Oxford Flood Alleviation Scheme

Detailed Design Hydraulic Modelling Report

IMSE500177-CH2-00-00-RP-HY-0130 | P04

28 January 2022

Environment Agency

IMSE500177

Oxford Flood Alleviation Scheme

Project No:	684232CH
Document Title:	Detailed Design Hydraulic Modelling Report
Document No.:	IMSE500177-CH2-00-00-RP-HY-0130
Revision:	P04
Document Status:	Final
Date:	28 January 2022
Client Name:	Environment Agency
Client No:	IMSE500177
Project Manager:	Phil Marsh
Author:	Chris Weeks
File Name:	IMSE500177-CH2-00-00-RP-HY-0130.docx

Jacobs U.K. Limited

1 Glass Wharf
Bristol, BS2 0EL
United Kingdom

www.jacobs.com

Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
P01	23/01/18	Draft modelling report	CJW	PJM		PJM
P02	19/02/18	Modelling report - additional commentary on model review	CJW	PJM		PJM
P03	12/10/21	Draft modelling report - incorporating latest climate change guidance (July 2021) and FAS model updates	CJW	BG	PJM	PJM
P04	28/01/22	Final Report to support FRA	CJW	PSR	PJM	PJM

Contents

Tables

Figures

1. Introduction

The Environment Agency (EA) WEM Lot 3 project Oxford Flood Alleviation Scheme (FAS) was awarded to Jacobs (formerly CH2M) in April 2015. The project included updating the existing (2014) hydraulic model to support early development of the outline FAS design (2016). Two stages of modelling then followed, a main modelling stage completed in 2018 and a final modelling stage completed in 2021. All stages of the modelling are covered by this report.

1.1 Hydraulic modelling extents

The hydraulic modelling extents cover approximately 19km of the River Thames from its confluence with the River Evenlode to downstream of Sandford Lock (NGR 445465, 209310 to 453880, 198620) and the River Cherwell from the A40 to its confluence with the River Thames (NGR 451540, 209970 to 452010, 205100). Figure 1.1 details the hydraulic modelling extents and key locations and Figure 1.2 details the key rivers and streams in Oxford.

