Figure 7 3: Modelled water levels at the confluence between Bulling Dike and Dearne

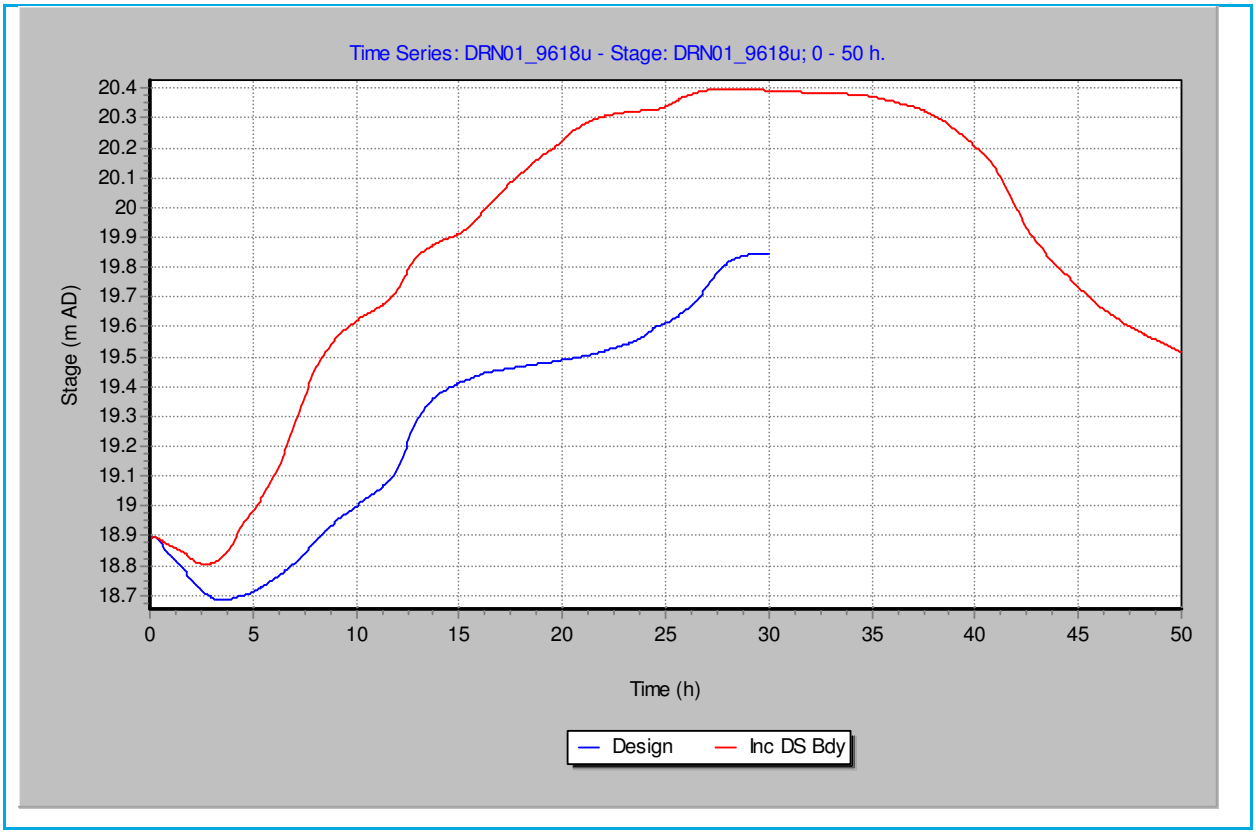
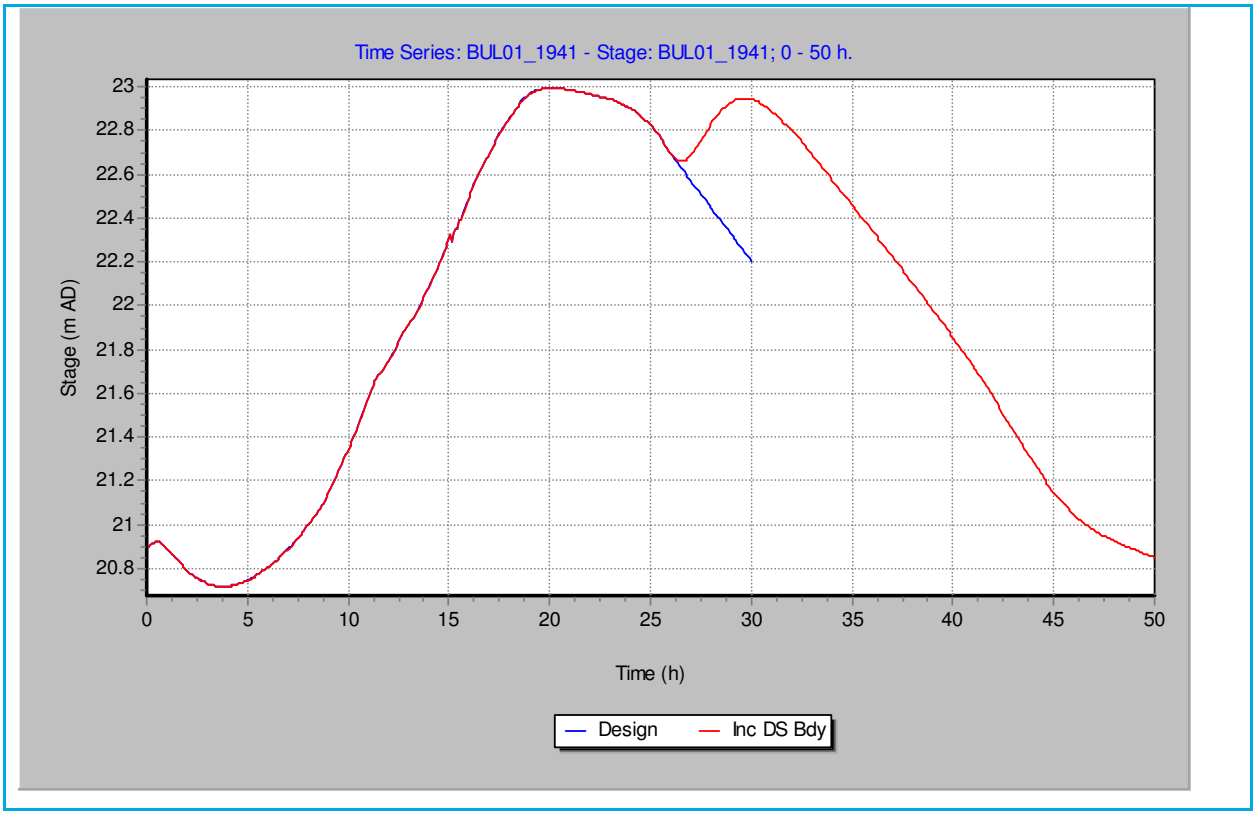
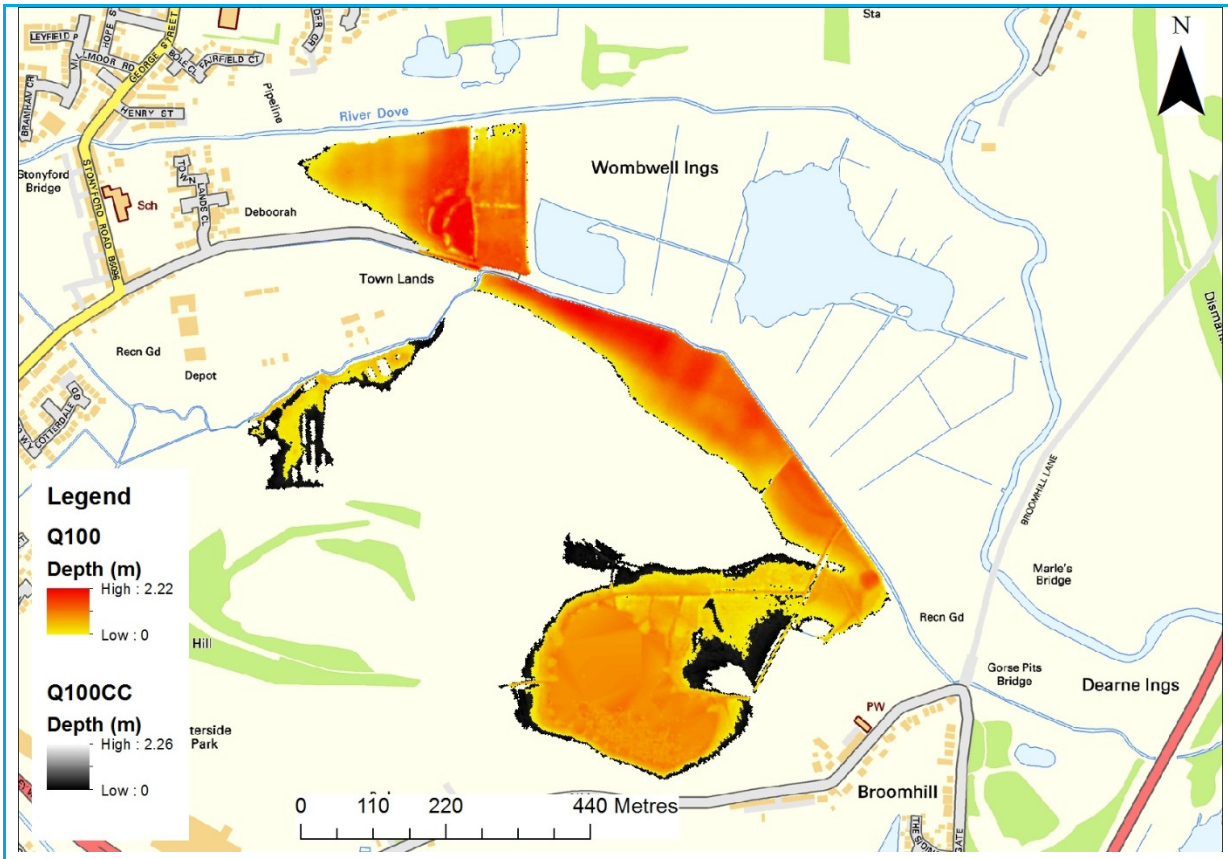


