Hampshire County Council

Durngate Flood Defence Modelling

Modelling Report

REP/002

Issue | 13 December 2017

Job number 257576-00

Ove Arup & Partners Ltd
63 St Thomas Street
Bristol BS1 6JZ
United Kingdom
www.arup.com

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Document Verification

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Job title		Durngate Flood Defence Modelling		**Job number** 257576-00	
Document title		Modelling Report		**File reference**	
Document ref		REP/002			
Revision	**Date**	**Filename**	DurngateFloodDefences_ModellingReport_ISSUE_Draft_Rev1.docx		
Draft 1	31 August 2017	**Description**	Draft issue		
			Prepared by	Checked by	Approved by
		Name	Tess Brooks	Dan van der Leer	Richard Brown
		Signature			
Issue	13 Sep 2017	**Filename**			
		Description	Final Issue – Revision updated to final; no other changes required based on this stage of modelling work.		
			Prepared by	Checked by	Approved by
		Name	Tess Brooks	Dan van der Leer	Richard Brown
		Signature			
Issue	6 Dec 2017	**Filename**	DurngateFloodDefences_ModellingReport_ISSUE_Final_Rev1.docx		
		Description	Incorporated updated modelling		
			Prepared by	Checked by	Approved by
		Name	Tess Brooks	Dan van der Leer	Richard Brown
		Signature			
Issue	13 Dec 2017	**Filename**	DurngateFloodDefences_ModellingReport_ISSUE_Final_Rev3.docx		
		Description	Minor updates to address client comments.		
			Prepared by	Checked by	Approved by
		Name	Tess Brooks	Dan van der Leer	Richard Brown
		Signature			

Issue Document Verification with Document ☐

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Appendices

1 Introduction

Arup were commissioned by Hampshire County Council (HCC) to undertake hydraulic modelling to assess the flood risk and potential flood mitigation associated with the proposed Durngate Flood Defence Scheme in Winchester, Hampshire.

This report summarises the fluvial flood modelling undertaken, including data sources utilised, updates to the baseline model through the incorporation of new survey data, modifications to the model to represent the proposed sluices, the scenarios modelled, and a discussion of the model results. The scope of the modelling work described herein does not extend to recommending exact sluice gate openings or control philosophy for flood flow conditions.

The sluice gate modelling was based on the updated baseline model with dimensions and levels taken from design drawings. The following scenarios have been modelled using the most up to date version of the model:

- Baseline (the 'existing situation').
- Proposed Durngate Sluices set to 50% open.

A superseded iteration of the modelling included the testing of a 'sluices 0% open' scenario. Results from this test are shown and discussed within this report as they are still relevant but flood maps for this are not presented as final deliverables.

The baseline and sluice scenario were run for the 100yr return period plus 20% increase in flows to allow for climate change. Flood depth plans and animations are provided for both scenarios.

The model results described herein show the newly / currently constructed flood defences upstream of North Walls are effective in preventing overtopping of these defences but there remains flooding onto Water Lane due to outflanking of the new flood wall and flooding down Eastgate Street due to overtopping at Durngate Place. The results from the sluice modelling show the proposed sluices could further reduce flood risk downstream if operated appropriately. However, fully closing the sluices would cause overtopping of the upstream flood defences, which would result in significant flooding. A careful balance would therefore need to be struck between reducing pass-forward flows and preventing the upstream defences from overtopping. Results suggest a primary flooding mechanism remains from overland flow southwards down Eastgate Street; it may be possible to prevent this flooding mechanism with a flood defence wall along a short stretch of Durngate Place here. Additional recommendations are provided at the end of this report.

2 Baseline model updates

A previous HCC study looked at the North Walls Flood Defence Scheme to the north of Winchester in 2015. It was agreed with HCC that the baseline model from this previous study[1] should be used in the current study to assess the flood risk impacts of installing three sets of sluice gates at the locations identified in Section 3.

2.1 Incorporating topographic survey

The baseline model was updated to incorporate new topographic survey data for Durngate[2] and information on any proposed and as-built flood defences from design crest level data and topographic survey drawing[3]. Elevation data was extracted from the survey drawings and used to create the following model layers within the TUFLOW component of the model:

- A Triangular Irregular Network (TIN) layer representing surveyed ground levels around Durngate (Figure 1). The TIN includes 'surface' and 'kerb' breaklines, where appropriate, to ensure these features are represented appropriately in the triangulation. The TUFLOW model uses linear interpolation to determine elevations between elevation points.
- Several Zlines layers representing breakline features. These include:
    - Kerbs (Figure 1, part of TIN layer).
    - Building threshold levels (Figure 2).
    - Walls (Figure 3).
    - Water Lane bank top levels upstream of new flood defence wall (Figure 4)
    - Newly / currently constructed flood defences upstream of Durngate Place (Figure 5). These flood defences are set to a minimum level of 37.5m AOD; higher levels are used where these are identified in the survey drawing.
    - Ground / building threshold levels at River Park Leisure Centre and Skate Park adjoining the newly / currently constructed flood defences upstream of North Walls (Figure 6).
    - Newly constructed flood defence wall at Water Lane with levels that vary from 36.9m AOD in the north to 36.8m AOD in the south (Figure 7).

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[1] ISIS model file: 1d_iSIS_WBWINW_300.DAT and TUFLOW control file: WBWINW_300_hazard_012Arup_100yrCC.tcf.
[2] 5S5A-Durngate, Winchester-Revision June 2017.
[3] WINCHESTER FLOOD DEFENCE – SURVEY (revision and date unknown, contains data regarding new and constructed flood defences between 2015-2017, provided by HCC on 25/07/2017).

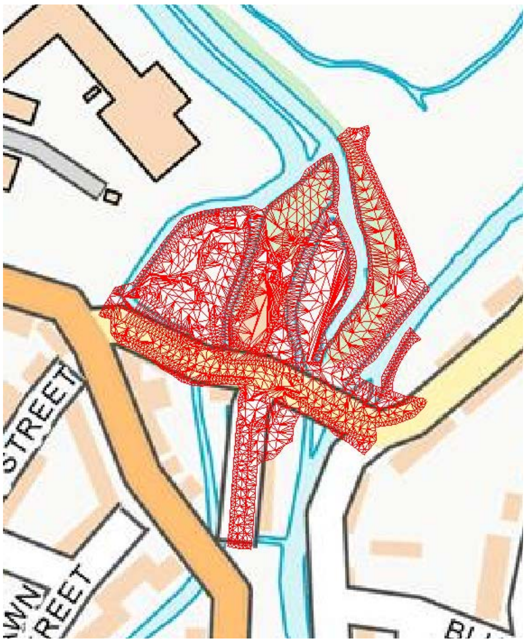

Figure 1: Resultant triangulation representing ground levels including kerb levels and riverside slopes.

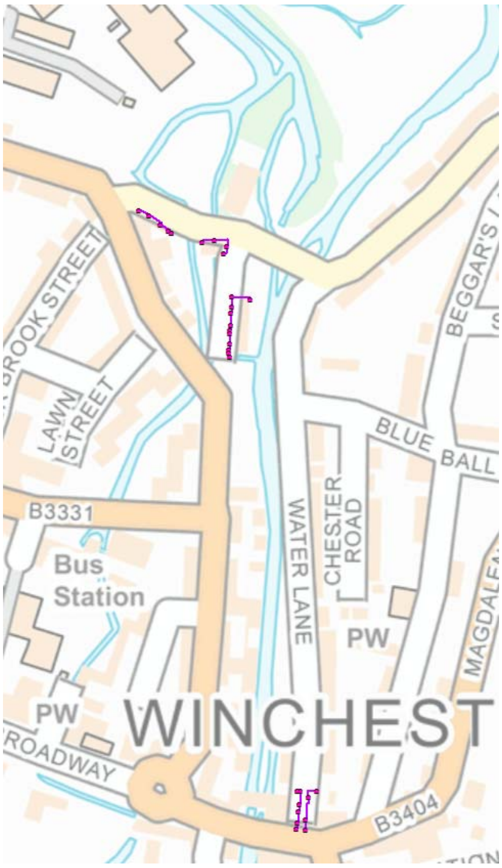

Figure 2: Building threshold levels from survey drawing 5S5A-Durngate, Winchester-Revision June 2017.