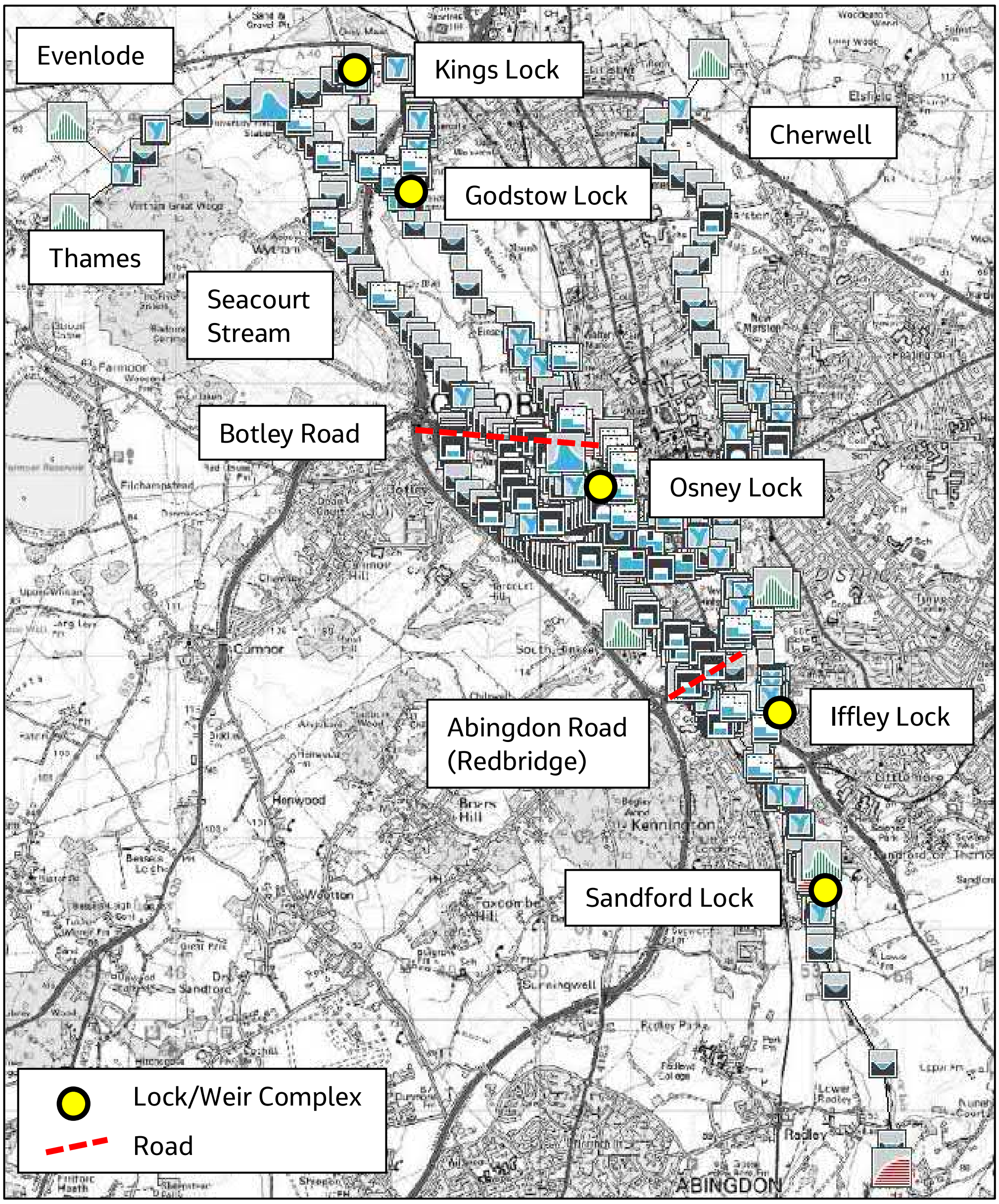


Figure 1.1: Hydraulic modelling extents and key locations

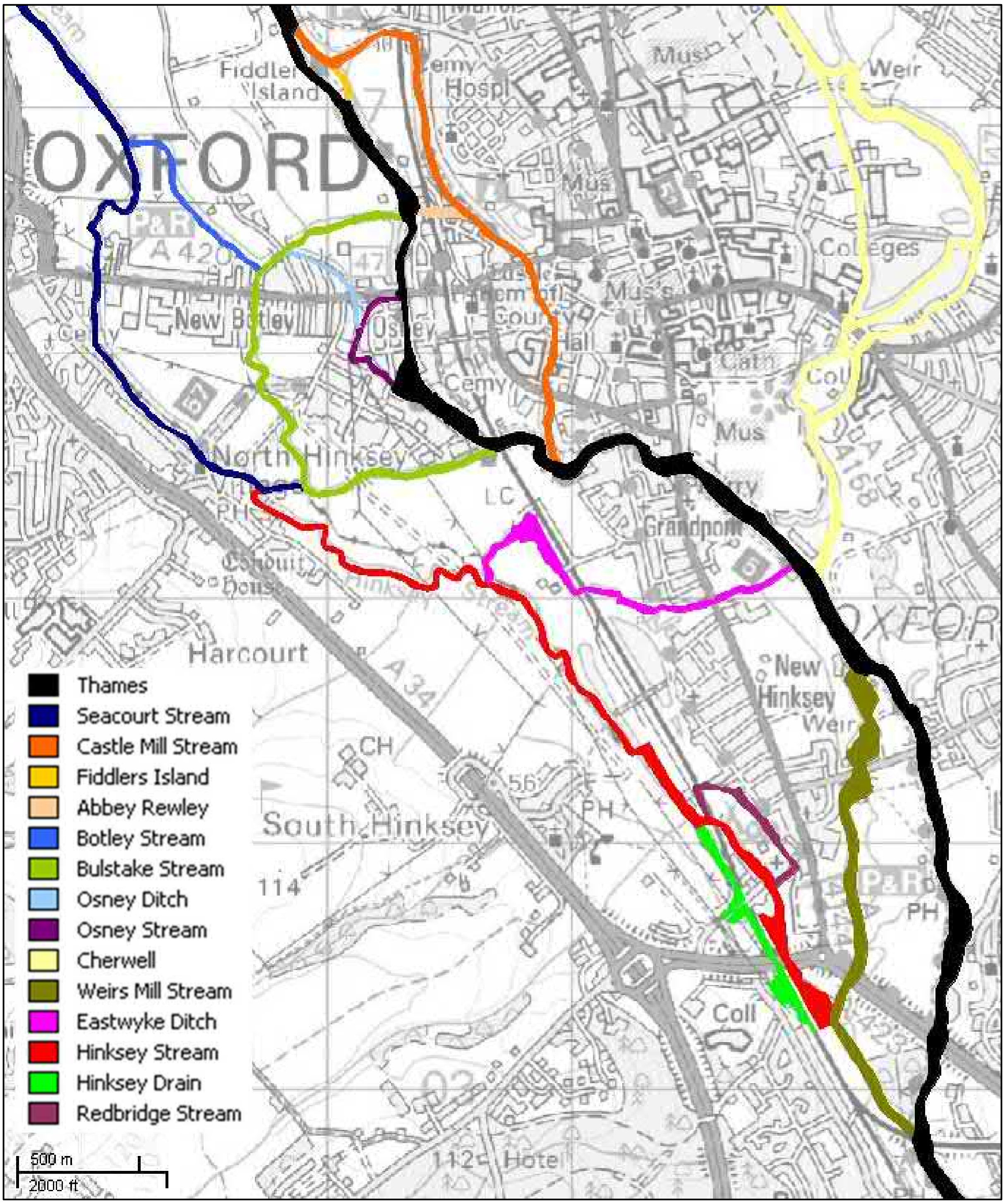


Figure 1.2: Oxford rivers and streams

1.2 Main and final modelling stages

The main modelling stage (2018) included baseline and outline design modelling and then follow-on detailed design modelling. The modelling incorporated new data collected for the Oxford FAS study which was used to update the previous baseline and outline design models and was followed by development of the new detailed design models.

The final modelling stage (2021) included updates to the initial stage models and again involved baseline and outline design modelling and then follow-on detailed design modelling. The updates included minor updates to the baseline, outline design and detailed design models, and also incorporated revised model inflows based on the latest climate change guidance[1] (published 22nd July 2021). The design model updates incorporated changes to the FAS scheme design around the A423 and other more minor updates.

The main modelling stage was previously reported in 2018 and supported the 2018 Flood Risk Assessment submission as part of the original planning application. Both the initial and final modelling stages are covered by this Detailed Design Hydraulic Modelling Report which supports the 2021 Flood Risk Assessment as part of the revised planning application.

The timeline diagram in Figure 1.3 presents the main and final modelling stages, including the peer reviews for the outline design and detailed design modelling. The timeline for the main modelling stage runs from April 2015 (model development) up to February 2018 (Detailed Design Model and Modelling Report). The timeline for the final modelling stage runs from February 2021 up to January 2022 (Final Design Model and Modelling Report).

1.3 Report structure

This report is structed as follows:

- Chapter 1 introduces and provides background to the project
- Chapter 2 describes the hydrological boundaries uses for the study and provides details to the updated 2021 climate change guidance
- Chapter 3 details the new surveys provided at the detailed design stage
- Chapter 4 provides details of the Do Minimum model updates and results for the 2018 version
- Chapter 5 describes the Oxford FAS design modelling and results for the 2018 version
- Chapter 6 reports on the external model review and sensitivity tests undertaken on the 2018 model version
- Chapter 7 details the updates to the 2021 version of the Do Minimum model
- Chapter 8 provides details on the model updates and results for the 2021 version of the FAS design
- Chapter 9 comments on the modelling uncertainty and limitations
- Chapter 10 reports on the external peer model review based on the 2021 model version
- Chapter 11 provides concluding remarks

[1] Flood and coastal risk projects, schemes and strategies: climate change allowances, Environment Agency, July 2021. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances

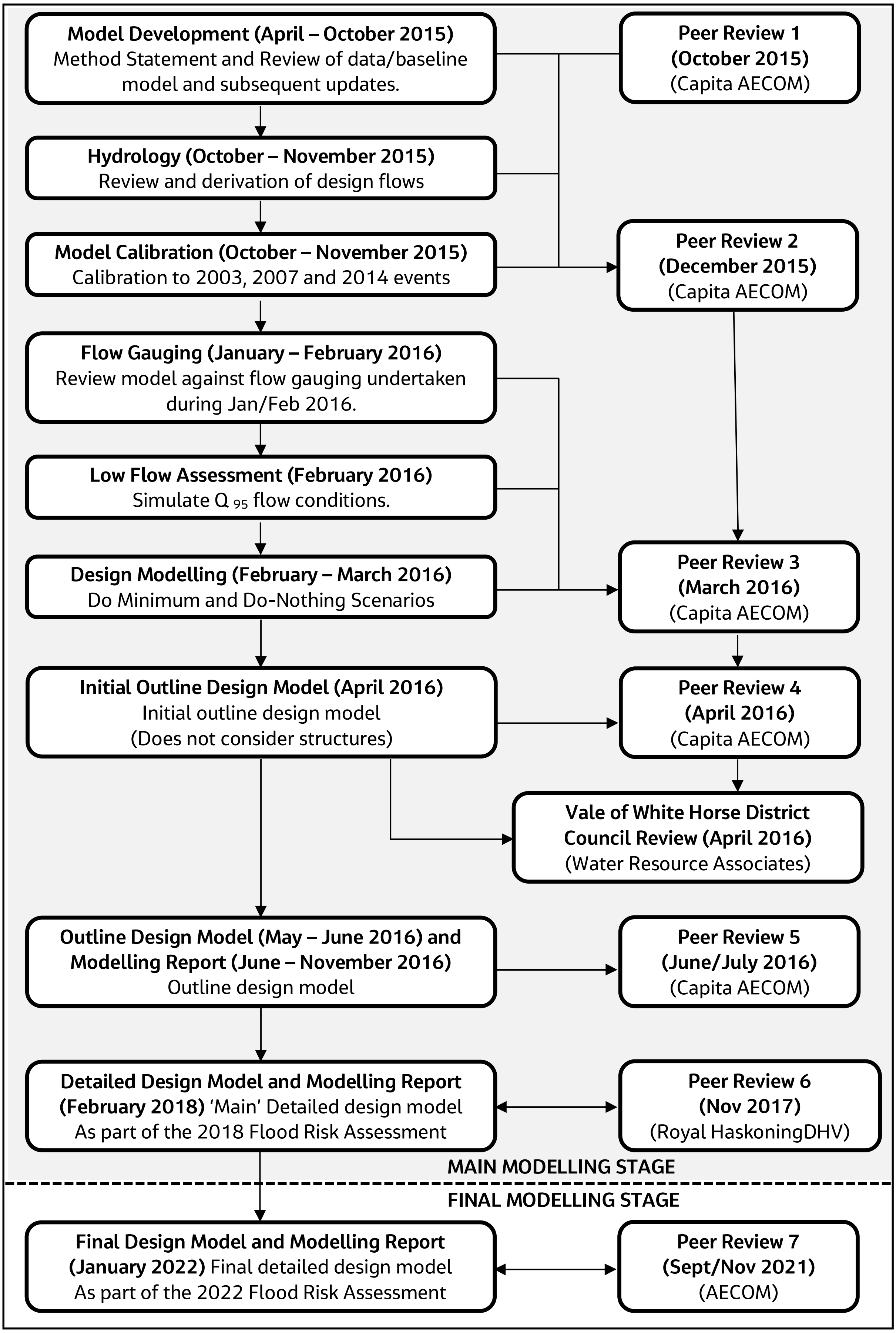


Figure 1.3: Modelling/study timeline

1.4 Accompanying technical reports

The following technical reports should be referenced for details on model development, hydrology, calibration, economics, geomorphology and groundwater modelling:

Initial model review and updates (2015) IMSE500177-HGL-00-ZZ-RE-N-000074	Hydrology (2016) IMSE500177-HGL-00-ZZ-RE-N-000077
Calibration (2016) IMSE500177-HGL-00-ZZ-RE-N-000075	Modelling Report - outline design (2016) IMSE500177-HGL-00-ZZ-RE-N-000124
Groundwater Modelling (2017) 63294 R2D1_All Figures.pdf	Geomorphological Impacts (2017) IMSE500177-CH2-COC-ZZ-RP-HY-0100
Downstream Impacts (2018) IMSE500177-CH2-XX-XX-RP-HY-0143	External Model Review (2018) Oxford_FAS_Model_Review_RHDHV_20171218.PDF
Baseline Modelling (2018) IMSE500177-CH2-00-00-RP-HY-0147	

1.5 Hydraulic modelling software - Flood Modeller-TUFLOW

Hydraulic modelling has used the Flood Modeller-TUFLOW software which combines two software packages for managing overland flow and rapid inundation modelling. It provides a flexible and comprehensive range of tools for designing cost effective engineering schemes, flood forecasting, flood risk mapping and developing catchment management strategies.