Figure 7 4: Modelled water levels at the confluence between Bulling Dike and Dearne



The outlines from the 100-year design event and the 100-year event with an allowance for climate change can be compared to gain an understanding of the sensitivity of the model to changes in discharge. **Error! Reference source not found.** shows that when the inflows to the model are increased to include an allowance for climate change, an increase in flood extent is observed over the entire study area. No further property was inundated, however the flood extents on the right hand floodplain opposite the sewage works and the area around Broomhill Flash did change.

Figure 7 5: Sensitivity to flow.

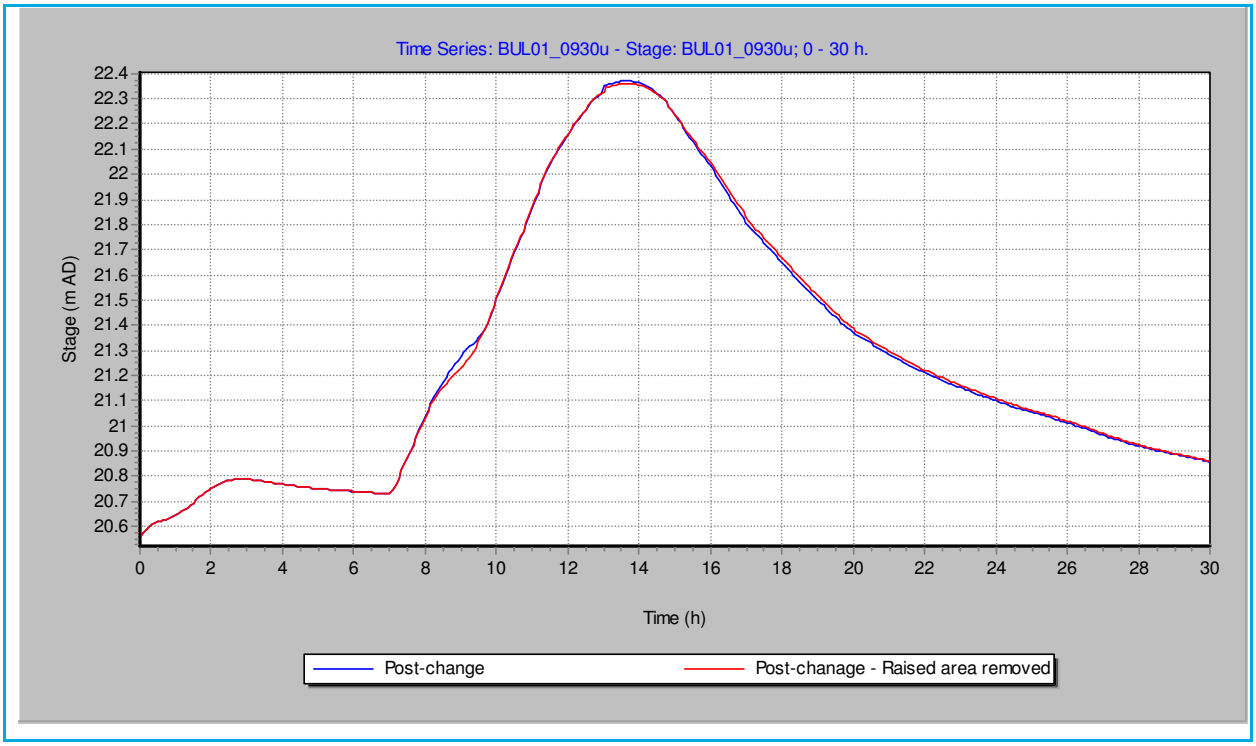


7.1 Further model testing

Following initial model review, a number of further tests were undertaken. It should be noted that these were undertaken using the inflows derived from the statistical FEH method rather than the Urban ReFH method, however the findings are unlikely to change.

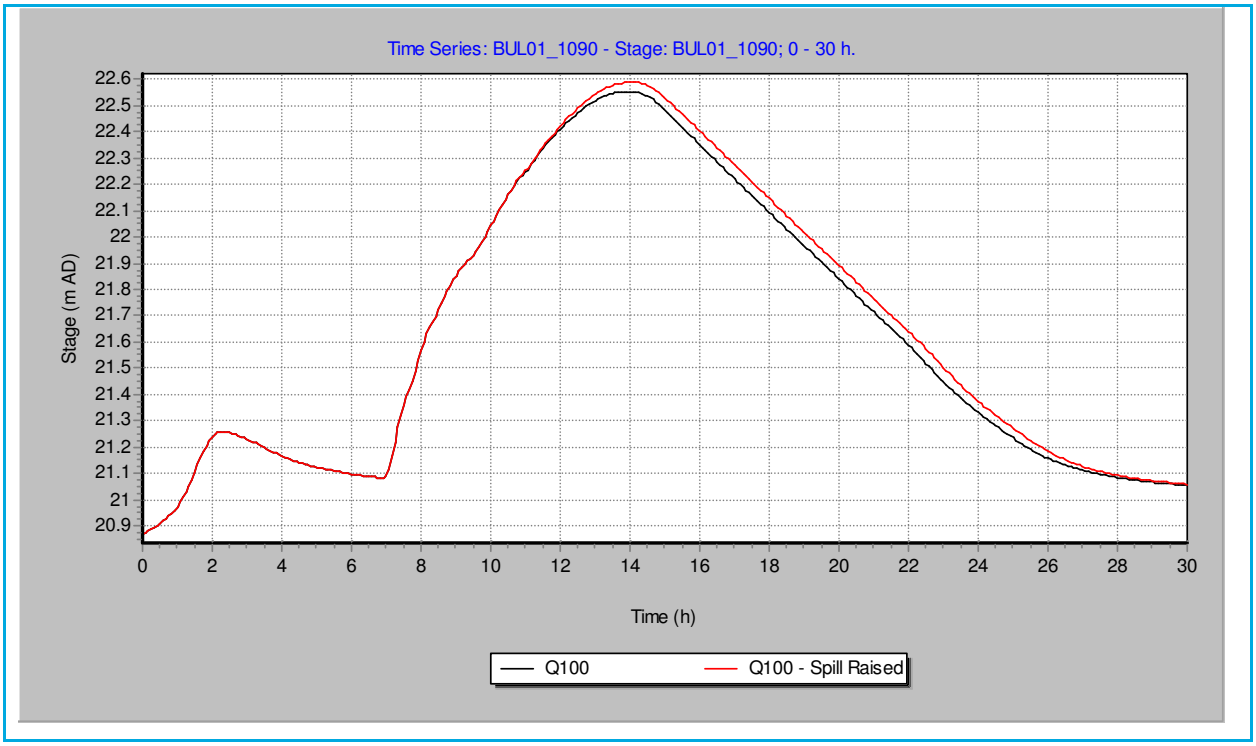
The sensitivity of modelled water levels to floodplain modifications was also assessed by removing the raised ground element (which separates the reed bed from the shallow wet grassland) from the model. Figure 7.6 shows that removing the raised ground made very little difference to modelled water levels downstream of the study site, indicating that the model is relatively insensitive to changes to the topography of the floodplain.

