling



Flood Modeller

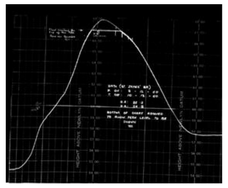
The hydraulic conditions of the river Avon prior to the Bath Flood Defence Scheme BFS were re-constructed in Flood Modeller

Important River Sections:
CS207 – Pulteney Bridge
CS206 – Pulteney Weir
CS196 – Widcombe Bridge
CS192 – Old Bridge

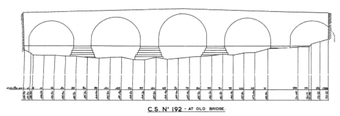
(4) Model parametrization

Flood Modeller Input:

- Inflow hydrograph
- Energy slope
- Manning's roughness coefficient
- Distance between cross sections
- River cross sections
- Hydraulic structures



Hydrograph: A microfilm version of the water levels recorded during the 1960 flood was found in the physical archives of the UK Centre of Ecology and Hydrology, Wallingford.



River cross section: Drawings of the river cross-sections were found in the Environment Agency's Digital Archives in Bridgwater under the keyword "Bath Flood Protection Scheme".

(5) Methodology

1. A typical shaped **inflow hydrograph** is specified at the upstream boundary of the river model.
2. It was then **scaled** to match the magnitude of previously estimated peak discharges.
3. **Flood Modeller** software routes the flood wave through the river system.
4. Flow rate, water levels and velocities are **calculated** at each of the specified cross-sections.
5. The **outcome** of this analysis is a set of **historical peak flow values**.

WP 1- Historical Evidence
- Chronology of past flood events
- Inventory of historical evidence
- Rainfall records

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WP 2- Hydraulic Modelling
- Hydraulic model of river Avon using Flood Modeller
- Determine shape of river inflow hydrograph
- Creation of error models

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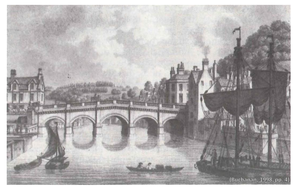
WP 3- Flood Frequency
- Bayesian modelling framework
- Statistical model development
- Assessment of resulting (combined data) model

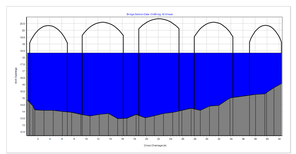
(6) The flood of 1960

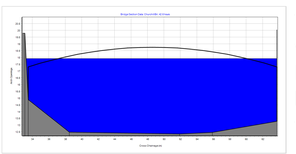
The flood of 1960 was considered a **catalyst event** for the policy of Bath. The event was smaller than previous historic floods but due to the city's development, the **economic impact was vast**.

Old Bridge | **Churchill Bridge**

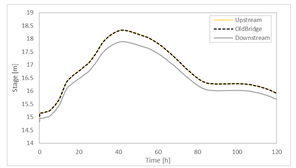


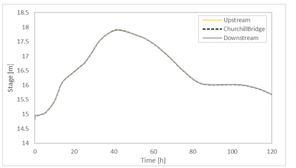
The Bath Flood Defence Scheme was initiated in 1964. The improvements included: deepening of the river bed removal of obstructions, and **the replacement of Old Bridge with Churchill Bridge**.





The five-arch masonry bridge was identified very early as being **prone to debris blocking** and an **obstacle** to the River Avon's flow.



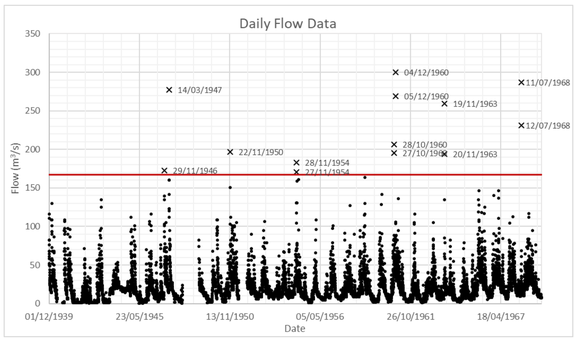


The comparison of the timeseries of stage during the 1960 flood for Old Bridge (left) and (right) Churchill Bridge shows that **Old Bridge created a 0.5 metre blockage** upstream.

(7) The practical relevance of the work going forwards

How can we use historical evidence of past flood events for contemporary flood risk assessments?

- The augmented series allows an **evaluation of long-term trends** in flood risk.
- The impact of the long-term augmented series from the River Avon on flood risk assessments will also be **assessed in neighbouring river systems**.



Conclusion: This research shows that reconstructing historical flood levels numerically is a possible approach to reduce the uncertainty of observed data series and extend them back in time. However, as central repository systems for this type of information don't exist, substantial effort is required to locate and translate the historical evidence into a useful format for modern risk assessments.

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Acknowledgments: *The authors are grateful to the Environment Agency staff in Bridgwater and the Centre of Ecology and Hydrology for their help and assistance. We would also like to show our gratitude to Jacobs for providing a Flood Modeller license for this research.*

References: Buchanan, R.A., 1998. Bath History. Millstream Books.