Flood inundation risk in Bath under different return periods

UCL

Introduction

Bath is located in the South West of England and is the only city in the UK to be listed as a World Heritage Site. The River Avon, which flows through Bath, has been closely associated with Bath's development, bringing a thriving economy to the area as a trade route.

But the Avon also has brought the risk of flooding. There are fourteen flood marks exist on the Widcombe wall from 1875 to 1960, with peak flows in December 1960 estimated to be as high as 398.5m^3/s. In the face of flooding, the government spent 3 million pounds in 1974 to build the present flood defenses.

However, as the city grew, the combination of hardened paving and the upgrading of the sub-base led to a reduction in the city's flood discharge capacity. The purpose of this map is to explore which areas of Bath today may be potentially at risk in the face of flooding under different return periods based on the sub-base condition.

Data sources

Figure 1 Hydrographic stations near Bath

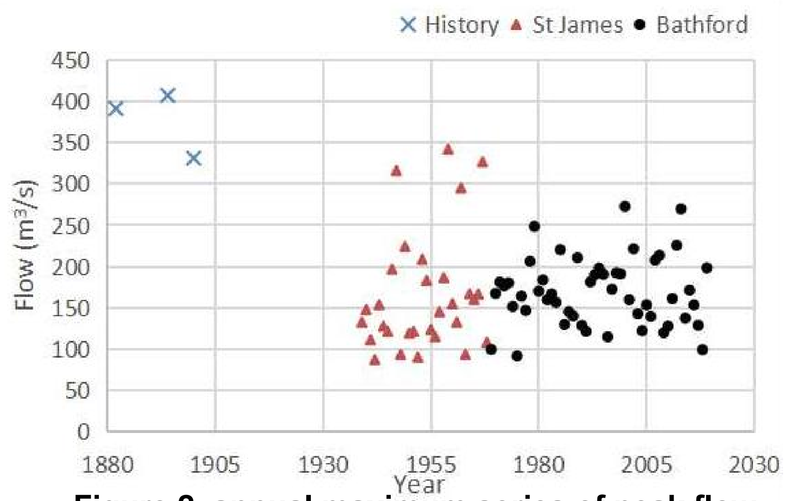


Figure 2 annual maximum series of peak flow

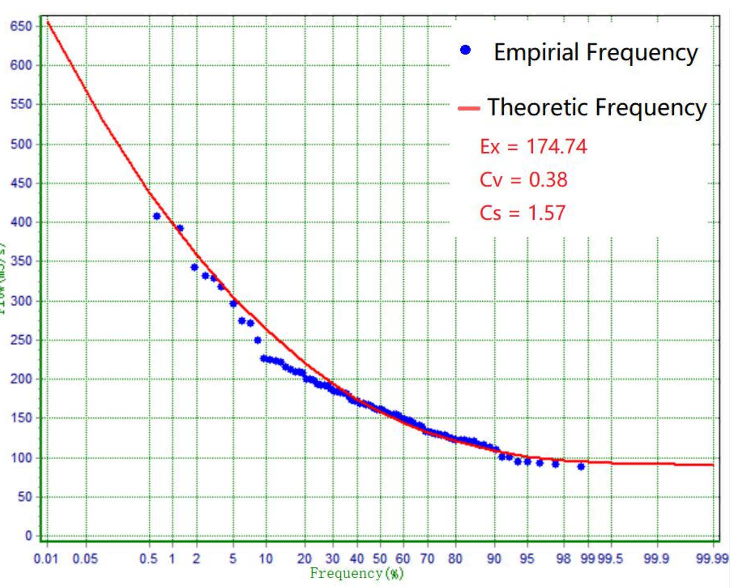


Figure 3 Peak discharge frequency curve

Hydrological data

The Bathford station (1969-present), upstream of Bath city, is chosen as the base station for the map for the river data analysis[1], as shown in Figure 1.

The annual maximum method is used to inquire the design flood volume, and as there were several floods in Bath prior to 1969, the equivalent flow at Bathford station is calculated[3] using the flow from St James (1939-1969)[2], and the data on the Windcomb wall[3] greater than 300m^3/s is used as the historical mega-flood value to obtain the annual maximum flow data (Figure 2). The frequencies are calculated using the independent sample method and finally fit with the P3 curve (Figure 3) to acquire the design flood flows at different return periods. Comparing the 100-year flow data from the literature[3][4], the design flood calculation is considered reasonable.