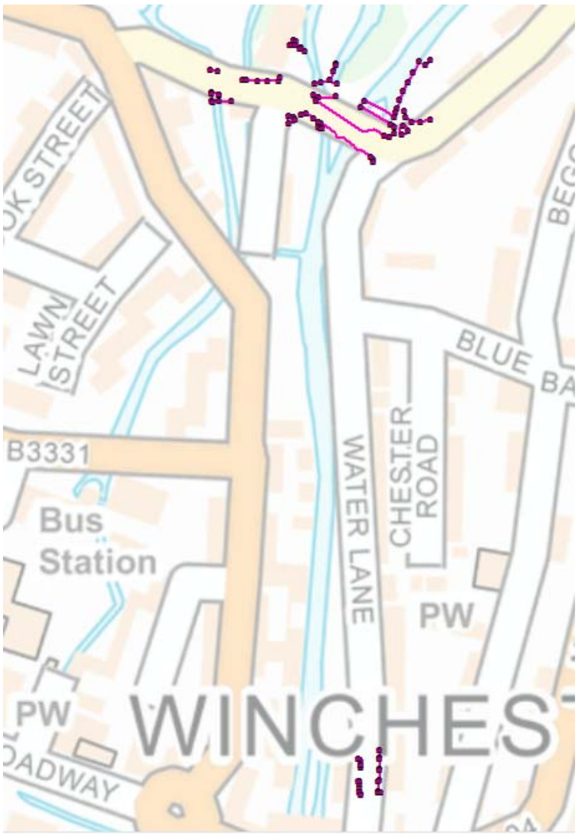

Figure 3: Updated wall levels from survey drawing 5S5A-Durngate, Winchester-Revision June 2017.

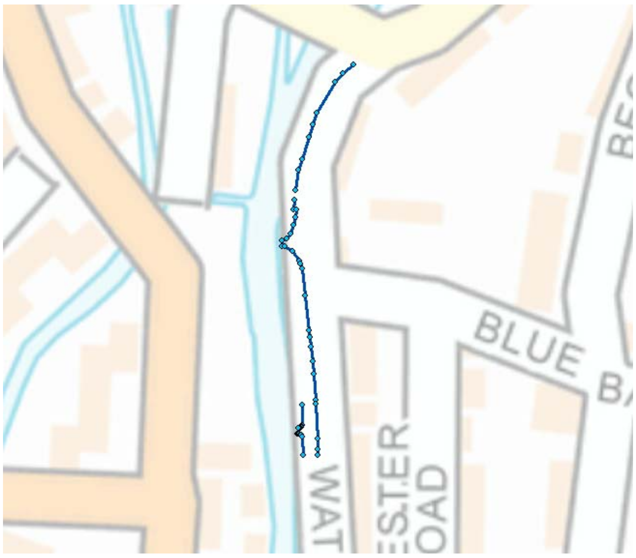

Figure 4: Water Lane bank levels from survey drawing 5S5A-Durngate, Winchester-Revision June 2017.

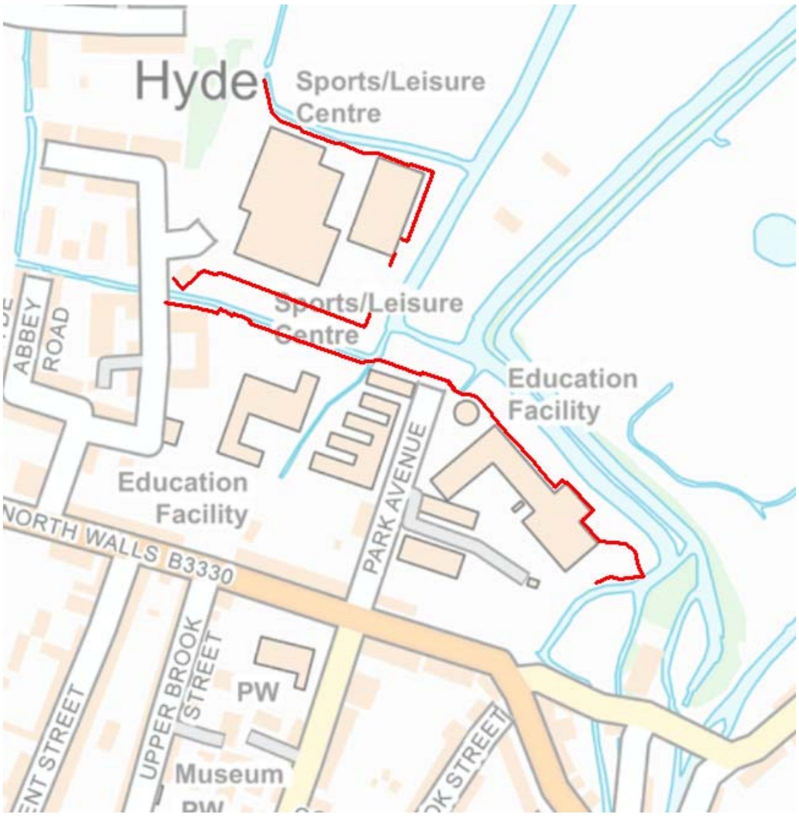

Figure 5: Newly / currently constructed flood defences upstream of Durngate Place from WINCHESTER FLOOD DEFENCE - SURVEY.DWG provided by HCC on 25/07/2017.

Figure 6: Updated ground and building threshold levels at River Park Leisure Centre and Skate Park from WINCHESTER FLOOD DEFENCE - SURVEY.DWG provided by HCC on 25/07/2017.

Figure 7: Water Lane flood defence wall and demountable flood gates from drawing RPF/160/001 Rev F Sept '14.

It was also confirmed by HCC that a sluice gate has recently been installed across the Upper Brook near Park Avenue to prevent flow down Upper Brook during flood conditions. The updated baseline model was therefore amended by removing the Upper Brook cross sections and downstream culvert (Figure 8).

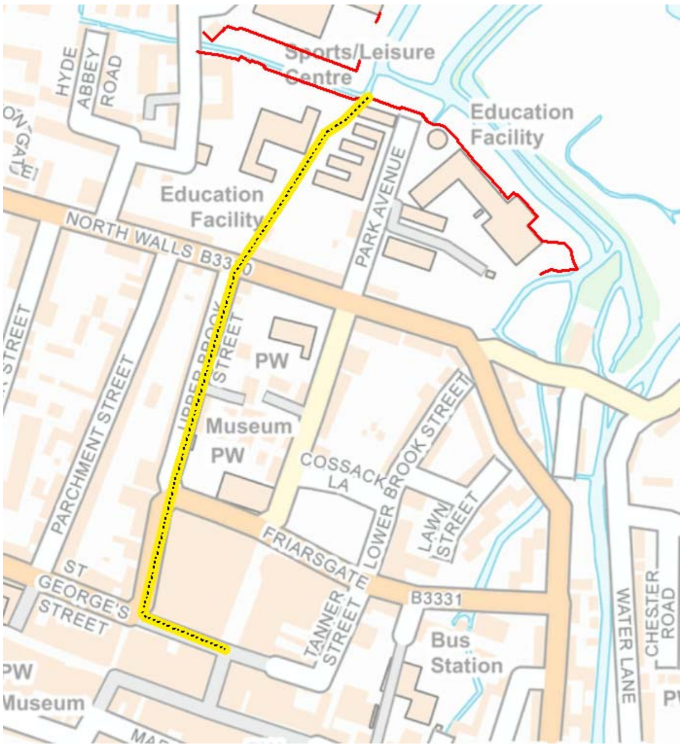

Figure 8: Location of Upper Brook model amendments (highlighted in yellow).

