Technical Note

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1 Introduction

The Underfall Sluices are located at the western end of the Floating Harbour by the Underfall Yard (Figure 1). Two of these sluices are fundamental for regulating the water level in the Floating Harbour. During normal flow conditions, operation of the sluices enables excess water in the Floating Harbour to discharge into the River Avon New Cut.

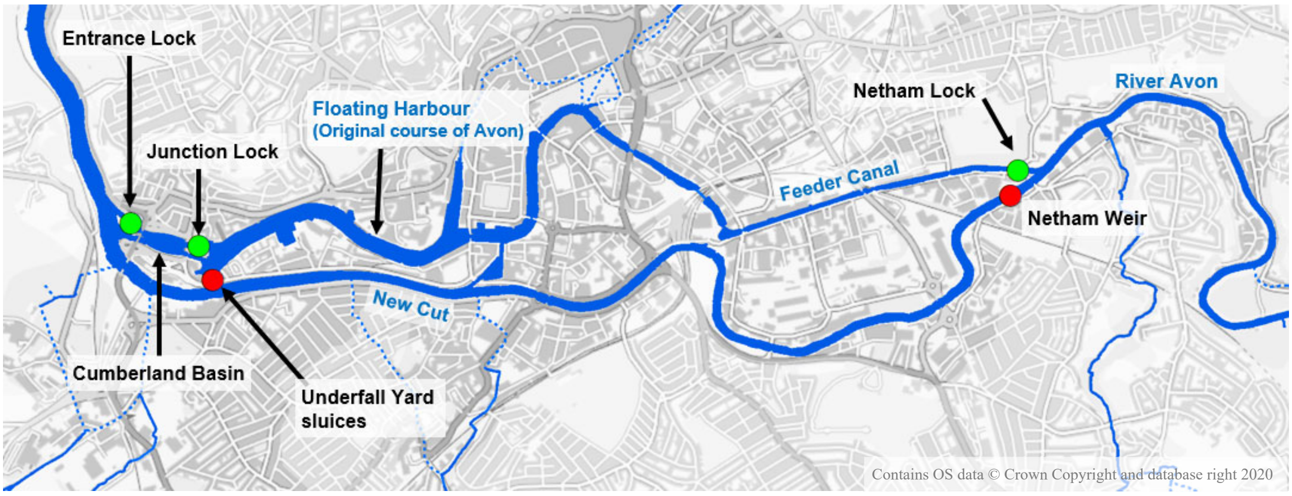

Figure 1: Location of Underfall sluices.

The number of operational sluices has reduced over the years, and at times the redundancy in the asset has been of major concern. As such, maintenance, repair and upgrade works have been prioritised for these assets.

Bristol City Council (BCC) aims to submit a bid for Flood Defence Grant in Aid (FDGiA) funding for the proposed works. To support this bid, Arup have been commissioned by BCC to undertake hydraulic modelling and analysis to determine the number of properties that would benefit from the proposed works.

This technical note presents an overview of the hydraulic modelling work and results.

2 Hydraulic modelling

It was agreed with BCC that the hydraulic modelling should be undertaken using the Bristol Avon Flood Strategy baseline (Do Minimum option) model. The model is a linked 1d-2d model. The 1d component, which is based on Flood Modeller Pro, represents the watercourses such as the River Avon and River Frome and associated riverine structures plus some areas of floodplain upstream and downstream of Bristol. The 2d component, which is based on TUFLOW, represents floodplain areas within Bristol, the Floating Harbour and the Feeder Canal. The extents of the 1d and 2d components of the model are shown in Figure 1.