Topographical data

DSM data from the National LIDAR Programme 2019[5] is used for Bath during flooding simulation, with a spatial resolution of 1m and a vertical accuracy of +/-15cm, which meet the accuracy requirements. The DSM data containing surface object elevations is selected to match the actual conditions and to facilitate the subsequent use of flood calibration elevations.

Finally, the greenfield data for exploring the relationship between flooded areas and greenfields is obtained from OpenStreetMap.

Design considerations and Map analysis

Map display

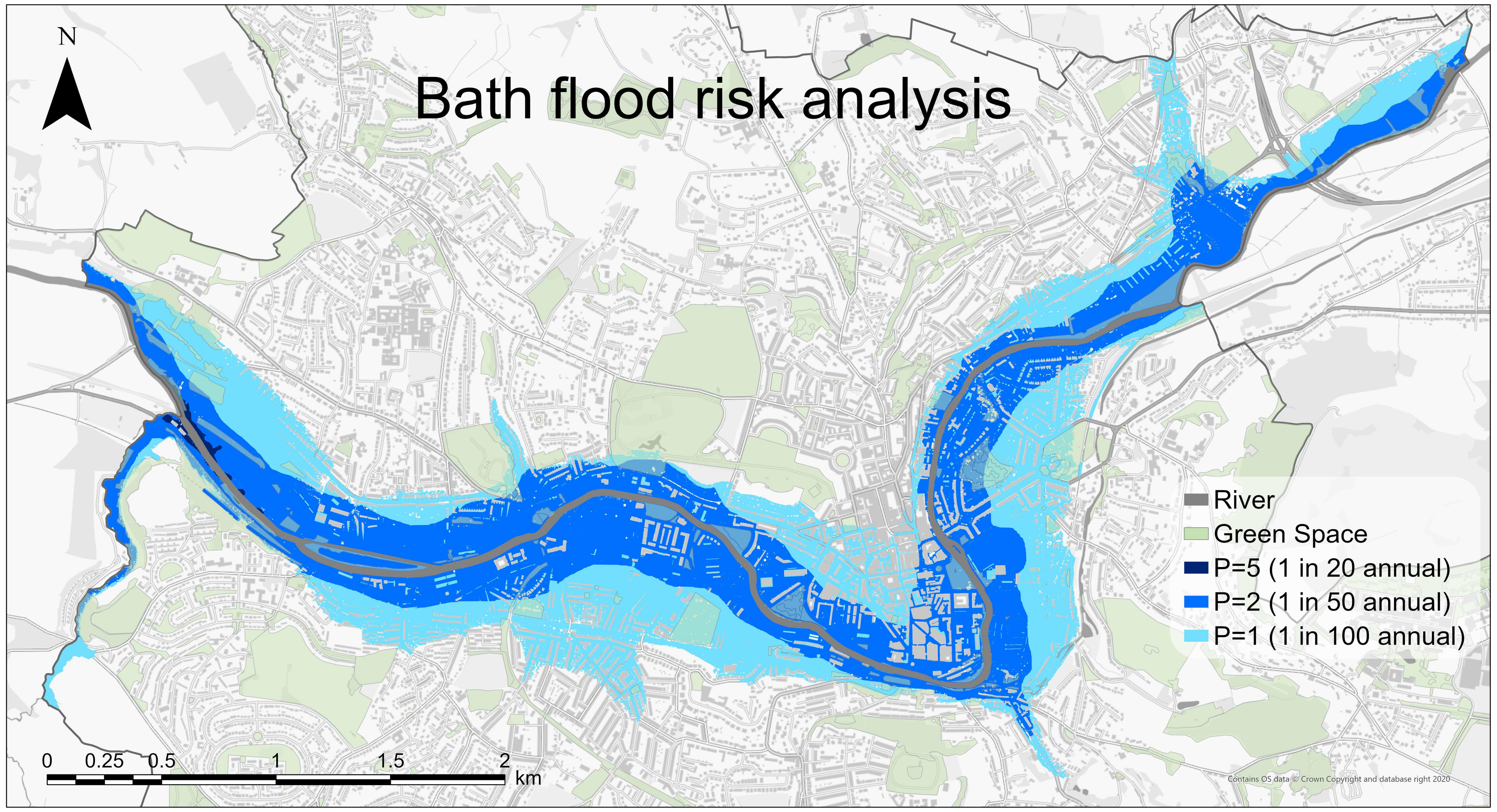
- As the poster's study area is the Bath, all vector and raster data were clipped using the Bath boundary and superimposed on a grey base map to highlight the result within the area.
- Floods of different return periods are selected to differ significantly in blue color and overlaid sequentially from low to high.
- Flood storage and drainage green areas are superimposed with increased transparency above the floods to facilitate comparison of overlap zone.