It is assumed that the sluice is lowered to prevent flows through the channel for the duration of a flood event and that the water levels in the River Itchen would need to exceed 37.5mAOD prior to any flooding occurring due to the river overtopping at this location.

2.2 Model stability enhancements

In testing the updated baseline model, oscillations in peak flow indicating instability were observed at several cross sections upstream of the Durngate area in the vicinity of Nun’s Walk. These oscillations occurred in the original baseline model. A form loss coefficient was specified in the 1d-2d link layer of the updated baseline model at this location (Figure 9) to reduce the oscillations; this had no significant impact on water levels in the study area.

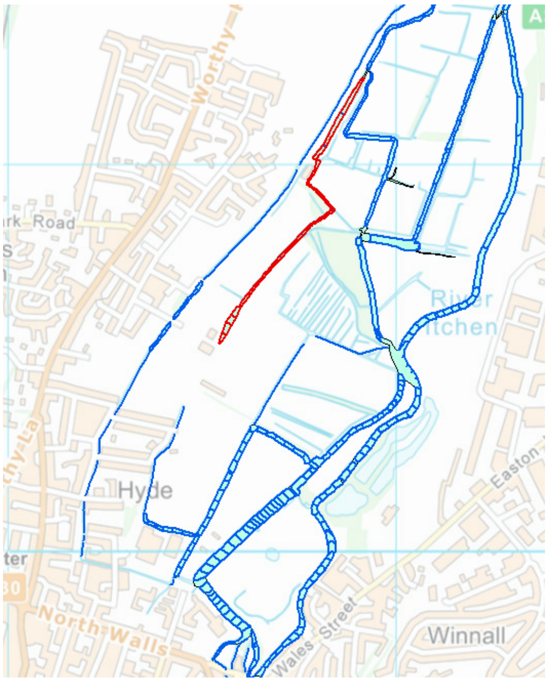

Figure 9: Location of upstream model amendments (red line indicates part of boundary condition model layer to which alterations were made).

Oscillations in water levels due to model instability were also observed along the open channels for a length of approximately 100m in the vicinity of the proposed sluice gates upstream of Durngate Place and adjacent to the Colledge. Instability occurred at this area in the previous version of the model. Incorporating the updated topographic survey data and the new flood defence wall initially resulted in greater oscillations along some of the channels here. Following a period of testing, the instability was eventually fully resolved by realignment of the 1d-2d connections in this area to reduce recirculation between 1d and 2d components of the model. The changes to the alignment are shown in Figure 11 and comprise:

- Most westerly channel: Moving of the 1d-2d connections further landward on both sides of the channel. The associated cross-sections in the 1d ISIS model were extended accordingly using the topographic survey data.

- Third channel from the west: Moving of the 1d-2d connection further landward on the right hand side (western side) of the channel.
- Small area between 3rd channel and 4th channel from the west: This small area was originally represented in the TUFLOW model and was connected to the adjacent reaches. There was significant recirculation between the 1d and 2d models here. To resolve this, this small area between the channels has been incorporated into the 1d ISIS model by extending the associated cross-sections using the topographic survey data.

Figure 10: Original (left) and updated (right) 1d-2d connections (red) showing area excluded from 2d TUFLOW model as modelled in 1d (hatched). Note all channels shown are modelled in 1d model.

2.3 Simulations

The updated baseline model was run for the 100yr return period plus 20% increase in flows to allow for climate change. Model results are discussed in Sections 4 and 5.

3 Proposed sluice gates

3.1 Introduction

HCC propose to construct sluice gates on three of the four channels where the River Itchen diverges upstream of Durngate Place to reduce the flood risk to the Durngate area of Winchester (Figure 11).

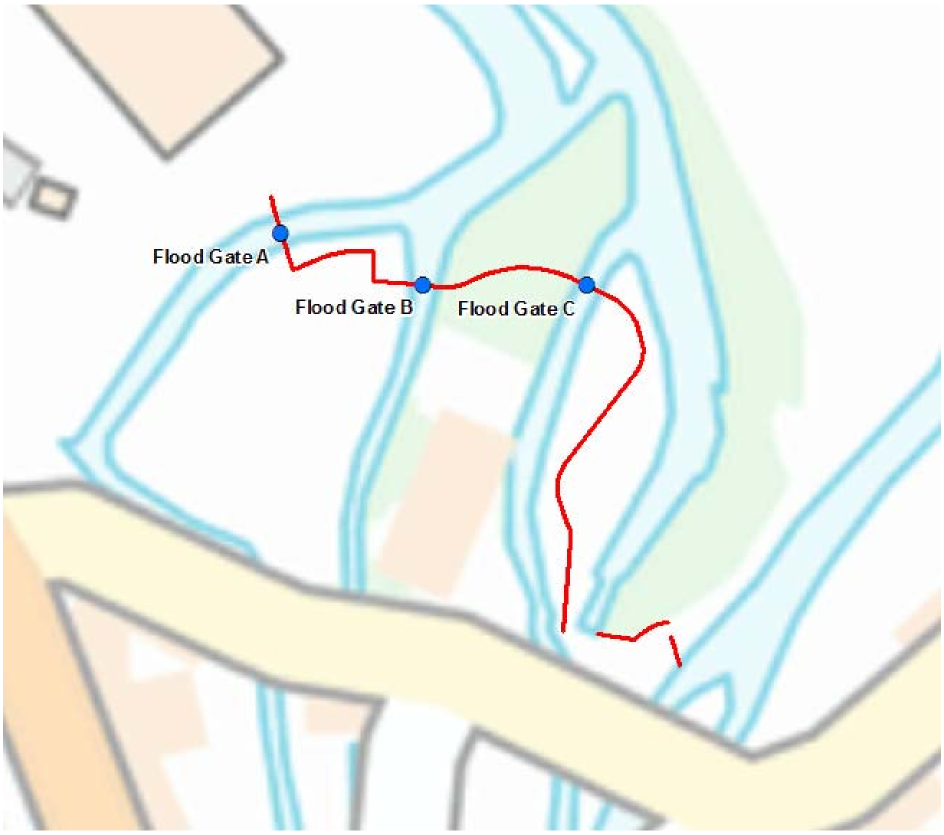

Figure 11: Location of Sluice gates upstream of Durngate Place as referenced in EC-RJXXXXXX-1400 PROPOSED FLOOD DEFENCE-1401 REV P1 03/02/2017 and EC-RJXXXXXX-1400 PROPOSED FLOOD DEFENCE-1402 REV P1 03/02/2017 (red line highlights location of proposed new defence bunds / walls).

The updated baseline model, as discussed in Section 2, was used as a basis to create a 'Sluices' model. This was modelled for a 'sluices 50% open' scenario; this partially closed state being considered *representative* of the approximate gate opening *that might be appropriate* during flood events. Note that the scope of the modelling work described herein does not extend to recommending exact sluice gate openings or control philosophy for flood flow conditions.

The sluice model was run for the 100yr return period plus 20% increase in flows to allow for climate change.