Flood Modeller 1D is a 1 dimensional open channel and culverted flow simulation engine, which includes a wide range of hydraulic structures including all common types of bridges, culverts, sluices and weirs. Logical rules are also available which can be added to moveable structures to accurately model how they operate during a flood event e.g., automated structures.

TUFLOW is a modelling package for simulating depth averaged 2D free-surface flows and was developed as a joint research and development project by WBM Oceanics Australia and the University of Queensland.

During the course of the project the software versions of Flood Modeller and TUFLOW have been updated at appropriate stages to ensure latest versions are applied and the model is compatible with all versions. Table 1.1 lists the software versions used.

Table 1.1: Hydraulic modelling software versions

Software	Outline Design	2018 Model Version	2021 Model version
Flood Modeller	v4.1 (double precision)	v4.3 (double precision)	v5.0 (double precision)
TUFLOW	v2013-12-AE (double precision)	v2016-03-AE (double precision)	v2020-10-AA (double precision)

Model simulation run parameters

The model simulations were run in an unsteady state with a 1.5 second 1D time step and a 3 second 2D time step. The timesteps are in line with TUFLOW model guidance based on the 2D model resolution of 10 metres (timestep in the range of $^{1}/_{2}$ to $^{1}/_{5}$ of the cell size).

1D model parameters

The model parameters in the 1D .ief run file are primarily set to the default values recommended by Flood Modeller. The exceptions are as follows:

- The dflood parameter is set to 10, which allows the 1D cross-sections to glass-wall up to a height of 10m if required, which is considered acceptable for a linked 1D-2D model.
- The maxitr parameter is set to 19, which allows the number of iterations per time step for the model to solve the shallow water equations. Performing more iterations increases the probability of model convergence.

The Matrix Dummy coefficient is set to 0.00001, which reduces the probability of the results matrix becoming singular and crashing the model.

2D model parameters

Sensitivity tests were undertaken on the 2D HX line FLC and 2D Boundary Viscosity Factor following Peer Review 2 (2016). The sensitivity tests predicted a maximum increase in peak water level of 1cm – 2cm when using a HX FLC of 0.5 (*TUFLOW guidance - typically 0.1 to 0.5*) and boundary viscosity factor of 3 (*TUFLOW guidance – changing this value in the range of 0 to 5 usually has little effect on results*).

The adjustments were found to reduce oscillations between the 1D-2D domain and due to the minor impact in water levels/flows and stability benefits between 1D and 2D, the sensitivity tested values were retained.

2. Hydraulic model inflows

No further work was undertaken on the hydrological analysis as part of the detailed design. The flows are as used for the outline design modelling. Information on the hydrological analysis can be found in the Oxford FAS Final Hydrology Report, February 2016 (IMSE500177-HGL-00-ZZ-RE-N-000077).

2.1 95% exceedance flows (Q_{95})

(applicable to the 2018 main and 2021 final modelling stages)

Q_{95} flows from gauging stations at Farmoor (Thames), Cassington (Evenlode), Enslow (Cherwell) and Islip (Ray) have been taken from National River Flow Archive as detailed in Table 2.1.

Table 2.1: Q_{95} flows

Station	Station Number	Watercourse	Q_{95} (m^3/s)
Eynsham	39008	Thames	1.150
Cassington	39034	Evenlode	0.629
Total Thames			**1.779**
Enslow	39021	Cherwell	0.657
Islip	39140	Ray	0.150
Total Cherwell			**0.807**

Source: National River Flow Archive http://nrfa.ceh.ac.uk/

The total Q_{95} flow at Sandford is 2.586m^3/s, flows at ungauged model inflow nodes (Sanug, Iffug, 47.SL and HD07.027) are not considered for Q_{95} and set as zero.

2.2 Mean monthly flows

(applicable to the 2018 main and 2021 final modelling stages)

Table 2.2 details the mean monthly flows which have been derived to support the design of the new channels within the FAS design.

Table 2.2: Mean monthly flows

Inflow	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
50.078Q	30.1	26.9	20.8	14.8	10.6	7.6	5	3.9	3.9	7.4	15.8	23.5
50.EVEN	7.6	6.9	5.6	4.3	3.0	2.3	1.6	1.3	1.3	2.1	4.1	6.0
CHER_A40	13	11.2	8.6	6.5	4.4	3.2	2.5	1.9	2	3.5	6.9	10
Sanug	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Iffug	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
47.SL	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
HD07.023	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Total at Sandford	51.7	45.9	35.8	26.2	18.4	13.4	9.3	7.3	7.4	13.3	27.3	40.3
Flow Rank (low to high)	12	11	9	7	6	5	3	1	2	4	8	10

2.3 Design flood flows

(applicable to the 2018 main and 2021 final modelling stages)

The Thames (Oxford area) flood forecasting model was used to provide the inflow hydrographs for the Thames and Cherwell in the 1D-2D model. The forecasting model covers a larger area than the 1D-2D model, with upstream boundaries at Farmoor (Thames) and Enslow (Cherwell) gauging stations and downstream boundary at Culham Lock.

The forecasting model was simulated with design inflows for the Thames (Farmoor), Cherwell (Enslow), Ray (Islip), Evenlode (Cassington) and minor Oxford Subcatchments to provide the peak flows at Sandford. The input hydrographs for Thames and Cherwell inflows to the 1D-2D model were then extracted from the forecasting model.

The peak design flood flows adopted for the study at Sandford Lock are detailed in Table 2.3, with comparison to the 2009 Oxford Strategy model and the 2014 Oxford Flood Risk Mapping Study. The flows for the more frequent events are similar. The differences in flows are more notable for the less frequent events.

Table 2.3: Peak design flood flows at Sandford Lock

Return Period (Years)	Peak Flow (m^3/s)		
	Oxford FAS	2009 Strategy	2014 Mapping Study
50% AEP (1 in 2)	140	142	140
20% AEP (1 in 5)	181	183	184
10% AEP (1 in 10)	206	206	-
5% AEP (1 in 20)	231	228	228
3.3% AEP (1 in 30)	246	-	-
2% AEP (1 in 50)	265	257	-
1.3% AEP (1 in 75)	281	268	259
1 % AEP (1 in 100)	292	278	264
0.5% AEP (1 in 200)	320	299	-
0.2% AEP (1 in 500)	359	-	-
0.1 % AEP (1 in 1000)	390	327	299

2.4 Climate change flows (2018 version)

(applicable to the 2018 main modelling stage)

Climate change simulations were undertaken to provide additional information for the Environment Agency's flood map. The outputs from the 1 % AEP (1 in 100) +35% simulations were used to inform freeboard allowances for proposed defences. These simulations scaled the model inflows by the percentages listed in Table 2.4.

Table 2.4: Climate change - peak flows at Sandford Lock

Scenario	peak flow (m^3/s)
1 % AEP (1 in 100) + 25%	353
1 % AEP (1 in 100) + 35%	386
1 % AEP (1 in 100) + 70%	477

2.5 Climate change flows (2021 version)

(applicable to the 2021 final modelling stage)

Climate change has been assessed following the new guidance[2] released in July 2021. Figure 2.1 shows the catchments where the climate change flow allowances are defined in the new guidance, the Cotswold Management catchment was selected for the study as it represents the Thames upstream of the FAS.

This modelling used the Central estimates (50th percentile) for the Cotswolds Management Catchment with flow allowances of +11% (2020s), +13% (2050s) and +30% (2080s). The modelling also tested the Upper End flow allowance of +82% (2080s). The modelling in 2021 no longer uses the present day flows derived in 2016 (as reported in 2018), instead the current guidance has been followed.

Table 2.5 gives the peak flows from the climate change scenarios derived from the present day flows at Sandford Lock. The peak flows at Sandford Lock indicate that the present day 1% AEP estimate, would be equivalent to 2% AEP for the 2020s, slightly less than 2% AEP for 2050s and approximately 5% AEP for 2080s (highlighted values in Table 2.5).