Analysis

For floods of different return periods, a flood at P=10 would not cause any inundation in Bath and is therefore not shown on the map; P=5 would result in a small amount of inundation downstream with a high degree of overlap with riverside-park; P=2 would lead to a large amount of pond on the riverside road; as for P=1, there are houses inundated in the riverside area. The maps show that the current subsurface conditions in the Bath have a large deficit in resilience to extraordinary flood, but is sufficient to withstand a 1 in 20 years flood.

The map overlays the green area shows that the green area along the river as a flood storage area overlaps the inundation area to a high degree, and the green space is reasonably set up to increase the proportion of parkland along the river to enhance the flood discharge and renewal.

As the map does not consider the role of water diversion and flood storage areas, the actual inundation place would be smaller. Considering that since 1969 the peak flood never exceeded P=5, the elevation of the city of Bath is tentatively considered that meet the flood control needs at this stage.



Methodology

The analysis of flood inundation under different return periods in Bath uses "non-source flood" because it is more concerned with subsurface conditions and elevations than "source flood", which focuses more on flow processes[7][8].

The mapping idea is shown in the flow chart on the right (Figure 4).

The value of water body areas of raw DSM data is blank and is replaced by neighborhood average value using raster calculator tool. And then puddle filling of the DSM data.

Design flood is calculated based on Bathford's typic flood hydrograph[8]. Flood flow is obtained by integration, and due to the lack of recession curve, taking into account the catchment effect of the packet zone, the line at the beginning and end of the flood hydrograph is considered to be the load flow of the river and is not integration (Figure 5).

For the treatment of the water surface elevation, the water depth is initially calculated using the equation Q=90.512*(h-0.8620)^0.870 fitting by website[1], then plus the station elevation as the initial flood elevation. As the peak flow measured by Bathford since the station was built is 272.658m^3/s (P≈8.5), the initial flood elevation obtained by fitting the function calculated by actual values may have a huge error, so the flood volume is used for calibration. The surface volume tool is used to obtain the inundation volume in the map, and the calculated flood flow is compared to reselect the flood elevation until it is reasonable. The area where the topographic elevation is less than the flood elevation is screened as inundation areas.