3.2 Sluice gate dimensions

The sluice gate geometry, including culvert and penstock dimensions, was obtained from the following drawings:

- EC-RJXXXXXX-1400 PROPOSED FLOOD DEFENCE-1401 REV P1 03/02/2017
- EC-RJXXXXXX-1400 PROPOSED FLOOD DEFENCE-1402 REV P1 03/02/2017
- EC-RJXXXXXX-1450 PROPOSED FLOOD DEFENCE DETAILS-1452 REV P2 27/01/2017

Table 1 details the dimensions incorporated into the sluice model. Each sluice gate has three penstocks. Dimensions in Table 1 are 'per opening' and were assumed to be identical for each penstock per gate. River bed levels were derived from the topographic survey drawing[4] at the point the line of proposed new defence crosses each watercourse. The gate height (required model parameter) was derived from the invert level of each opening, not including silt, and the top level of the penstocks when closed which was agreed by HCC to be the level of the proposed new flood defence bunds between each gate (37.60mAOD). Therefore, when the penstock gates are closed, the watercourses will effectively be blocked off with no overtopping until the water level exceeds 37.6m AOD.

Dimension / Level	**Flood Gate A** 3 penstocks and 1500mm diameter pipes	**Flood Gate B** 3 penstocks and 1500mm diameter pipes	**Flood Gate C** 3 penstocks and sheet piled supporting walls
Culvert height (m)	1.5	1.5	0.9
Culvert width (m)	1.5	1.5	1.5
Culvert allowed to silt up to depth (m)	0.25	0.25	0.25
Culvert invert level notes	200mm below lowest point of existing watercourse	200mm below lowest point of existing watercourse	35.33m AOD (bed level)
Lowest bed level of existing watercourse (mAOD)	35.02	35.55	35.33
Invert level of opening (not including silt) (mAOD)	34.82	35.35	35.33
Invert level of opening including silt (mAOD)	35.07	35.6	35.58
Soffit level of opening (mAOD)	36.32	36.85	36.23
Culvert length (m)	2	3	N/A (Sluice only)
Gate height (m)	2.78	2.25	2.27

Table 1: Durngate Sluice Dimensions for Model Input

[4] 5S5A-Durngate, Winchester-Revision June 2017

3.3 Model representation of sluice gates

A ‘Sluices’ model was created based on the updated baseline model and the information provided in the drawings as discussed in Section 3.2. The proposed sluice gates were represented in the 1d ISIS component of the model using three sluice units at each of the three locations shown in Figure 11. For flood gates A and B, culvert units and associated culvert inlet and outlet units were also added to represent the culverts under the penstocks as shown in the design drawing (see example below). Dimensions input to the model are as described in Section 3.2.

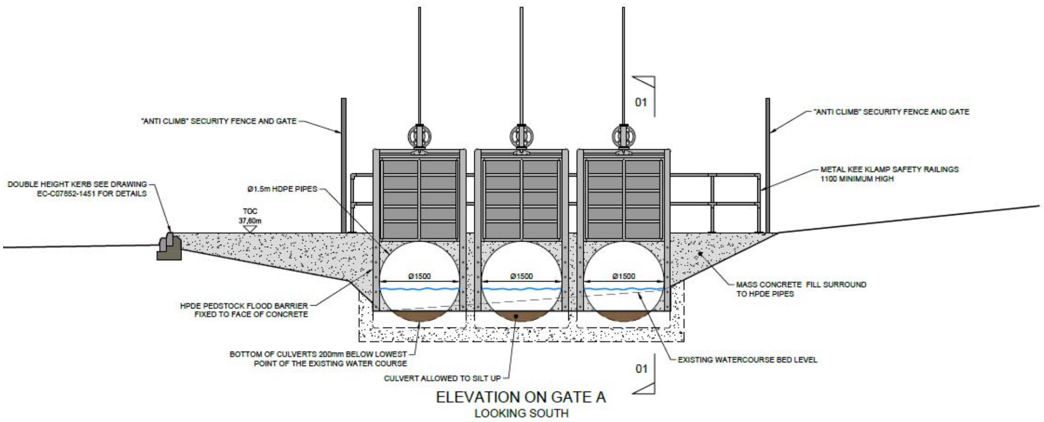

Figure 12: Example of Flood Gate schematic extracted from drawing EC-RJXXXXXX-1450 PROPOSED FLOOD DEFENCE DETAILS-1452 REV P2 03/02/2017.

The sluice model was then set up and run with each of the above sluice gates set to 50% open; this partially closed state being considered *representative* of the approximate gate opening *that might be appropriate* during flood events. Instability around flood gate B required that two of the three penstocks at that gate were set to be initially closed, opening to 50% over the first hour of the simulation. This is well before the flood peak and will not affect maximum water level results. The sluice model was run for the 100yr return period plus 20% increase in flows to allow for climate change. Model results are discussed in Sections 4 and 5.

A superseded iteration of the modelling included the testing of a ‘sluices 0% open’ scenario. The 0% open model was found to be too unstable to complete, therefore a further model was created in which the portion of the channel downstream of the sluices and the Brook Street and Union Street culverts beyond were removed in order to represent the effects of the sluices being fully closed.

4 Flood mapping deliverables

The flood mapping deliverables produced from the model results are listed below. A summary of the model results, with reference to the flood mapping deliverables, is given in Section 5.

4.1 Flood depths

Maximum flood depths were extracted from the model results and are presented as flood depth plans in Appendix A:

- A01 Updated Baseline Model for a 100yr Return Period + CC based on 20% increase in flows.
- A02 Proposed Durngate Sluices set to 50% open for a 100yr Return Period + CC based on 20% increase in flows.

4.2 Impact on flood depths upstream of Durngate

The increase in maximum flood depths due to the sluices scenario for the floodplain area between Durngate Place and the A34 is presented in drawings A03a (the south part) and A03b (the north part) in Appendix A.

4.3 Animations

Animations showing the flood progression during the modelled flood event were produced from the raw model results. These show flood depths and flow directions allowing flooding mechanisms to be observed. Animations are provided for:

- Updated Baseline Model for a 100yr Return Period + CC based on 20% increase in flows.
- Proposed Durngate Sluices set to 50% open for a 100yr Return Period + CC based on 20% increase in flows.

5 Review of results

5.1 Updated baseline model

As discussed in Section 2, the model from the 2015 HCC North Walls Flood Defence study was updated to include new topographic survey and levels of flood defences newly built or currently under construction. The updated baseline and previous model results are compared in Section 5.1.1 while the flooding mechanism at Water Lane is assessed in Section 5.1.2.

5.1.1 Previous vs updated model

Figure 13 compares flood extents from the previous and updated baseline model for the 100yr Return Period event + CC (20% increase in flows).

It can be observed from Figure 13 that the baseline model updates, which include amendments to the flood defences upstream of Durngate Place, has decreased the flood extent at:

- The River Park Leisure Centre
- Park Avenue and the adjacent University Campus, Winchester Gallery and St Bede Primary School.
- Upper Brook Street and Middle Brook Street
- Part of the shopping precinct between Friarsgate and Silver Hill
- The vicinity of the southern end of Colebrook Street.

However, flood extents have increased in some areas, most notably:

- Adjacent to College Street and College Walk.
- Adjacent to Kingsgate Road downstream of College Walk.

A primary flooding mechanism to the city centre in both the previous and updated baseline models is from overland flow southwards down Lower Brook Street that originates from overtopping of the channels immediately upstream and downstream of Durngate Place.