Figure 7 6: Sensitivity to floodplain modifications



The bridge at BUL_010930 was previously modelled with a notch in the spill to represent the additional culverts above the main barrel. As a sensitivity test, the notch was removed and the height of the spill raised. Immediately upstream of the bridge, the water levels increase by around 0.03m compared to the baseline 100-year return period run (Figure 7-7). The difference decreases upstream of the bridge, with a negligible difference observed in the vicinity of where the proposed flood bund will be located.

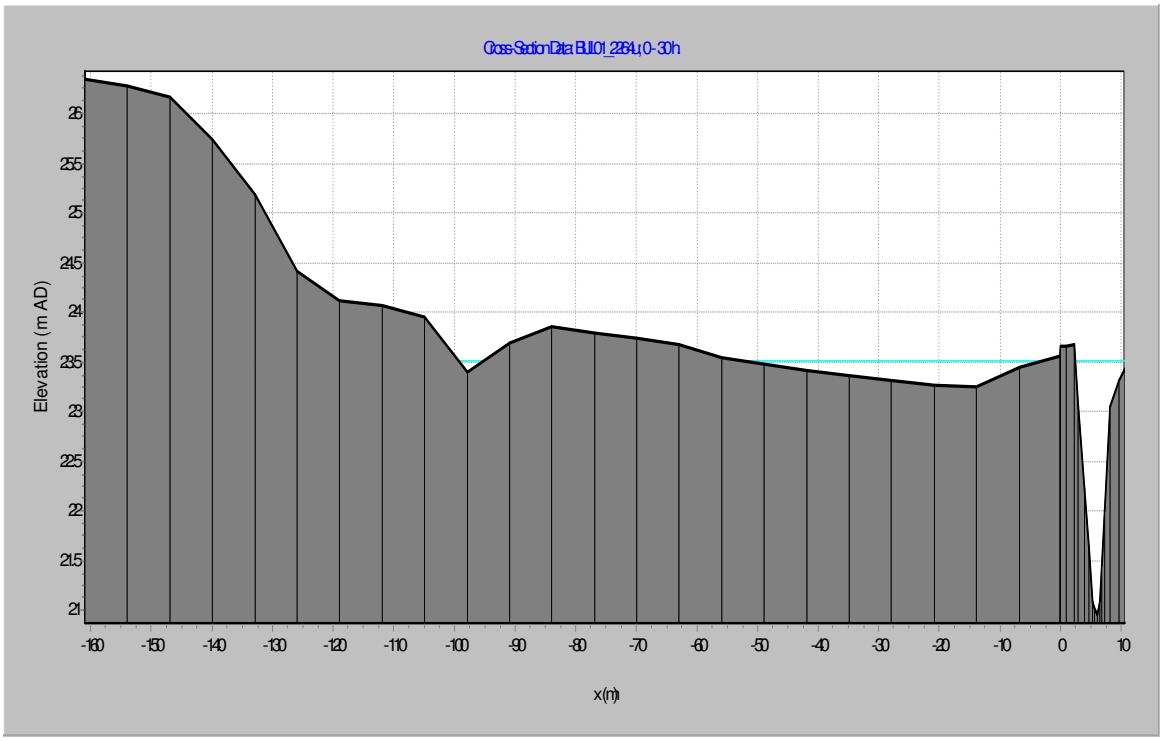
igure 7 7: Sensitivity to bridge modifications