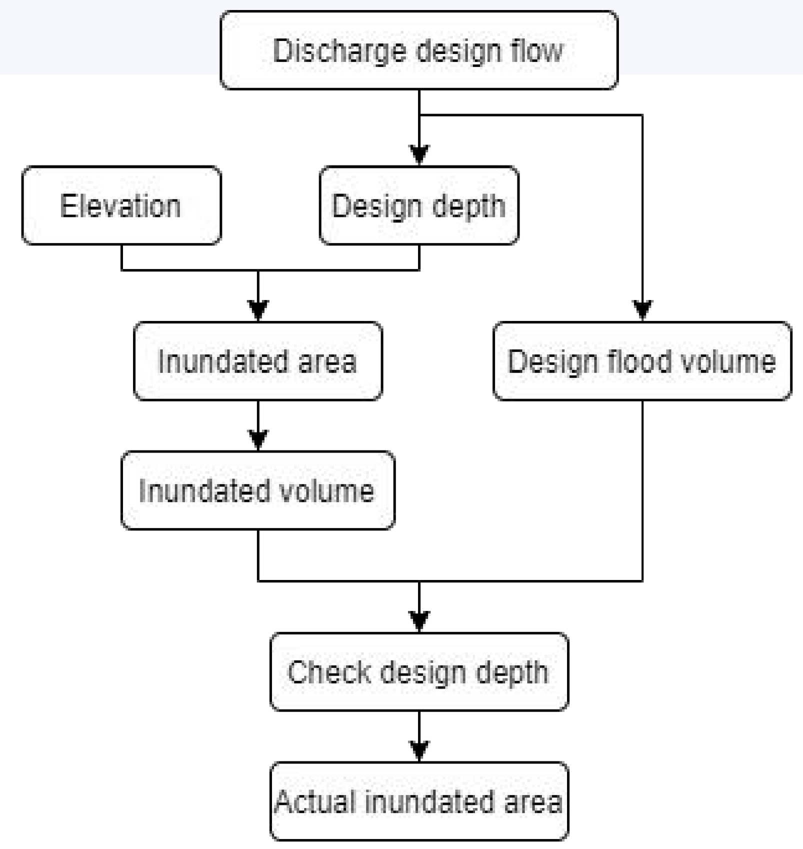


Figure 4 Methodology flowchart

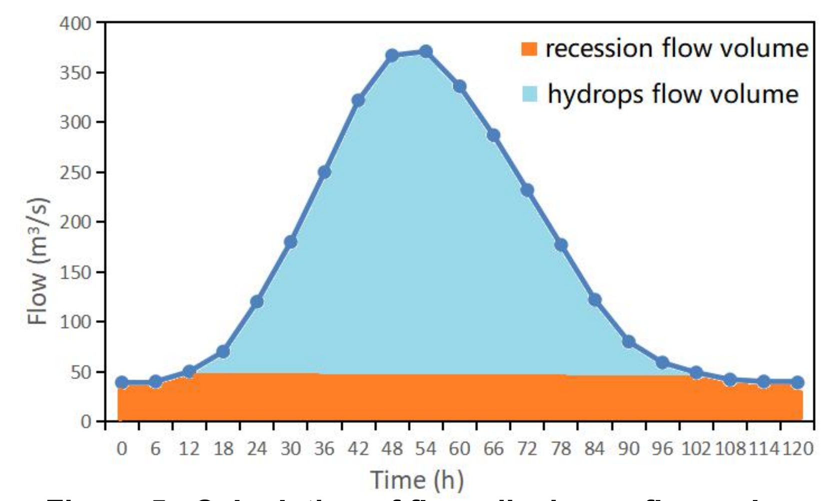


Figure 5 Calculation of floor discharge flow volume

Reference

[1] National River Flow Archive. 53018 - Avon at Bathford. [2021-10-23]. https://nrfa.ceh.ac.uk/data/station/info/53018

[2] National River Flow Archive. 53003 - Avon at Bath St James. [2021-10-23]. https://nrfa.ceh.ac.uk/data/station/info/53003

[3] Stamataki I, Kjeldsen TR. Reconstructing the peak flow of historical flood events using a hydraulic model: The city of Bath, United Kingdom. Flood Risk Management. 2021; 14:e12719. https://doi.org/10.1111/jfr3.12719

[4] Kjeldsen T, Jerry T. Flood frequency analysis for the River Avon at Bath. Poster session presented at 12th British Hydrological Society National Symposium, Birmingham, UK United Kingdom. 2014.

[5] Department for Environment Food and Rural Affairs. National LIDAR Programme. 2019 [2021-11-15]. https://environment.data.gov.uk/dataset/2e8d0733-4f43-48b4-9e51-631c25d1b0a9

[6] Ding ZX, Li JR, Li L. Flood inundation analysis method based on GIS grid model.Journal of Hydrology, 2004(06):56-60+67.

[7] Guo SC, Du PJ, Meng YP, et al.Dynamic monitoring of flood conditions in the middle and lower reaches of the Yangtze River supported by time-series Sentinel-1A data.Journal of Remote Sensing ,2021,25(10):2127-2141.

[8] Reed DW. Design flood hydrographs for the Avon at Bathford. 1988. Retrieved from http://nora.nerc.ac.uk/id/eprint/14226/1/N014226CR.pdf

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