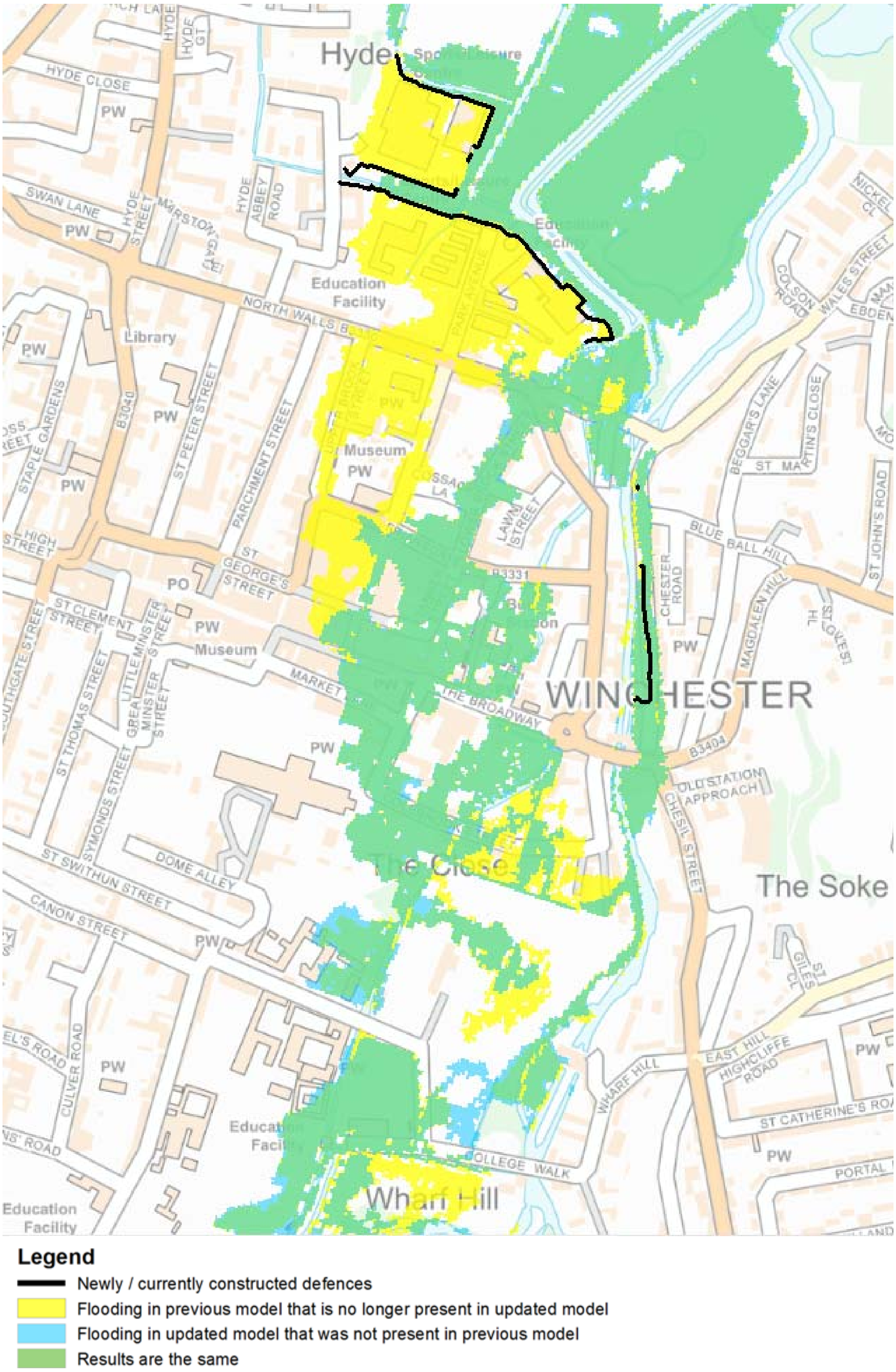

Figure 13: Previous vs. updated baseline 100yr Return Period + CC flood extents.

5.1.2 Water Lane flood mechanisms

The baseline model for Durngate has been updated in the vicinity of the southern end of Water Lane with ground levels from the June 2017 survey drawing[2] (Figure 3). Levels for the newly constructed Water Lane dwarf flood defence wall and demountable flood gates were extracted from drawing RPF_160_001 Rev F Sept '14 (Figure 14).

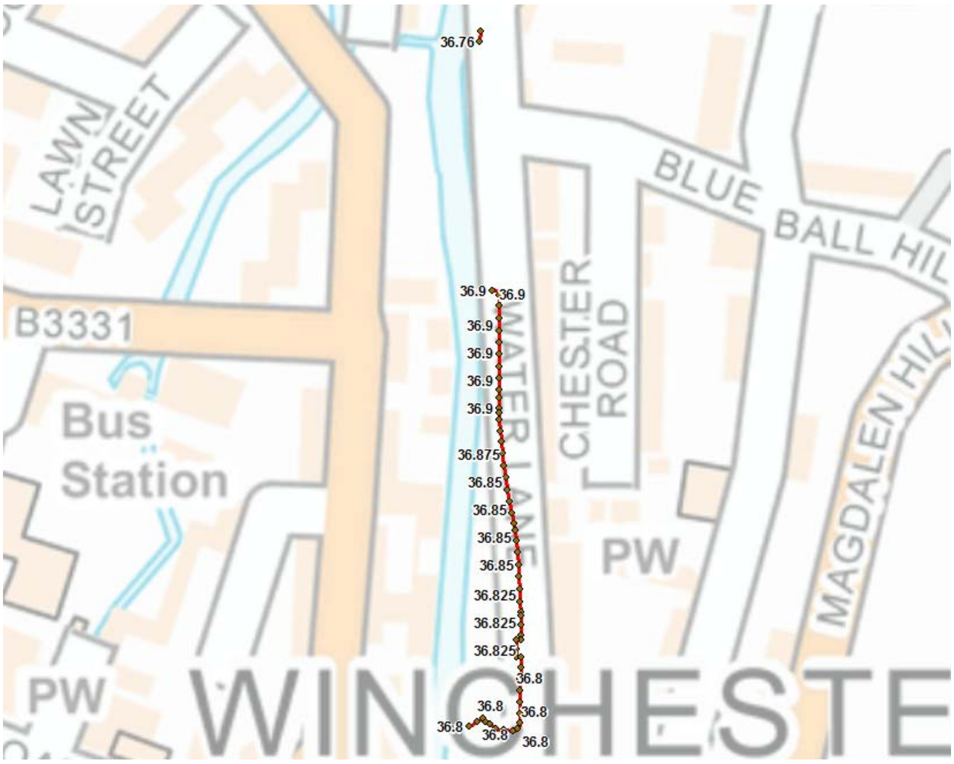

Figure 14: Water Lane Flood Defences levels from drawing RPF_160_001 Rev F Sept '14.

Along the northern end of Water Lane, the highest bank levels between the river bank and the lane were extracted from the survey drawing[3] and added to the model using Zlines (Figure 15).

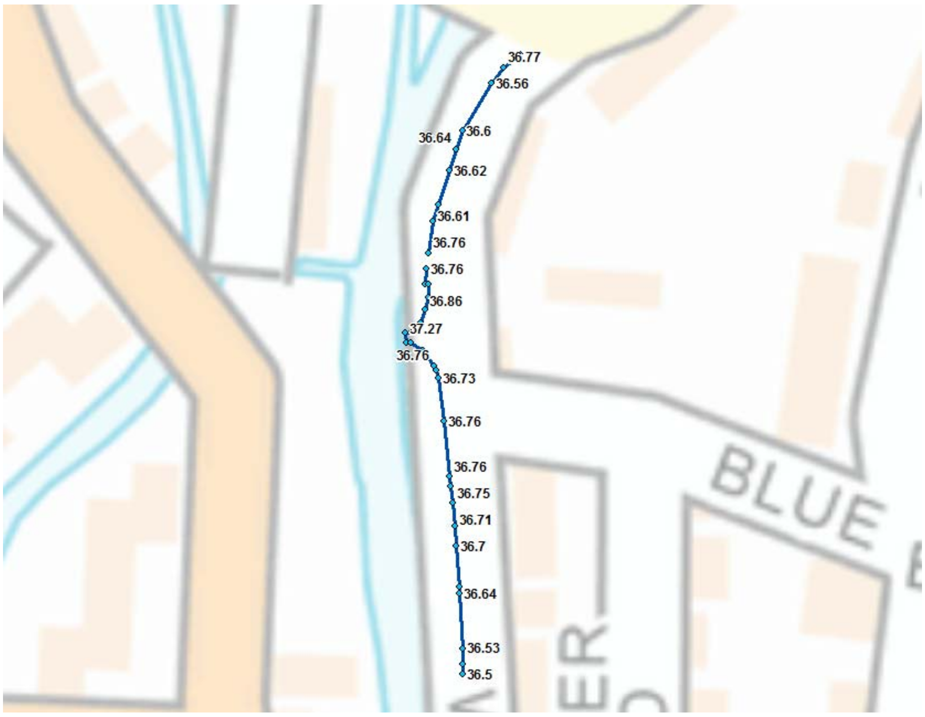

Figure 15: Bank top levels along Water Lane north of the new flood defence wall from drawing WINCHESTER FLOOD DEFENCE - SURVEY.DWG provided by HCC on 25/07/2017.