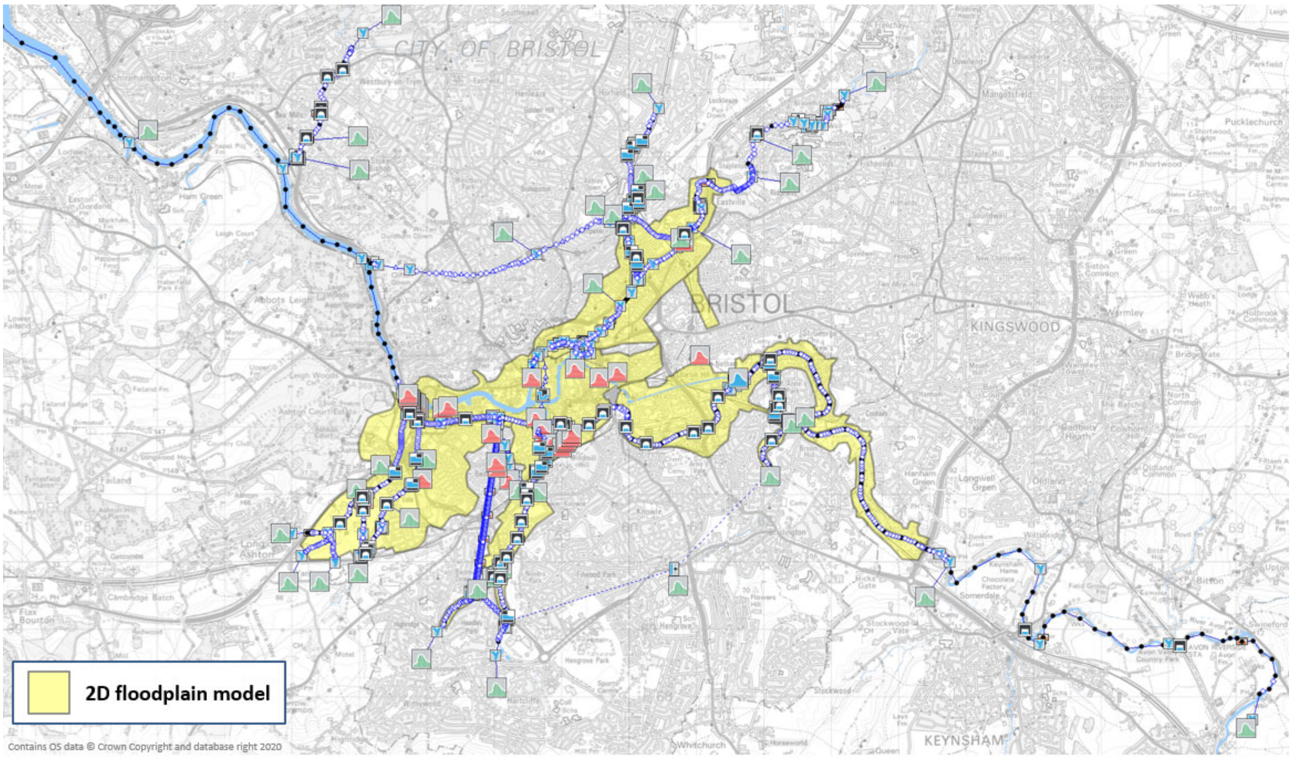

Figure 2: Extents of 1d model (node icons) and 2d model (yellow areas).

The baseline model includes the two currently operational Underfall sluices used to regulate water level in the Floating Harbour. The baseline model assumes these sluices are fully operational. The operation of these sluices in the baseline model is controlled automatically using the following logical rules:

1. If Floating Harbour water level is less than 6.20m AOD: Open the sluices.
2. If Floating Harbour water level is greater than 6.20m AOD and River Avon water level is less than 5.95m AOD: Open the sluices.
3. If Floating Harbour water level is greater than 6.20m AOD and River Avon water level is greater than 5.95m AOD: Close the sluices.

The baseline model assumes Netham Lock, Entrance Lock and Junction Lock gates remain closed for the duration of all modelled flood events, regardless of whether they are fluvially or tidally dominant. This is considered to be a conservative assumption as it may be possible to operate these gates during a flood event to reduce water levels in the Floating Harbour.

Two scenarios were set up using the hydraulic model:

1. Underfall sluices failed closed, i.e. preventing any discharge between the Floating Harbour and the River Avon. It was agreed with BCC that this failure scenario should only be modelled for fluvially dominant events as this scenario would cause fluvial flows from the Feeder Canal and River Frome to become trapped in the Floating Harbour.
2. Underfall sluices failed open, i.e. allowing tidal ingress from the River Avon into the Floating Harbour. It was agreed with BCC that this failure scenario should only be modelled for tidally dominant events.