The model inflow boundaries have been scaled by the climate change factors, as such the model may not exactly match the flows presented in Table 2.5, as the flows are routed through the hydraulic model which represents flow timing from the sub catchments and floodplain storage/attenuation etc.

Sensitivity tests has considered the selection of the catchment allowances as reported in Section 7.4.

Table 2.5: Climate change - peak flows at Sandford Lock (2021 assessment)

Scenario	50% AEP 2-year	20% AEP 5-year	10% AEP 10-year	5% AEP 20-year	3.3% AEP 30-year	2% AEP 50-year	1.3% AEP 75-year	1% AEP 100-year	0.5% AEP 200-year	0.2% AEP 500-year	0.1% AEP 1000-year
Present Day (2016 assessment)	140	181	206	231	246	265	281	292	320	359	390
+11% 2020s Central	155	201	229	256	273	294	312	324	355	398	433
+13% 2050s Central	158	205	233	261	278	299	318	330	362	406	441
+30% 2080s Central	182	235	268	300	320	345	365	380	416	467	507
+82% 2080s Upper End	255	329	375	420	448	482	511	531	582	653	710

[2] Flood and coastal risk projects, schemes and strategies: climate change allowances, Environment Agency, July 2021. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances

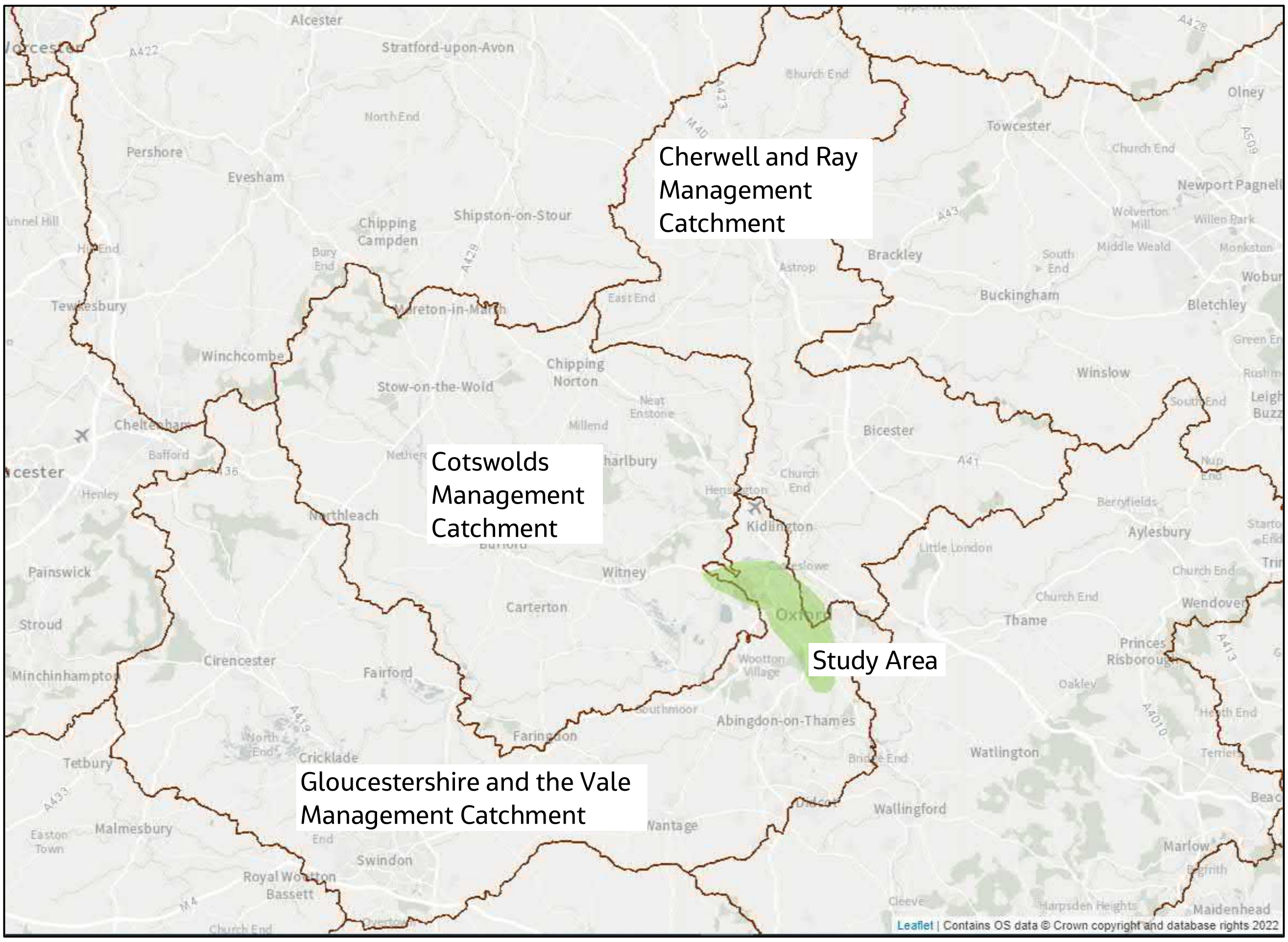


Figure 2.1: Climate change allowance catchments

3. Detailed design models - survey data used for modelling

Additional survey was undertaken for the detailed design between September 2016 and April 2017, at the locations of the features of the Oxford FAS (new channel profiles, embankments etc.) The survey included river channel surveys and topographic surveys which have been incorporated into the models in advance of the 2018 main modelling stage.

3.1 River channel survey

Reaches of Seacourt Stream, Hinksey Stream and Weirs Mills Stream have been surveyed at the locations detailed in Figure 3.1. Cross sections are surveyed at approximately 20-25m intervals and include details of bridges and weir structures. The new sections have been compared to the older data which was used in the previous models (surveyed during the 1980’s). The comparison shows a reasonable match, details of the comparison are included in Appendix A.

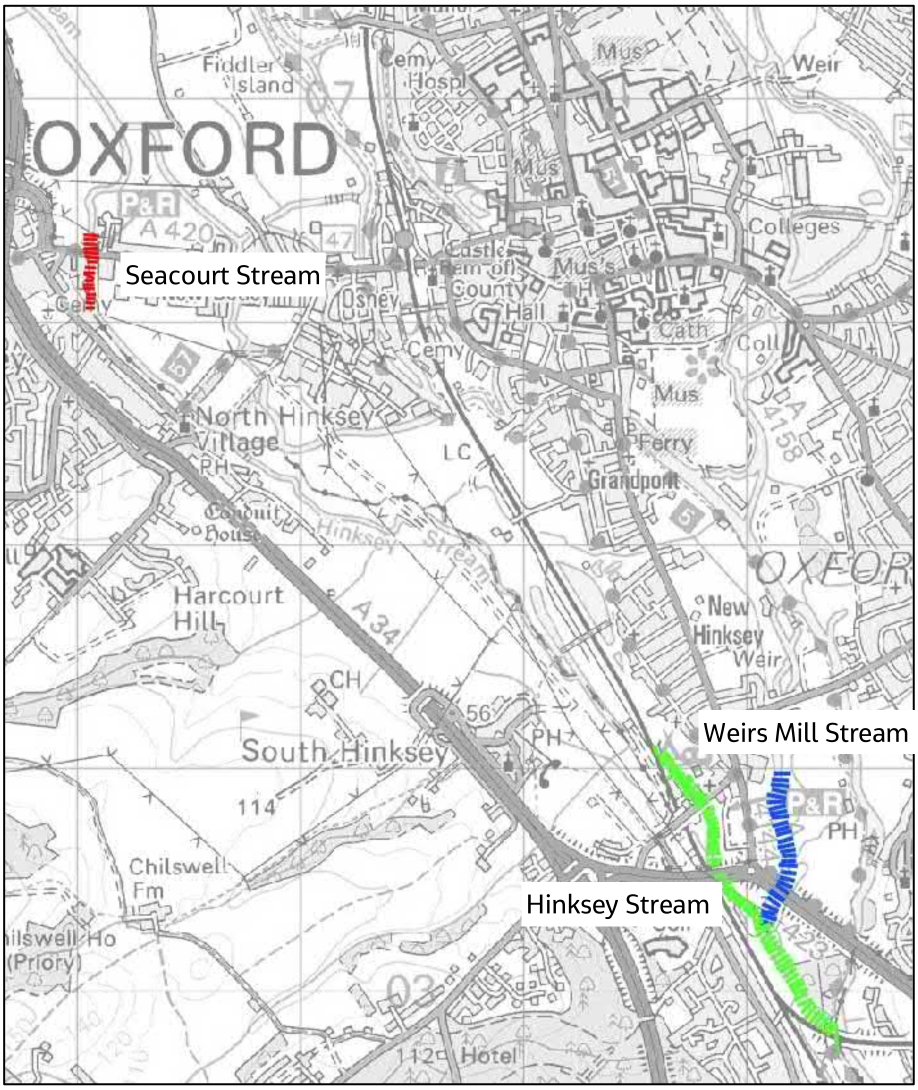


Figure 3.1: Oxford rivers and streams - surveyed reaches

3.2 Topographic surveys

Topographic surveys which include spot levels and break-lines for features (top of banks etc.) were undertaken at the locations detailed in Figure 3.2 and Table 3.1.