The bank levels and wall levels in the model have been compared against the maximum water levels in the adjacent channel to determine where overtopping occurs. Maximum water levels for the channel are presented in Table 2 for the 1d model node points shown in green in Figure 16. Plot Output lines have been digitised in the model to enable overtopping flows to be extracted; these are labelled as WaterLn[X] in Figure 16.

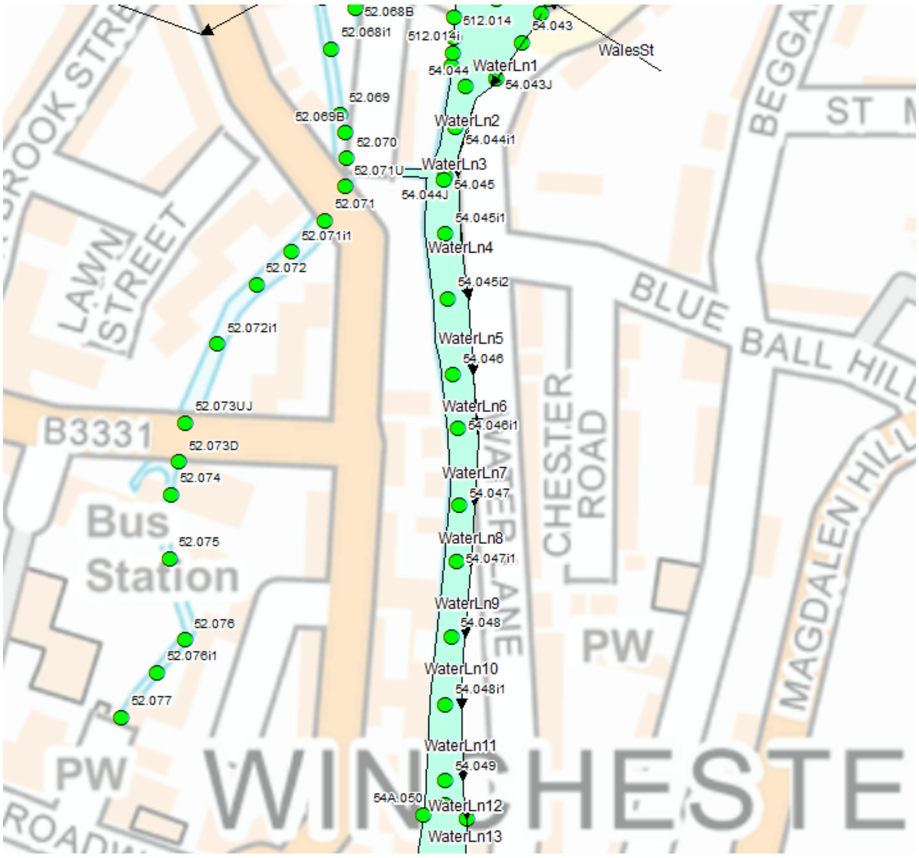

Figure 16: Location of 1d ISIS model nodes and PO lines along Water Lane.

During the updated baseline 1 in 100yr + CC event, overtopping occurs along Water Lane immediately downstream of the junction of Water Lane and Durngate Bridge, upstream of the newly constructed flood defence wall (Figure 17). This commences 4.75hrs from the start of the modelled flood event. The maximum water level at the nearest 1d model node that occurs during the flood event is 37.001m AOD.

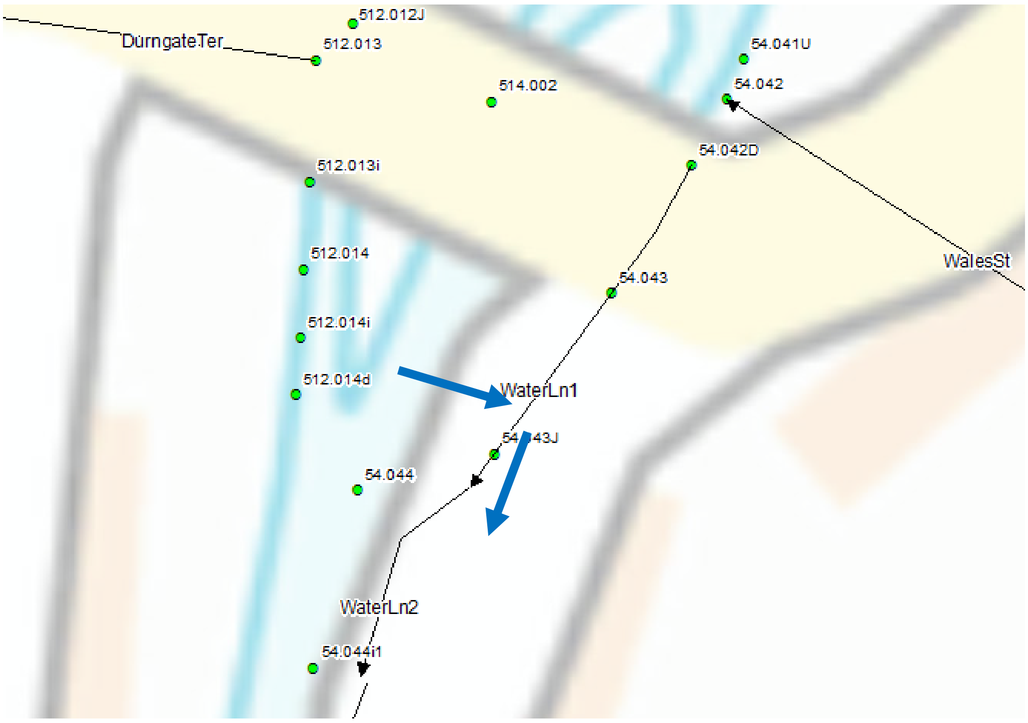

Figure 17: Location of initial overtoping (indicated by blue arrows) along Water Lane north of flood defence wall.

Overtopping also occurs to the south of the Water Lane flood defence wall at 4.5hrs (Figure 18) and in the area between the flood wall and the River Itchen at 4.0hrs from the start of the modelled flood event. The wall does not overtop during the 100yr Return Period + CC (20% increase in flows) event.

Maximum water levels and flows in the channel adjacent to Water Lane are shown in Table 2.