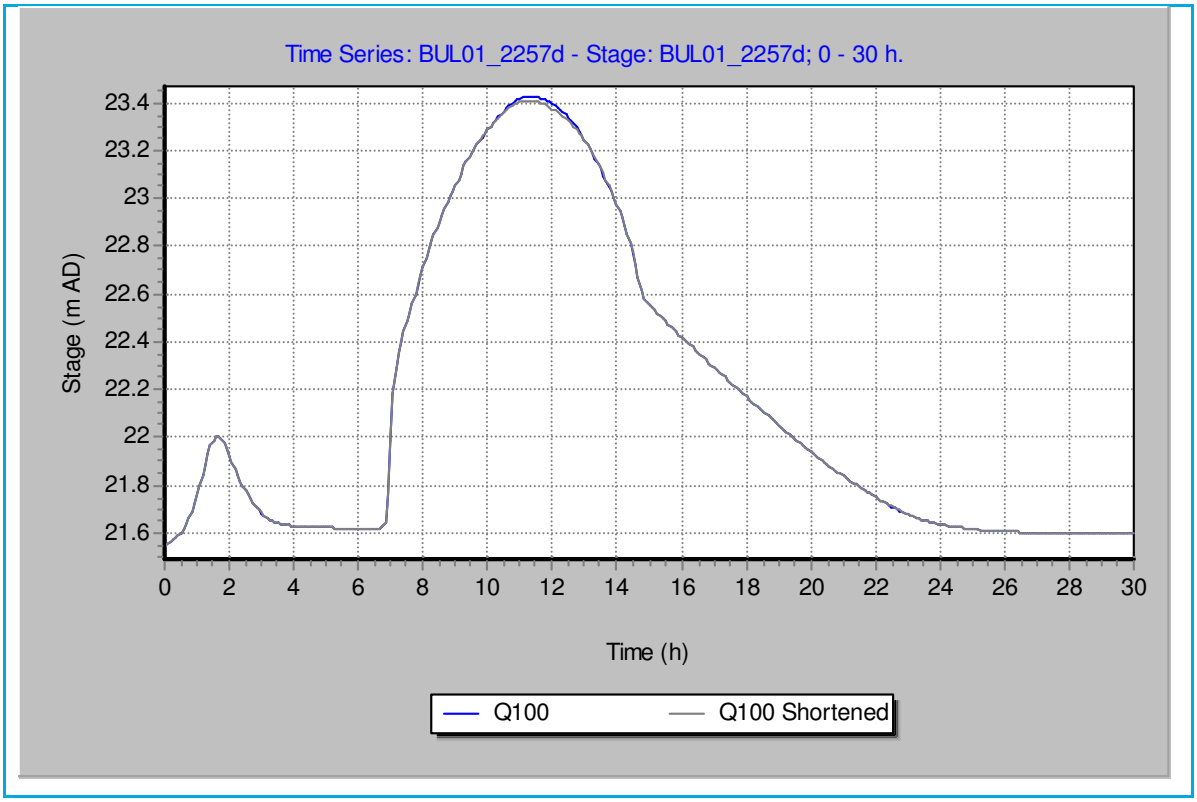
It was identified that the representation of the floodplain at BUL01_2264, could lead to overestimation of the floodplain storage because the left hand floodplain was slightly lower than the bank top level, and in the current configuration of the model, the floodplain will fill up from the bottom below bank top. The floodplain has this profile for only a short distance and schematising the floodplain differently for this small area is seen as an overcomplicating given this section of the model is not in the immediate area of interest. Therefore as a conservative sensitivity test the left and floodplain of BUL01_2264, BUL01_2257 and the spill between the two sections were truncated at the left hand bank, thus removing the floodplain from the model. Figure 7-8 shows that immediately downstream of the truncated sections the peak modelled water level is 0.01m higher when the sections are truncated. No change in water levels is observed on the study site. This shows that the current schematisation of the model is reasonable.

Figure 7 8: Sensitivity to bridge modifications

Floodplain section



Sensitivity test results


Time Series: BUL01_2257d - Stage: BUL01_2257d; 0 - 30 h.
Stage (m AD)
23.4
23.2
23
22.8
22.6
22.4
22.2
22
21.8
21.6
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Time (h)
Q100
Q100 Shortened

8. Model performance

This chapter gives an overview of model performance in terms of:

- Simulation run time
- Known start up checks and warnings
- Known negative depths and their significance/cause
- Illustration of mass balance and change in volume through the model run.

8.1 Run times

On a 64-bit 12 processor 3.2ghz, 32GB RAM computer, it takes around 2.5 hours to run the full 30 hour simulation.

Times for computers of different specifications will vary.

8.2 Known start-up checks and warnings

The model generates no checks or warnings on start-up.