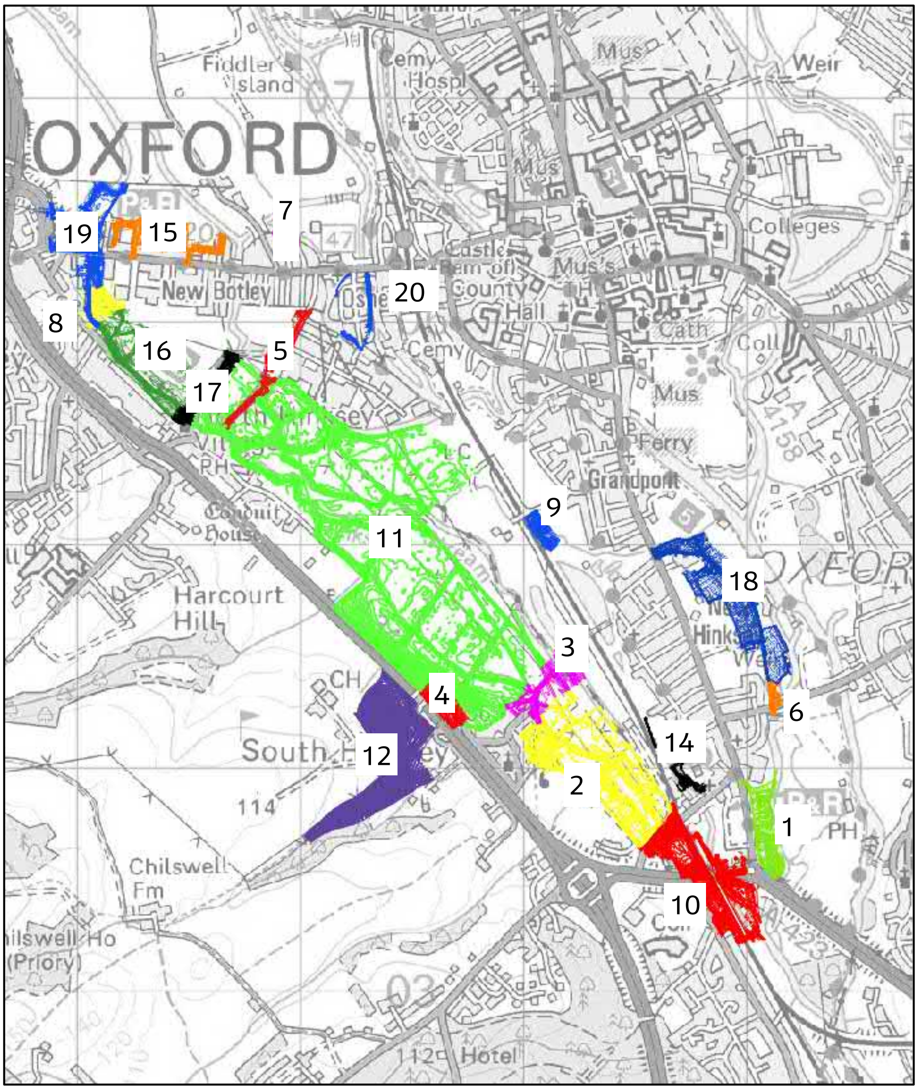


Figure 3.2: Location of topographic surveys

Table 3.1: Topographic surveys

Survey Name			
1.	TJ00553-01 - East of Abingdon Road	10.	TJ00553-10 - Redbridge P&R
2.	TJ00553-02 - Manor Farm	11.	TJ00553-11 - South Hinksey Level
3.	TJ00553-03 - Devils Backbone	12.	TJ00553-12 - Chiswell Path
4.	TJ00553-04 - South Hinksey	14.	TJ00553-14 - Campsite
5.	TJ00553-05 - North Hinksey	15.	TJ00553-15 - Seacourt P&R
		16.	TJ00553-16 - Botley Fields

Survey Name		10.	TJ00553-10 - Redbridge P&R
6.	TJ00553-06 - Weirs Lane	17.	TJ00553-17 - Willow Walk
7.	TJ00553-07 - Henry Helen Road	18.	TJ00553-18 - Hotel New Hinksey
8.	TJ00553-08 - Botley Full	19.	TJ00553-19 – Botley Level
9.	TJ00553-09 – Grand Pont	20.	TJ00553-20 – Osney Island

The surveys have been converted to grid format to allow comparison to the LiDAR DTM (1m resolution). Figure 3.3 details the differences in elevation from subtraction of the LIDAR DTM from the topographic surveys. Generally, the topographic survey has lower elevations than the LiDAR DTM, showing differences of 5–10 cm on open ground and exceeding 25 cm in heavily vegetated areas.