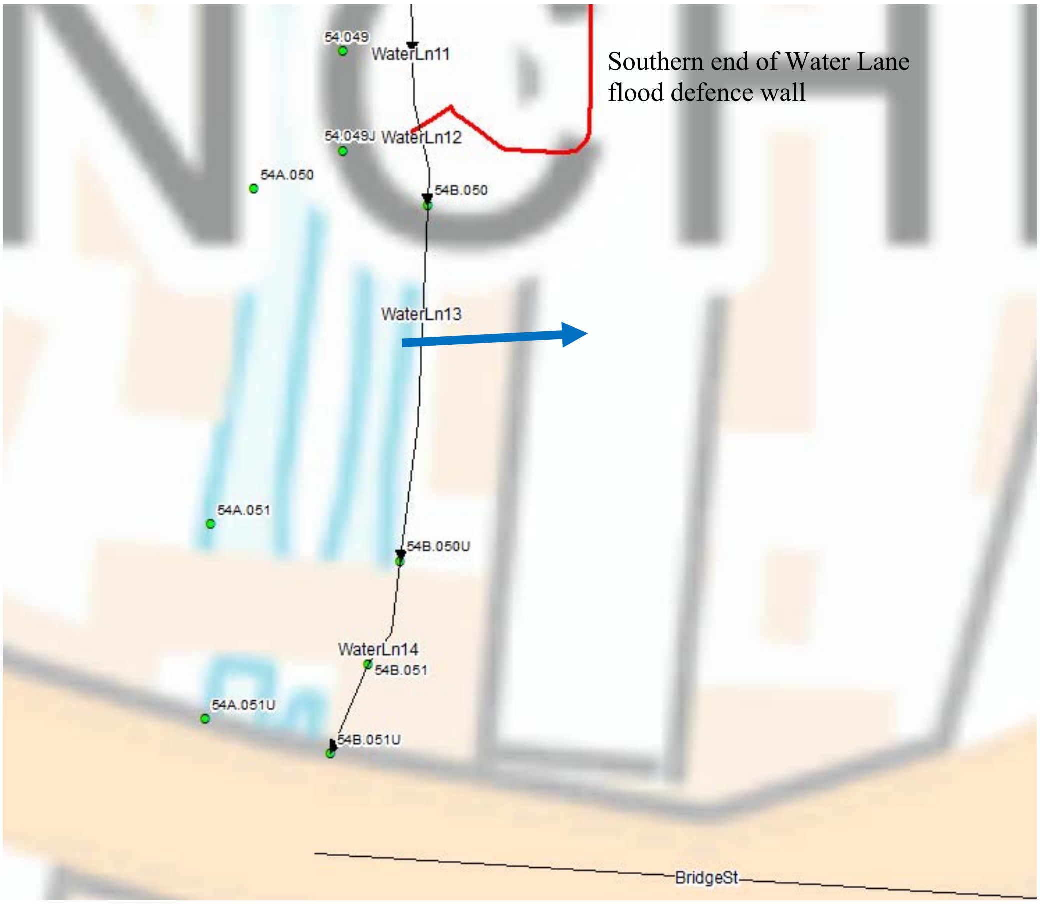

Figure 18: Location of initial overtopping (indicated by blue arrow) south of the Water Lane flood defence wall.

Table 2: Maximum water levels and flows in channel adjacent to Water Lane for 100yr + CC event.

PO Line label	1d ISIS node	Max flow in channel (m^3/s)	Max overtopping flow (m^3/s)	Max water level in channel (m)	Time of max water level (hr)
WaterLn1	54.043J	4.54	1.6273	37.001	14.955
WaterLn7	54.046i1	14.407	0.6639	36.891	15.019
WaterLn8	54.047	14.105	0.3789	36.868	14.789
WaterLn9	54.047i1	14.055	0.7651	36.853	14.959
WaterLn10	54.048	13.455	0.8775	36.847	15.057
WaterLn11	54.048i1	13.167	0.4099	36.835	15.015
WaterLn12	54.049	13.869	0.0000	36.811	14.788
WaterLn13	54.049J	14.421	1.1402	36.793	14.969
WaterLn14	54A.051[1] 54B.050U[2]	10.469 4.398	 0.0000	36.773 36.841	14.954 15.056

Notes: 1) 54A.051 is on western channel and 2) is on eastern channel.

5.2 Sluice model results

As discussed in Section 3.3, a 'Sluices' model was created to represent the proposal to install sets of three penstocks on three of the four channels of the River Itchen upstream of Durngate Place. This was run with the sluice gates set to 50% open.

The following sections summarise the effect on flood risk due to the sluice gates for the 100yr return period plus 20% increase in flows to allow for climate change. The flood depth plans enable a comparison of baseline with sluice option.

5.2.1 Impact of sluices 50% open

The model results show that the proposed sluices in the half open (50%) scenario would result in:

- Reduction in flood extent and flood depths downstream of the sluices compared to the baseline model. Note overtopping still occurs at Durngate resulting in flows down Lower Brook Street but the flood flows and volumes here are reduced compared to the baseline.
- Increases in water level in the river and floodplain upstream of Durngate at Winnall Moor of up to approximately 0.06m compared to the baseline. This increase in water level is due to the sluices acting as a restriction to flows, which increases upstream flood storage. The increase in water level reduces in an upstream direction and at the A34 main road there is zero increase in water level (see drawings A03a and A03b in Appendix A).

The increase in peak upstream flood volume has been assessed using the maximum flood depth results from the 2d component of the model representing the floodplain. Results are presented in Table 3 for each area shown in Figure 19. The total increase in peak floodplain volume upstream of Durngate is approximately 14,000m^3.

Table 3: Peak flood volume on floodplain between Durngate Place the A34 for the 100yr+20% event.

	Peak Volume (m^3) *		
Area	**Baseline**	**Sluices 50% open**	**Increase in peak volume (m^3)**
A	11,765	12,291	526
B	89,395	94,575	5,181
C	47,016	48,803	1,787
D	49,006	51,416	2,410
E	31,425	34,813	3,387
F	5,558	6,588	1,030
TOTAL	**234,164**	**248,486**	**14,321**

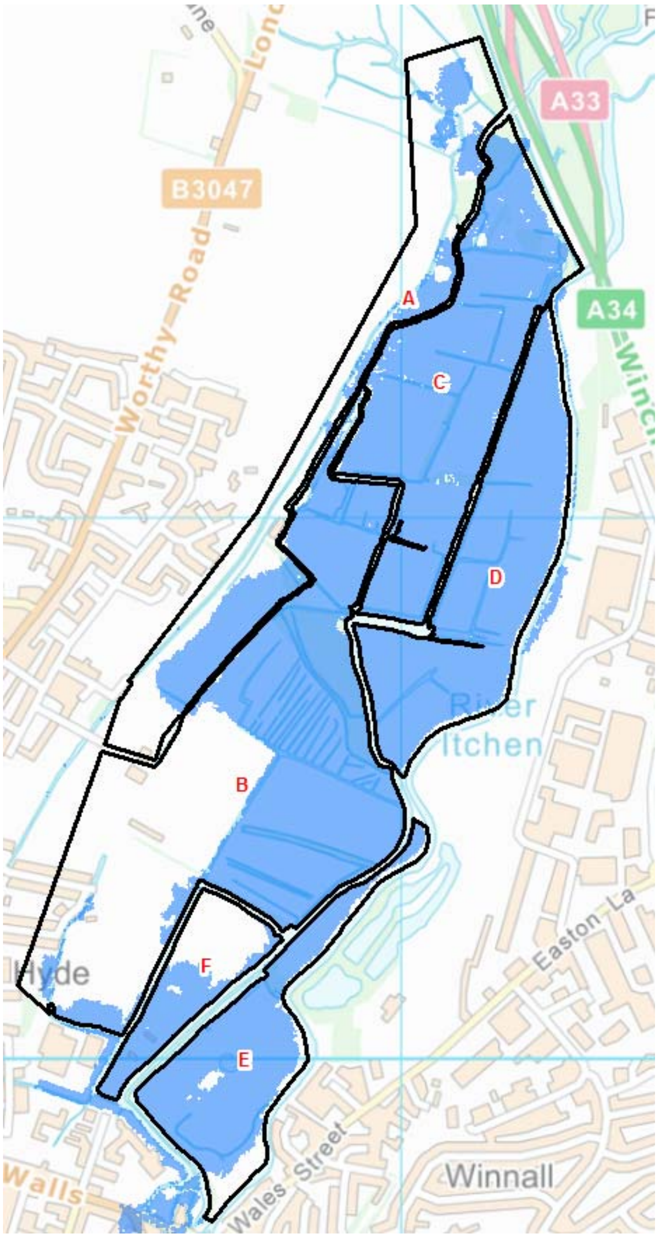

Figure 19: Floodplain areas assessed for increase in peak flood volume.