For both the above scenarios, it was agreed that the sluice failure should be assumed to occur from the start of the simulation (or as close to the start as practicable).

It was agreed with BCC that the above scenarios should be modelled for the 2030 climate change epoch as this incorporates a 10% increase in fluvial flows, which is consistent with the central climate change allowance for river flows for the '2020s' (which is applicable for all years from 2015 to 2039) based on current guidance[1].

Model simulations were run for each of the above two scenarios for the 1:20yr, 1:75yr and 1:100yr return periods. To ensure consistency, the simulations were run using the same version of the modelling software (Flood Modeller Pro and TUFLOW) as was used to undertake the baseline (Do Minimum option) modelling for the Bristol Avon Flood Strategy.

The baseline model results for the above return periods were taken from the Bristol Avon Flood Strategy to negate re-running the baseline model.

3 Model results

3.1 Flood extents

Flood extents have been created from the raw model results for the baseline scenario and for the two sluice failure scenarios (failed open and failed closed).

Flood maps comparing the baseline scenario to the sluices failed closed scenario for fluvial events are presented in Figures A1 to A3 in Appendix A. These show the failure of the sluices in a fluvial event would cause significant flooding around the Floating Harbour and the Victoria Street area and would significantly increase flooding from the Feeder Canal in the St Philips Marsh area and flooding from the Frome at Cabot Circus. The increase in flooding is due to fluvial flows entering the Floating Harbour via the Frome and Feeder Canal no longer being able to discharge into the River Avon at the Underfall Sluices, i.e. the flows becomes trapped in the Floating Harbour. As discussed in the previous chapter, the modelling assumes that the lock gates and flood gates remain closed throughout the flood event, which is a conservative assumption. The increase in water level

[1] Flood and coastal risk projects, schemes and strategies: climate change allowances, Environment Agency, July 2020.

in the Floating Harbour is sufficient to overtop the area around the Floating Harbour and to increase the water levels in the River Frome.

Flood extents were also created for the baseline scenario and the sluices failed open scenario for tidal events. Review of these flood extents showed that failure of the sluices in this scenario would cause no increase in flood extent compared to the baseline for any of the three return periods tested. In some locations there is a marginal reduction in flood extent, most notably near Cumberland Close in the 1:100yr tidal event (Figure 3). Inspection of the model results show this is due to water in the Floating Harbour draining down before the peak of the tidal surge event, thereby creating capacity within the Floating Harbour to store flood water (Figure 4). Given this result, flood maps are only presented for fluvial events for baseline and sluices failed closed scenarios.