8.3 Negative depths

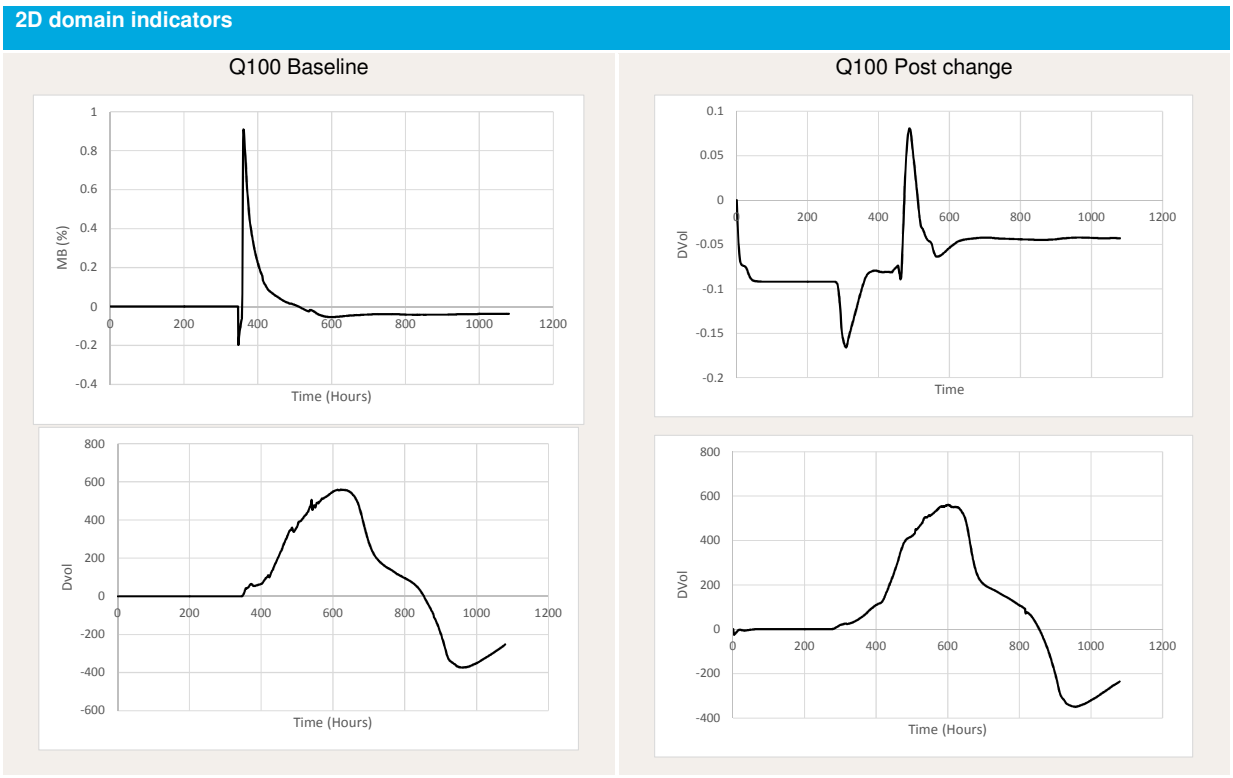
The model does not generate any negative depths during simulations.

8.4 Performance measures

Mass balance indicators are illustrated below for the 100-year baseline scenario. It can be seen that the overall cumulative mass balance percentage stay below 1%. The dVol is largely smooth in profile.

In the post change scenario the mass balance errors are less than 0.5%, the DVol is generally smooth.

Figure 8-1: Model performance indicators



8.5 Robustness

The model runs stably for all return periods in the baseline model.

9. Model simulations

A series of model simulations have been undertaken to assess the flood risk and flood risk management options in the study area. The following tables describe the scenarios and events that have been modelled.

Model Run	Control file	Flags required	Key representation	Return periods simulated
Baseline	BUL_Q5.tcf	n/a	Baseline	5-year
	BUL_Q10.tcf	n/a	Baseline	10-year
	BUL_Q25.tcf	n/a	Baseline	20-year
	BUL_Q50.tcf	n/a	Baseline	50-year
	BUL_Q75.tcf	n/a	Baseline	75-year
	BUL_Q100.tcf	n/a	Baseline	100-year
	BUL_Q100cc.tcf	n/a	Baseline	100cc

9.1 Calibration/validation

No gauged data is available for this river is available, but it is possible to sensibility check the model results against local knowledge (what little of it there is). Figure 9-1 and Figure 9-2 shows that large portions of the proposed wetland area was inundated in the 2007 floods. Similar patterns of inundation are observed in the 10-year and 25-year return period events in the existing situation modelling (Figure 9-3). This seems a low return period for such inundation, but without any more detailed hydrometric data of the event, it is impossible to use this information to alter the inflows to the model.

Figure 9-1: Proposed wetland area in 2007 floods (Photo Jeff Lunn)