5.2.2 Impact of sluices 0% open

A superseded iteration of the modelling included the testing of a ‘sluices 0% open’ scenario. Results from this test are shown in Figure 20. The model results show that the proposed sluices in the fully closed (0% open) scenario would result in:

- Increase in upstream water level in the river of approximately 0.28m adjacent to the Leisure Centre. This significant increase in upstream water level is caused by the increased restriction on pass-forward imposed flows by the sluices.
- The increase in upstream water level results in overtopping of the newly constructed flood defences causing significant flooding at the Leisure Centre and to the south of the newly constructed flood defence wall. Flood

extents and flood depths are significantly greater than for the baseline model.

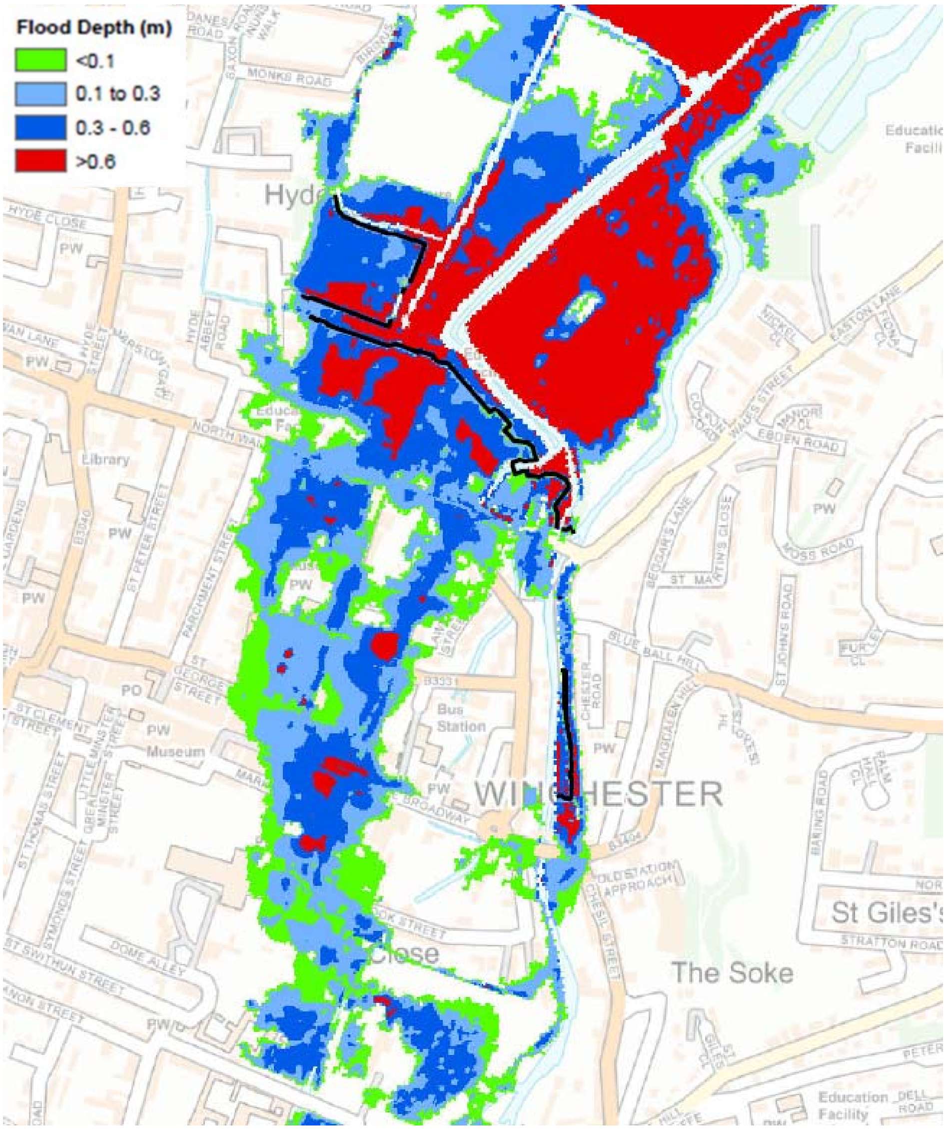

Figure 20: Flood depth results for Sluices 0% open scenario.

6 Conclusions and recommendations

Hydraulic modelling has been undertaken to assess the flood risk and potential flood mitigation associated with the proposed Durngate Flood Defence Scheme in Winchester. This work has involved updated the baseline model, developing a new 'sluice' model and assessing the impact of the sluices for pre-defined sluice gate openings, these being 50% open and 0% open (fully closed). The scope of the modelling work described herein does not extend to recommending exact sluice gate openings or control philosophy for flood flow conditions. The models have been run for the 100yr return period plus 20% increase in flows to allow for climate change.

The baseline hydraulic model from the previous study was updated to incorporate the newly / currently constructed flood defences upstream of North Walls and adjacent to Water Lane and the topographic survey around Durngate collected in June 2017. The results from the updated baseline model show that the newly / currently constructed walls would be effective at preventing overtopping for the 100yr plus climate change event tested based on the provided defence levels. The results show there would still be overland flow originating from overtopping of the channels immediately upstream of Durngate Place. The model results also show overtopping would occur upstream and downstream of the new flood wall on Water Lane.

The model results have identified that the proposed sluices and associated bund could reduce flood risk downstream if operated appropriately, though there remains an overland flow path south along Lower Brook Street. The results show that fully closing the sluices would cause overtopping of the newly / currently constructed flood defences upstream, which would result in significant flooding. The results suggest a careful balance would need to be struck between reducing pass-forward flows and preventing the upstream defences from overtopping.

Results suggest a primary flooding mechanism is from overland flow southwards down Lower Brook Street that originates from overtopping of the channels around Durngate Place. It may be possible to prevent this flooding mechanism with a flood defence wall along a short stretch of Durngate Place here.

It is recommended that:

1. The outflanking of the new Water Lane defence is considered and addressed.
2. Should the sluice option be taken further, it is recommended that further modelling is undertaken to determine appropriate sluice gate openings or control philosophy for flood conditions. This should consider a range of different sluice gate openings and/or control rules and could also consider whether the existing sluice structures at Durngate can be used to alleviate downstream flood risk. Trigger levels for the operation of the sluices could also be derived using modelling.
3. Should the sluice option be taken further, consideration should be given to the inclusion of a flow control structure, such as a sluice gate, on the 4th

channel from the west on the upstream side of Durngate Place. This channel does not currently have a flow control structure and the impact of sluice gates on other channels may cause the flows in this channel and associated flood risk to increase. A flow control structure here could help balance flows across all the channels at Durngate to maximise and optimise the control of pass forward flows.

4. The flooding mechanism southwards down Lower Brook Street is considered and addressed, e.g. through a new flood defence wall along Durngate Place.

5. Improved conveyance through Winchester is considered for reducing flood risk in Winchester. This should also include consideration of impacts on downstream flood risk of conveyance works.

6. Any new flood defence designs should be incorporated where appropriate into the hydraulic model.

7. Any new designs should consider the current climate change guidance and should incorporate a freeboard to account for uncertainty in the modelling and in physical processes.

8. The proposed sluices should be considered in the wider context of flood risk management in Winchester including the impact on the surface water drainage system due to river locking of outfalls.

Appendix A

Flood depth plans