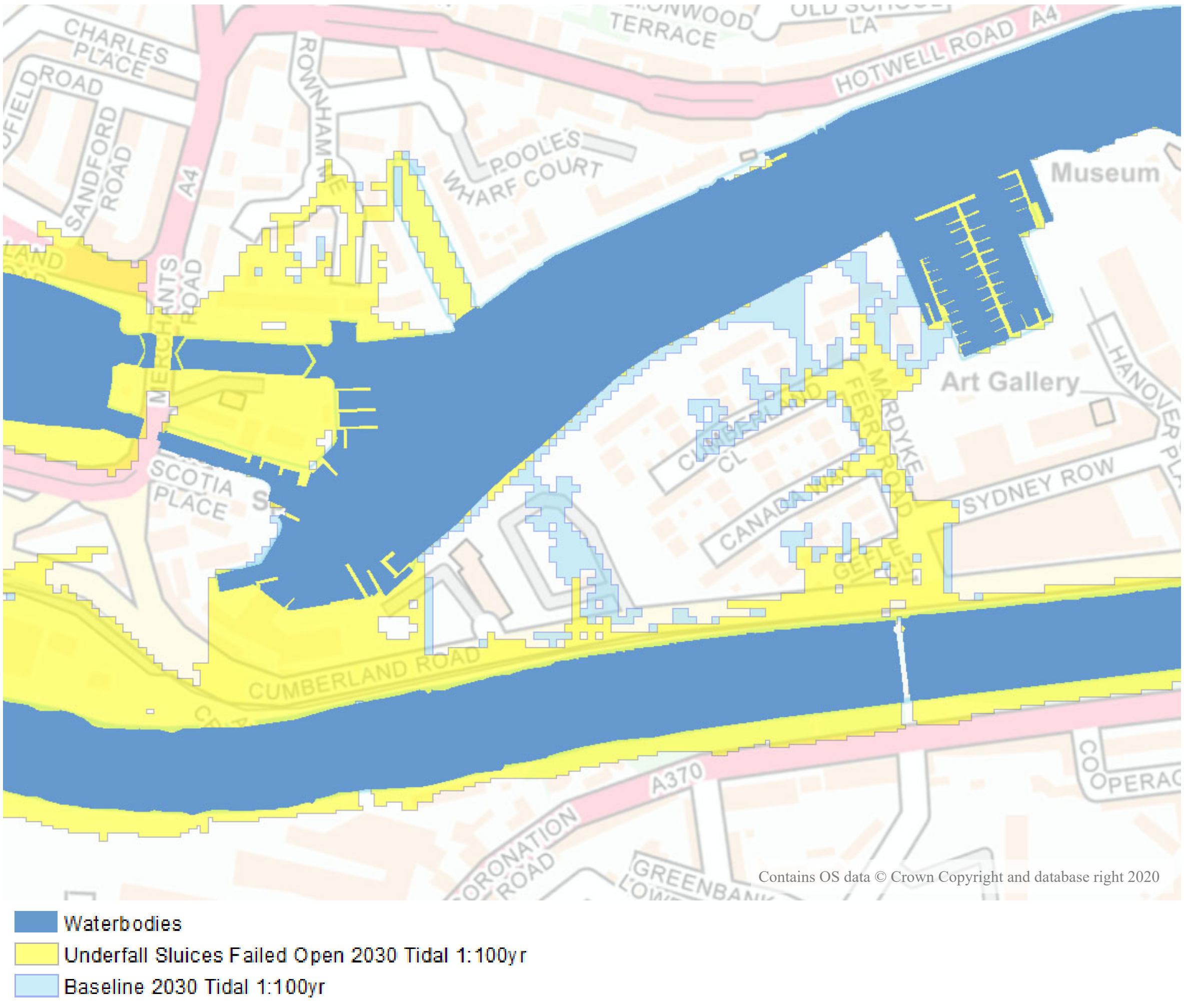

Figure 3: Baseline vs sluices failed open scenario for 2030 Tidal 1:100yr event. Note the yellow layer is on top of the light blue layer.