- **Figure 9-2: EA historic flood information**

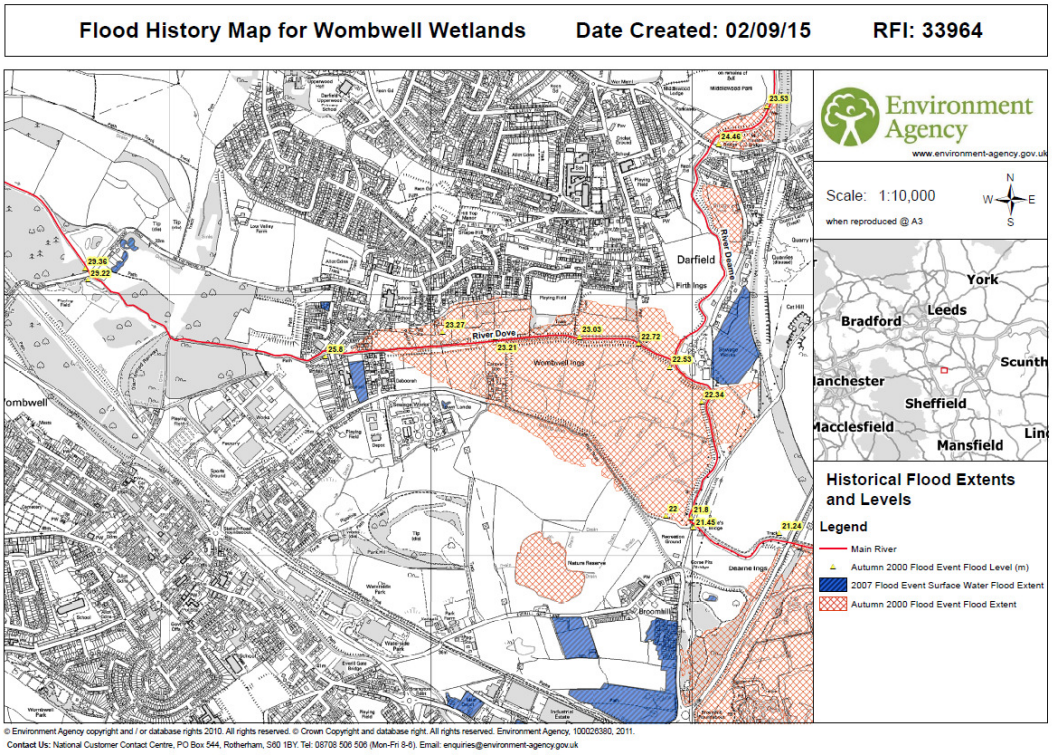


Figure 9-3: Pre-change flood outlines

10-year Return Period event

25-year Return Period event

In the 2007 flood event, the right hand bank of the Dove was overtopped upstream of Stoneyford Bridge. This water inundated many properties before flowing into Bulling Dike. As discussed above, the extent of flooding observed on the site of the proposed wetland shows that the current modelling suggested a return period of between 10 and 25-years on the wetland. Examination of the hydraulic model shows that the right hand bank of the Dove is overtopped at return periods of 10-years and higher (small volumes in the 10-year event). Despite some changes being made to the right hand bank and model (since 2007 the elevations of the right hand bank where the overtopping occurred have been altered by the addition gabion baskets), this suggests that the representation of overtopping over the right hand bank of the Dove occurs at a sensible return period (relative to the flooding patterns observed on the floodplain).

9.2 Explanation of TUFLOW model file types

.tcf = TUFLOW Control File	Control file for the model drawing together all of the below files:
.tgc = TUFLOW Geometry Control file	Defines topography and distributed roughness
.tbc = TUFLOW Boundary Condition file	Defines 2D boundaries and 1D-2D links
.tmf = TUFLOW Material File	Defines roughness values
.tef = TUFLOW Event File	File that defines different inflow combinations that can be called in the modelling using –ex flag
.trd = TUFLOW Common Commands File	Reference file for common run parameters that do not vary between different run versions
.ecf = ESTRY Control File	Control file for 1D ESTRY components

9.3 Baseline model runs

Run Reference:	**BUL_Q100.tcf**	
Purpose of Runs:	To model the required AEP flood events with the topography 'as now'.	
ESTRY/ TUFLOW file and Version:	File names:	
	BUL_Q100.tcf	
	BUL_004.tgc	
	BUL_002.tbc	
	BUL.tmf	
Notes:		
Run Time:	Model event duration: 30hours; simulation time: 4 hours.	
Return period(s):	100-year	
Boundary Conditions:	As above	
Run Settings:	In the 2D domain the timestep is 1 second and in the 1D ISIS model it is 1 second.	
Comments on results:	This run is stable for all return periods.	

Appendix A: Initial Modelling

Introduction

This section describes the initial modelling work, focused at refining the representation and understanding of the flooding mechanisms that will be directly affected by the proposed wetland habitat.

Initial modelling updates

The updating of the original 2009 model has been necessary to improve the representation of the current flooding mechanisms surrounding the proposed wetland. The original 2009 model was produced to determine the flooding mechanisms on the River Dearne, River Dove and Bulling Dike watercourses. The model was primarily focused on the most densely populated areas of Wombwell (Stonyford Bridge, Station Road, Cotterdale Gardens etc). Therefore, the upstream watercourse extents around these residential areas a good coverage of LIDAR and other supporting dataLess data (including LIDAR) was available for the downstream, less populated areas,

In order to enhance the representation of flooding mechanisms in the lower reaches of the catchment the most recent LIDAR and other supporting data was integrated into the model.

The main issues on each watercourse and the updates made on them are detailed in the following sections.

River Dove - model updates

The main modelling issues on the River Dove and updates used to resolve them and the resulting benefits are as follows:

- Left bank floodplain only represented in the model cross sections (DOVE01_992 and DOVE01_726) - Most up to date 1m DTM LIDAR data used to create a reservoir unit (Wombwell_C) and spill unit crest levels along the left bank (**better represents attenuation of the left bank floodplain, movement of water over the left bank and distribution of flow to the left bank or right bank**)
- Not enough cross section detail in model between cross section DOVE01_726 and DOVE01_0000 - Interpolate cross sections added at 50m intervals (**better represents the downstream flow through the channel towards the confluence with the River Dearne and refined the models initial water levels which affected by oscillations in the model resulting in artificially high water being calculated, causing overtopping into the area occupied by the travellers site (reservoir unit Wombwell_B)**.
-

More modelling details can be seen in the supporting model log "1D Model register v0.1.xls"

Bulling Dike - model updates

The main modelling issues on Bulling Dike and updates used to resolve them and the resulting benefit are as follows:

Right bank flood plain only represented in the model cross sections (BUL01-1886, BUL01-1518 and BUL01-1200) - Most up to date 1m DTM LIDAR data used to create a reservoir unit (ProWetland_R) and spill unit crest levels along the left bank (**better represents attenuation of the right bank floodplain [were the proposed wetland area is located in its current state], movement of water over the right bank and distribution of flow to the left bank or right bank**)

More modelling details can be seen in the supporting model log "1D Model register v0.1.xls"

Limitations of model updates

The initial update of the 2009 model has only focused on the downstream extent of the River Dove and Bulling Dike. Therefore, any changes in the upstream sections of the catchment have not as yet been integrated into the current model version.