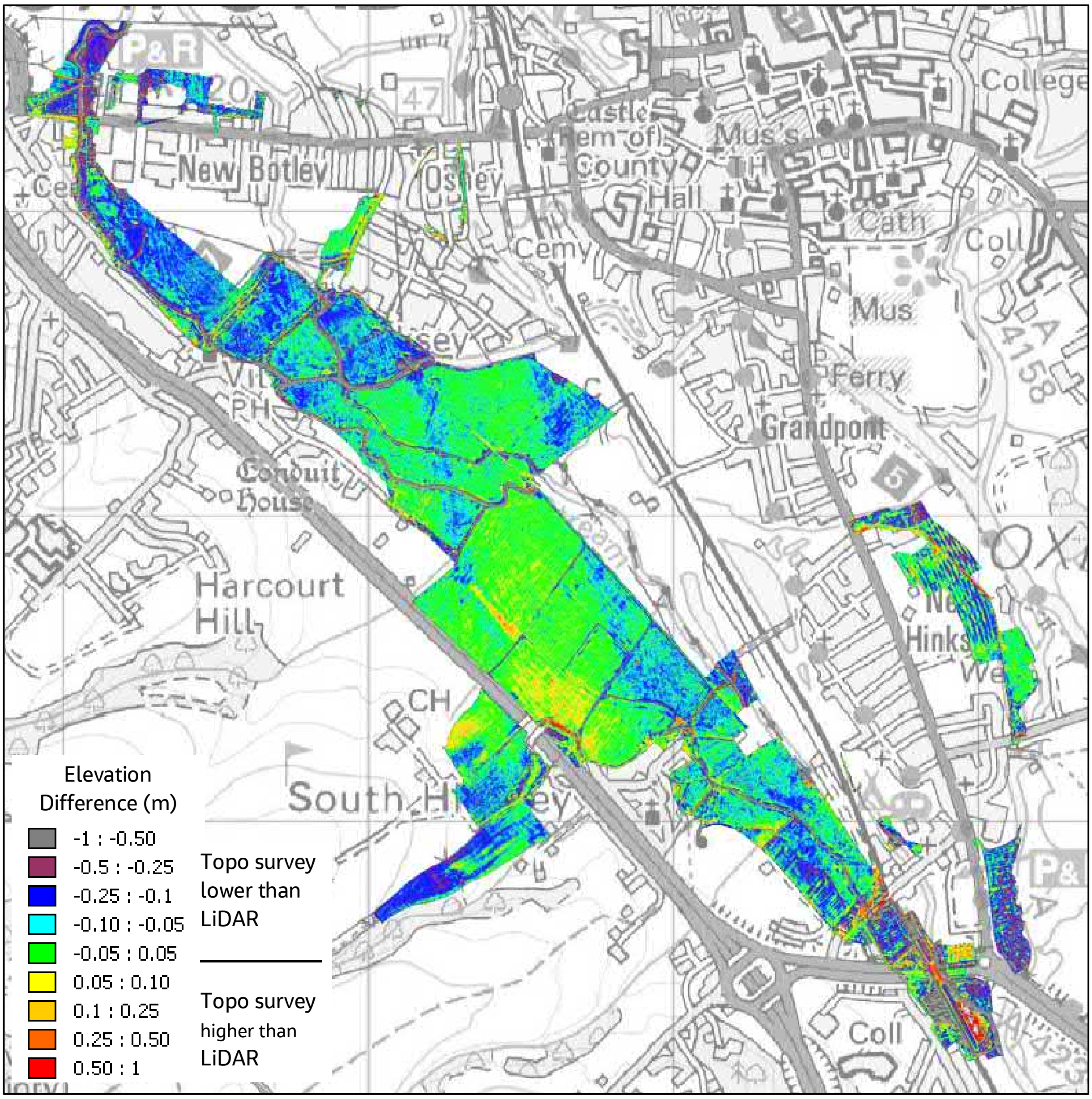


Figure 3.3: Elevation difference between topographic survey and LiDAR

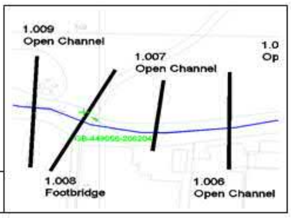
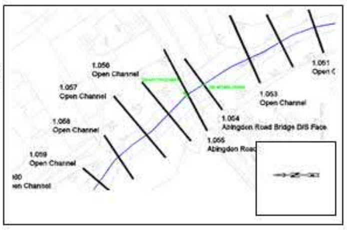
3.3 Gauge board datum level at telemetry stations

The new channel surveys of Seacourt Stream and Hinksey Stream included surveying of the gauge board levels at the telemetry stations Minns Estate (Seacourt) and Cold Harbour (Hinksey).

The surveys show that the telemetry at Minns Estate could be recording water levels higher than observed (by 0.1m) and at Cold Harbour the recorded levels could be lower than observed (by 0.01m). Records of the gauge board survey and telemetry at the time of the survey are detailed and compared in Table 3.2. The data indicates that an adjustment of (-0.098m) applied to the Minns Estate telemetry would match the surveyed water level. At Cold Harbour, the gauge board adjustment (+0.01m) would improve the difference between the surveyed water level and telemetry, although there would still be a difference of 0.02/0.03m.

The telemetry data was used for calibration of the model during the outline design study. Applying the adjustments to the telemetry would improve the results of the model calibration at Minns Estate and at Cold Harbour.

Table 3.2: Gauge board levels

Minns Estate (Seacourt Stream)		Cold Harbour (Hinksey)	
ENVIRONMENT AGENCY — GAUGE BOARD DESCRIPTION GAUGE ZERO LEVEL: -0.098mODN LEVEL TAKEN AT GAUGE BOARD READING 56.00M WAS 55.902mODN Method: GNSS Date: 19/12/2016 Time: 12:01:41 Water Level: 54.98m   DESCRIPTION: Gauge Board situated on right bank at the upstream face of Footbridge, South of Botley Bridge, Oxford. SURVEYED BY: MLS LTD DATE SURVEYED: 19/12/16 JOB NUMBER: 16_275 GAUGEBOARD CO-ORDINATES Easting 449056 Northing 206204 K.M. Square: SP 4906		ENVIRONMENT AGENCY — GAUGE BOARD DESCRIPTION GAUGE ZERO LEVEL: 0.010mODN LEVEL TAKEN AT GAUGE BOARD READING 56.00M WAS 56.01mODN Method: GNSS Date: 11/10/2016 Time: 15:24 Water Level: 53.93m   DESCRIPTION: Gauge Board situated on U/S Face of Abingdon Road Bridge. Hinksey Stream. SURVEYED BY: MLS LTD DATE SURVEYED: 13/10/16 JOB NUMBER: J00551 GAUGEBOARD CO-ORDINATES Easting 451799 Northing 203841 K.M. Square: SP 4520	
Survey Water Level 19/12/2016 12:01	54.98m	Survey Water Level 11/10/2016 15:24	53.93m
Telemetry Water Level 19/12/16 12:00	55.08m	Telemetry Water Level 11/10/16 15:15	53.90m
Gauge Zero Adjustment (-0.098m)	54.98m	Gauge Zero Adjustment (+0.010m)	53.91m
		Telemetry Water Level 11/10/16 15:30	53.89m
		Gauge Zero Adjustment (+0.010m)	53.90m

4. Main modelling stage: Do Minimum model (2018)

The Do Minimum model developed during the previous study has been updated with the new topographic surveys and data. The model schematisation included updated modelling methods for Hogacre Ditch and Hinksey Ditch. The model updates included general updates to incorporate new information made available and also specific to Seacourt Stream and Hinksey Stream. The location of the ditches and streams is shown in the overview map in Figure 4.1.

The model schematisation and updates made are detailed in this section. The downstream model boundary is also considered. The model has been run for the full range of design events. Key model files are detailed in Appendix A.

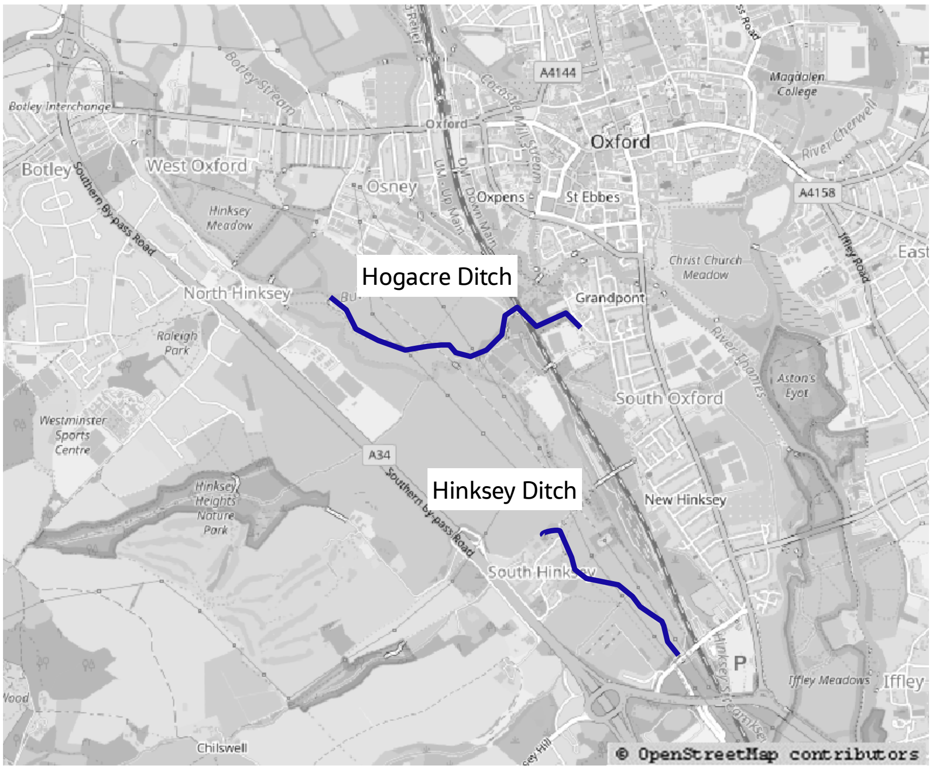


Figure 4.1: Overview map - location of ditches and streams updated in Do Minimum model (2018)

4.1 Model schematisation

The model has been schematised to represent all floodplain features in 2D (TUFLOW) and all watercourses in 1D using Flood Modeller, except for Hogacre Ditch and Hinksey Ditch. Following the model review (Appendix H), additional reporting is included below on the modelling methods for the Hogacre Ditch and Hinksey Ditch.

4.1.1 Hogacre Ditch

There are no channel surveys for Hogacre ditch to allow the watercourse to be represented in the 1D model, the ditch was not represented in the 2014 flood mapping model. For the 2-year event, flood depths ranging from 0.2m – 0.7m are predicted in the floodplain surrounding the ditch. The ditch is not maintained and is heavily vegetated, given the flood depths inclusion of the ditch would have a negligible impact on results. Therefore, the upper reaches of the ditch are not included in the model schematisation. The lower reaches are more defined within the LiDAR DTM and appear to be maintained through Grandpont. In this area 1D cross sections have been derived from the LIDAR DTM and included in the model. The schematisation of Hogacre ditch is detailed in Figure 4.2.