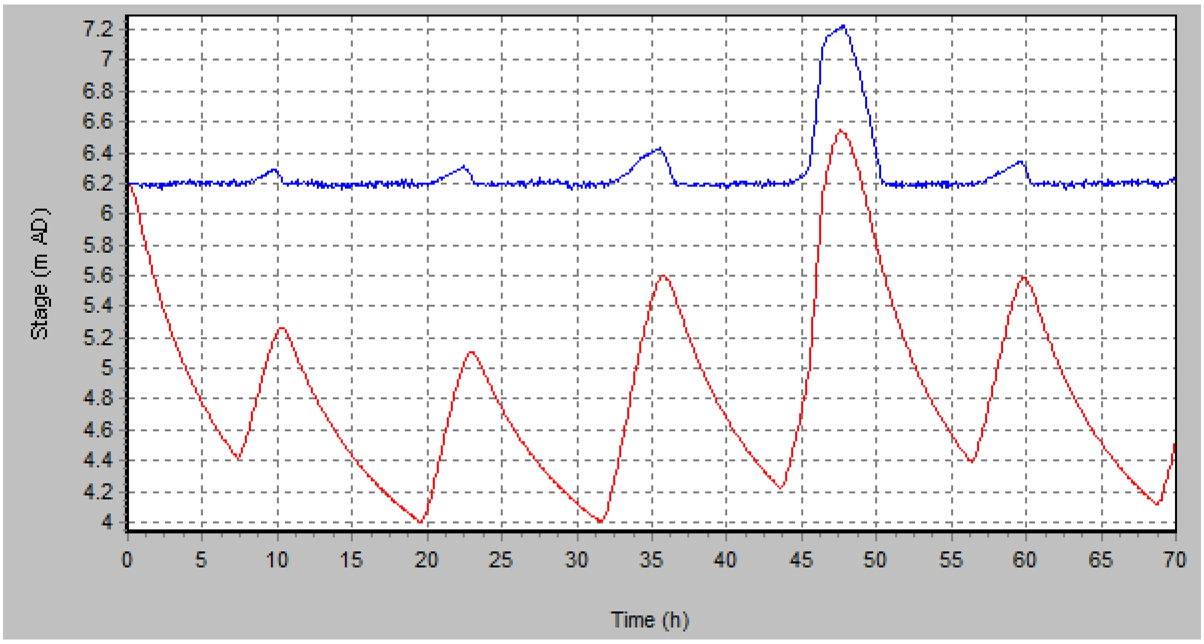

Figure 4: Water level vs time for the Floating Harbour for the 2030 Tidal 1:100yr event. Baseline (blue) vs Sluices failed open (red).

3.2 Property counts

Property counts have been undertaken for the baseline scenario and the sluices failed closed scenario for fluvial dominant events only. This is because the results show that the sluices failed open scenario, which was modelled for tidal events, would not increase flood extent compared to the baseline (see Section 3.1).

Property counts have been derived using the same property dataset and the same method as were used for the Bristol Avon Strategy property counts. The property dataset comprises building polygons from OS MasterMap data with additional attributes including those extracted from the National Receptor Database (NRD) points layer and assumed threshold levels. Assumed threshold levels are based on the average LIDAR level across the building footprint + an assumed 300mm threshold height. The property dataset includes one building polygon for each NRD property, therefore there are multiple duplicate polygons for buildings containing more than one property such as blocks of flats. The property dataset does not include any residential houseboats in the Floating Harbour.

Maximum water level grids were extracted from the raw model results. The 'Zonal Statistics as Table' ArcMap tool was then used to extract maximum water levels for each property based on the associated building polygon. A spreadsheet calculation was then set up to count the number of flooded properties, i.e. those where the maximum water level is greater than the assumed threshold level. Properties downstream of Entrance Lock were excluded from the property counts as the model is 1d only here and results may be inaccurate. This is not expected to influence the outcome of this assessment given the sluice failure scenarios have virtually no impact on peak river water levels here.

The property counts, which are only provided for fluvial dominant events, are presented in Table 1. These property counts are cumulative with return period, i.e. they correspond to the number of properties flooded for the given return period as opposed to the additional number of number of properties flooded compared to the previous return period. Outcome Measure 2 (OM2) values can be derived from these property counts. It is recommended that for OM2, the property counts corresponding to those having floor type *Not 'Upper or Possible Upper'* are used.

Table 1: Property counts for baseline and sluices failed closed for fluvial dominant events.

		Baseline			**Sluices failed closed**			**No. of properties benefiting**		
Type	**Floor type**	**1:20y**	**1:75y**	**1:100y**	**1:20y**	**1:75y**	**1:100y**	**1:20y**	**1:75y**	**1:100y**
Residential	Upper or Possible Upper	7	27	34	49	105	115	42	78	81
	Not 'Upper or Possible Upper'	16	95	110	112	220	244	96	125	134
	All	23	122	144	161	325	359	138	203	215
Non-Residential	Upper or Possible Upper	4	25	37	35	71	78	31	46	41
	Not 'Upper or Possible Upper'	119	240	272	337	511	545	218	271	273
	All	123	265	309	372	582	623	249	317	314
Total	Upper or Possible Upper	11	52	71	84	176	193	73	124	122
	Not 'Upper or Possible Upper'	135	335	382	449	731	789	314	396	407
	All	146	387	453	533	907	982	387	520	529

4 Summary and conclusions

Hydraulic modelling and analysis has been undertaken to determine the number of properties that would benefit from the maintenance, repair and upgrade works proposed for the Underfall Sluices. This is intended to be used by BCC to support their bid for FDGiA funding.

The modelling has shown the Underfall Sluices offer significant flood risk benefit for fluvially dominant events but no flood risk benefit for tidal events. Model results for fluvially dominant events have been presented in the form of flood extent maps and property counts that compare the impact of the sluices failed closed scenario to the baseline.

DOCUMENT CHECKING (not mandatory for File Note)

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