Conclusion and findings of initial modelling updates

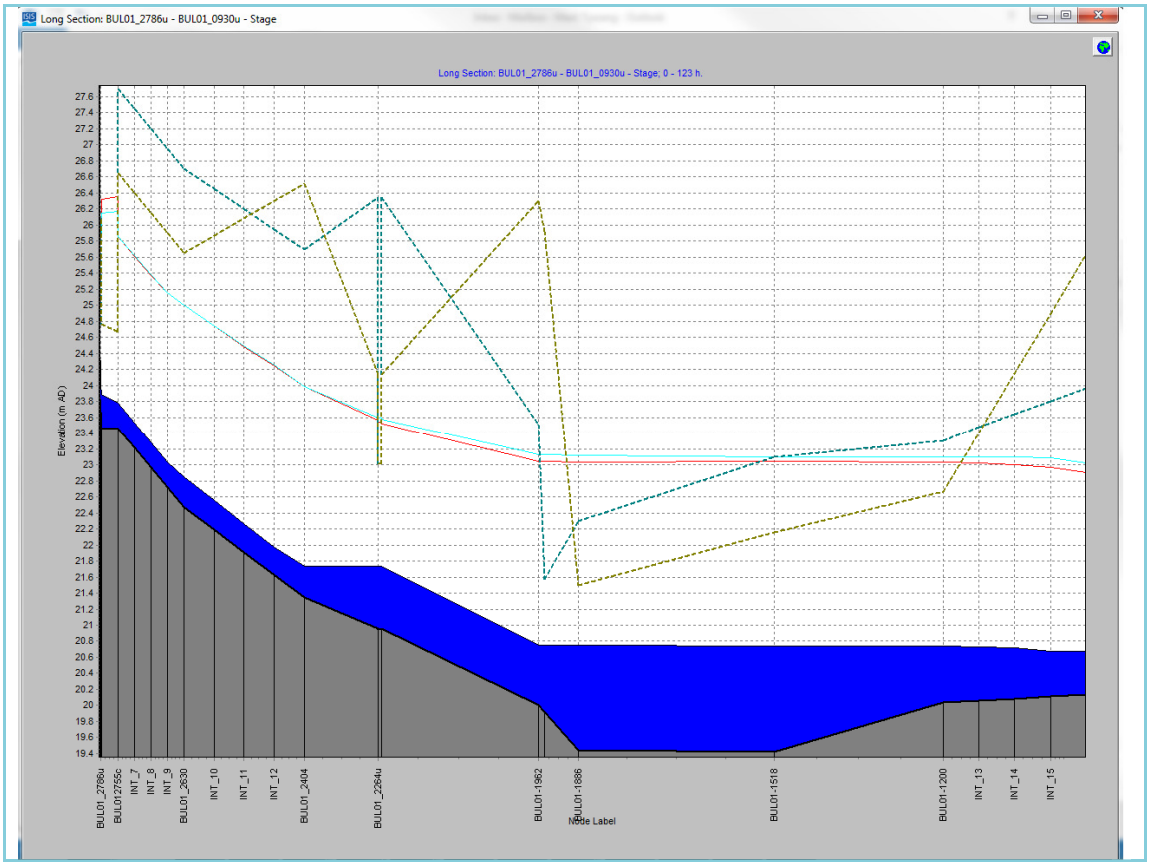
The updating of the 2009 model has resulted in a more refined and enhanced representation of the flooding mechanisms surrounding the proposed wetland area. The main observations and refinements are listed below:

- Enhanced representation of flooding mechanisms along the downstream extent of the River Dove
- Refined representation of flooding mechanisms within the flood plain (left bank of Bulling Dike and right bank of the River Dove) that contains the Ings Lane Traveller's site
- Refined representation of flooding mechanisms within the flood plain (right bank of Bulling Dike) that contains the proposed wetland area.

The refined representation of flooding to the Ing's Lane Travellers site (reservoir unit - "Wombwell_B") shows that the main source of flood water comes from the left bank overtopping of Bulling Dike and not the right bank of River Dove as previously represented in the 2009 model. This is a key point as the introduction of the wetland along the right bank of Bulling Dike is adjacent on the opposite bank to the spill point that inundates the Traveller's site. Any reduction in flood risk from the development of the wetland should provide flood risk benefits to the site.

Due to the location of the proposed wetland any reduction in flood risk to properties (apart from the Ing's Lane Traveller site) will be restricted to an area approximately 440m upstream (BUL01_2404) to the waste water treatment works. In line with the study programme, after we have run a range of wetland options a clearer understanding of the flood risk benefits from the proposed wetland can be achieved. The back water effect along Bulling Dike, comparing the updated and original models, is shown in Figure 3-5.

Figure 9-4: Bulling Dike long section comparing updated and original models - small drop in water level causing a back water effect up to BUL01_2404)



Blue line is original model water level
Red line is updated model water level

The resulting enhanced model now provides us with a better understanding and more confidence in the flooding mechanisms around the proposed wetland development site. Additionally, the effect of the proposed wetland on the surrounding flooding mechanisms and the associated flood risk will be clearer.

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