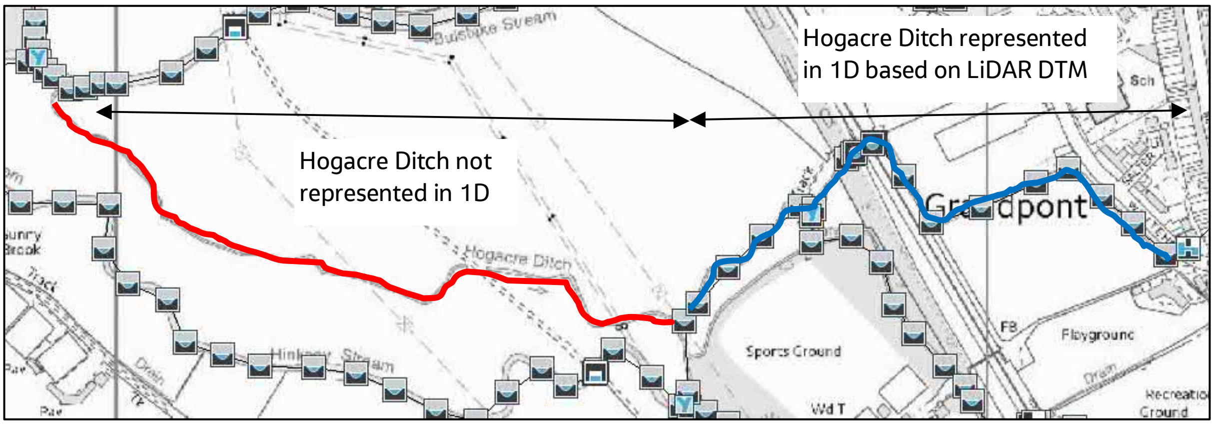


Figure 4.2: Hogacre Ditch schematisation

4.1.2 Hinksey Ditch

Hinksey Ditch was represented in the 2014 flood mapping model as a 2D gully line, to represent a flow route (Figure 4.3). The ditch is located within the floodplain, for the 2-year event flood depths ranging from 0.3m – 0.7m are predicted. Survey is available (dated 1991) and attempts were made during the outline design stage to represent the channel in 1D. However, representing the channel in 1D resulted in stability problems and oscillation of flows from 1D to 2D (due to the small channel size and floodplain depths). Therefore, the 2D schematisation of the channel was retained. At the downstream end of the 2D gully line, the railway access track culvert is used to provide a link from the 2D model back to the 1D model (using a SX type link and orifice unit to present the culvert).

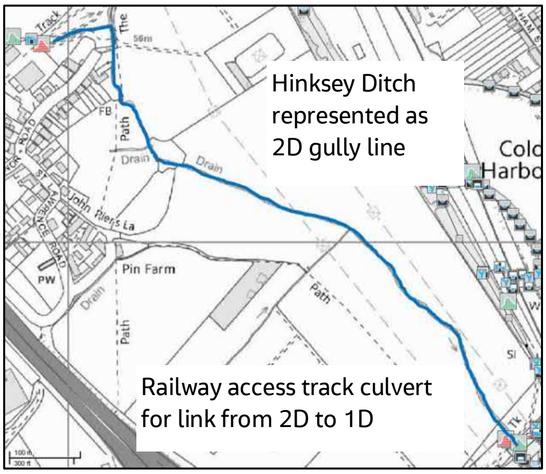


Figure 4.3: Hinksey Ditch schematisation

4.2 Model updates

Updates were made to the 1D model to incorporate the new channel survey and as built records for the Network Rail culvert and works at Mundays Bridge. The 2D model was updated using the new Topo DTM in preference to the LiDAR DTM and z-lines added to represents features of the floodplain. The locations of the updates are detailed in Figure 4.4 and described in the in Table 4.1 and Table 4.2 for the updates to the 1D and 2D model.

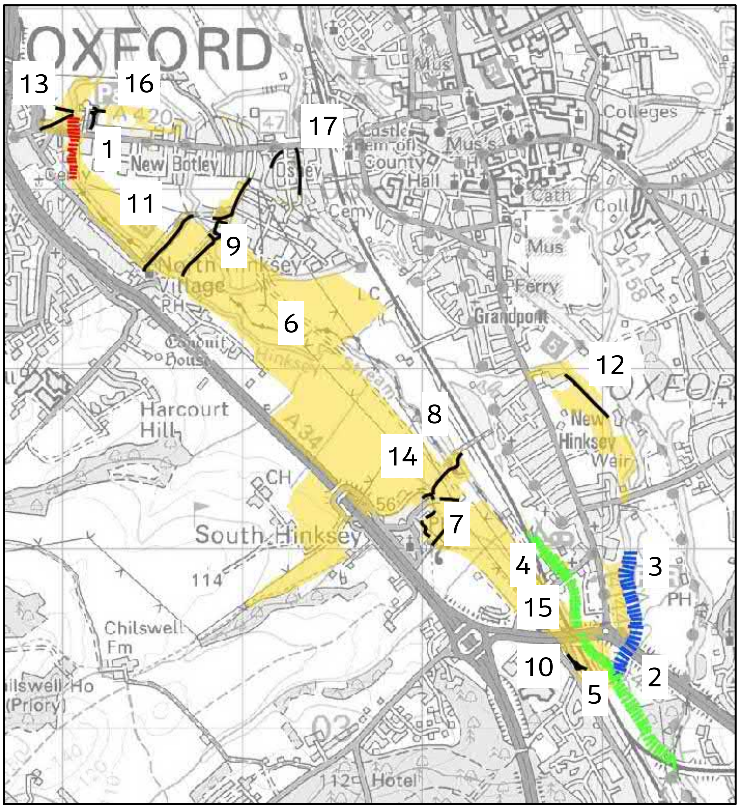


Figure 4.4: Locations of model updates

Table 4.1: Update to Do Minimum model – 1D

Ref	Update	Description	Survey Ref
1	Seacourt Stream: Botley Bridge to Hinksey Stream	Sections 47m.28S to 47m.024B replaced with SS.012 to SS.001 Sections 47m.024B to 47m.016Bd replaced with 47m.024 to 47m.016 Sections 47m.016Bd to 47m.015B replaced with SC02.014 to SC02.010	J00550 - 2016 00007 – 1982 08169 – 2004
2	Hinksey Stream: Cold Harbour Railway to River Thames	Sections 46g.016C to 46g.001E replaced with HKS073 to HKS001	J00551 - 2016
3	Weirs Mill Stream: 70m d/s Iffley Weirs to Hinksey Stream	Sections 46h.065A to 46h.051A replaced with WMS.031 to WMS.001	J00552 - 2016
4	Network Rail culvert	Culvert added to Do Minimum model with inlet orifice plate	J00551 – 2016 and As Built
5	Mundays Bridge reach	Sections MU01.009 to MU01.007d replaced with K007 to K001. Pond adjacent to hin3b6a modelled in 1D	B174 As Built - 2013

Table 4.2: Update to Do Minimum model – 2D

Ref	Update	Description	Survey Ref
6	Topo DTM	Use the Topo DTM where is overlaps the LIDAR DTM	J00553 (all)
7	2D Z-line South Hinksey	Floodplain feature added using top of bank string from Topo 2d_zsh_J00553_02_L.shp | 2d_zsh_J00553_02_P.shp	J00553_02
8	2D Z-line Devils Backbone	Improved track level of Devils Backbone 2d_zsh_J00553_03_L.shp | 2d_zsh_J00553_03_P.shp	J00553_03
9	2D Z-line Ferry Hinksey Road, area d/s Willow Walk	Feature added to represent levels at Ferry Hinksey Road and track across Bulstake Stream and floodplain 2d_zsh_J00553_05_L.shp | 2d_zsh_J00553_05_P.shp	J00553_05
10	2D Z-line Pond area	Floodplain feature added using top of bank string from Topo 2d_zsh_J00553_10_L.shp | 2d_zsh_J00553_10_P.shp	J00553_10
11	2D Z-line Willow Walk	Improved track level of Willow Walk 2d_zsh_J00553_17_L.shp | 2d_zsh_J00553_17_P.shp	J00553_17
12	2D Z-line Hotel New Hinksey	Floodplain feature added using top of bank string from Topo 2d_zsh_J00553_18_L.shp | 2d_zsh_J00553_18_P.shp	J00553_18
13	2D Z-line Seacourt Stream	Floodplain feature added using top of bank string from Topo 2d_zsh_J00553_19_L.shp | 2d_zsh_J00553_19_P.shp	J00553_19
14	Devils Backbone	Estry Culvert dimensions improved	J00553_03
15	Network Rail Track Raising	2d_zsh_rail_proposed_01_polyline.shp | 2d_zsh_rail_proposed_01_point.shp	Network Rail Model
16	2D Z-line Seacourt P&R Road	Floodplain feature added using top of bank string from Topo 2d_zsh_J00553_15_L.shp | 2d_zsh_J00553_15_P.shp	J00553_15
17	2D Z-line Osney Island	Floodplain feature added using verge and road string from Topo 2d_zsh_J00553_20_L.shp | 2d_zsh_J00553_20_P.shp	J00553_20

Following the model review (Appendix H), additional reporting is included below to clarify the schematisation for the Seacourt Stream (Ref 1, Table 4.1) and Hinksey Stream (Ref 2, Table 4.1).

4.2.1 Seacourt Stream

The model review queried one of the new cross sections for Seacourt Stream which included 2 channel sections (node SC02.010, surveyed 2004). This section was reviewed and confirmed by new topographic survey and retained within the model (Figure 4.5).

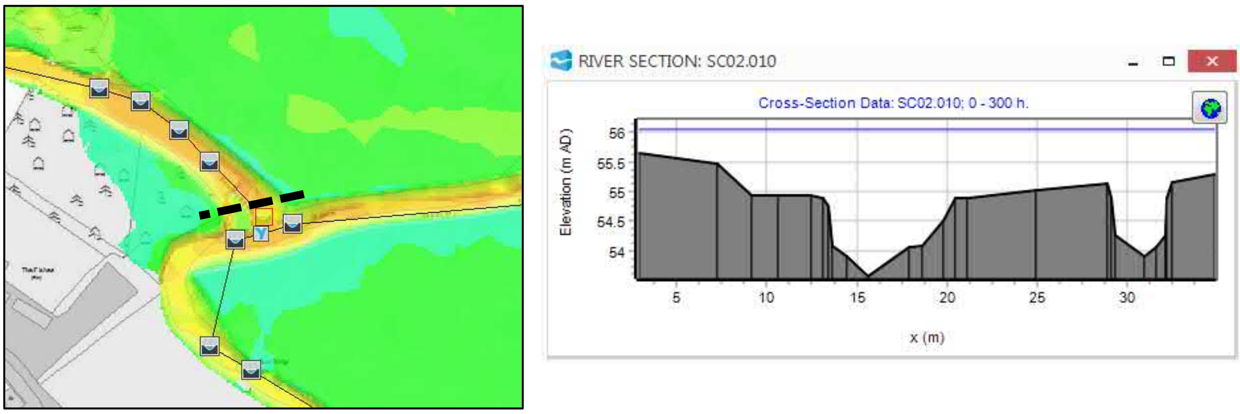
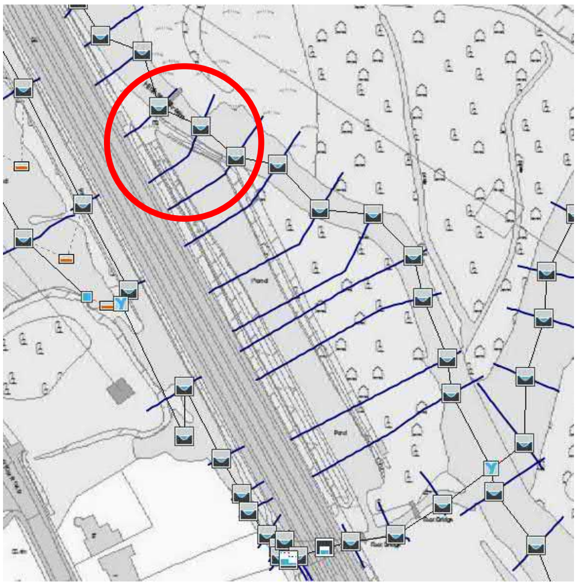


Figure 4.5: Seacourt Stream

4.2.2 Hinksey Stream

The review queried the cross sections at HKS.034, HKS.033 and HKS.032. Initially the right bank sections were deactivated due to a localised raised bank. This had a minor localised impact on the results due to the right bank deactivation. The sections have been extended up to the railway using the bank level.

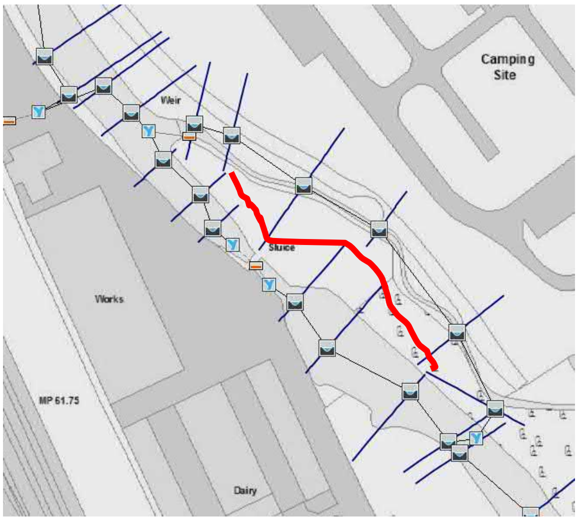
These results show the 2-year event remaining in bank (as the bank is not exceeded) and events 5-year and above using the extended cross section.



The 2014 model represented a single reach of cross sections for the Towles Mill reach. The model was updated with new cross sections at Towles Mill. The schematisation included separate reaches for the main channel and bypass channel.

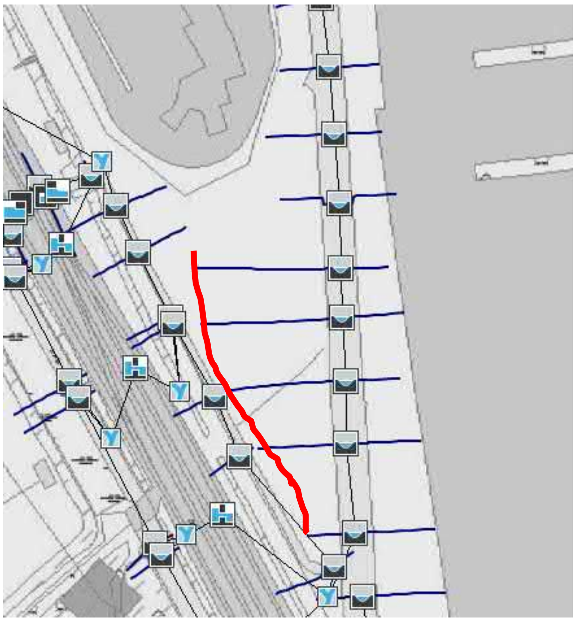
The review queried why spills were not included between the reaches (indicated by red line).

As the reaches are short and water levels are very similar in the parallel channels, the requirement of a spill was not necessary. The influence on results of not having the spill would be negligible.



Similar review query on why spills were not included between the reaches (indicated by red line).

As the reaches are short and water levels are very similar in the parallel channels, the requirement of a spill was not necessary. The influence on results of not having the spill would be negligible.



4.3 Downstream boundary

The model downstream boundary is located 2.7 km below Sandford Lock, represented as a normal depth boundary which has been used for updated do minimum and detailed design models. The normal depth boundary is suitable for the flood model, confirmed by the previous model calibration and the sensitivity test undertaken during Peer Review 2 (Outline Design modelling). The sensitivity test concluded the impact of raising the water levels by +0.25m at the boundary would extend just upstream of Sandford lock (increase in 1cm), there was no increase in water level at Iffley Lock (Head and Tail).

However, for low flows the normal depth boundary would not represent the downstream SHWL at Abingdon Lock and would underestimate the water level below Sandford Lock. Therefore, the downstream boundary has been adjusted for the low flow model. Figure 4.6 compares the modelled flow/water level relationship at Sandford Lock Tail, which shows the problem with the original boundary at low flow (dashed line). The results from the adjusted low flow boundary and flood model show good agreement with the spot flows which were gauged as part of this study.

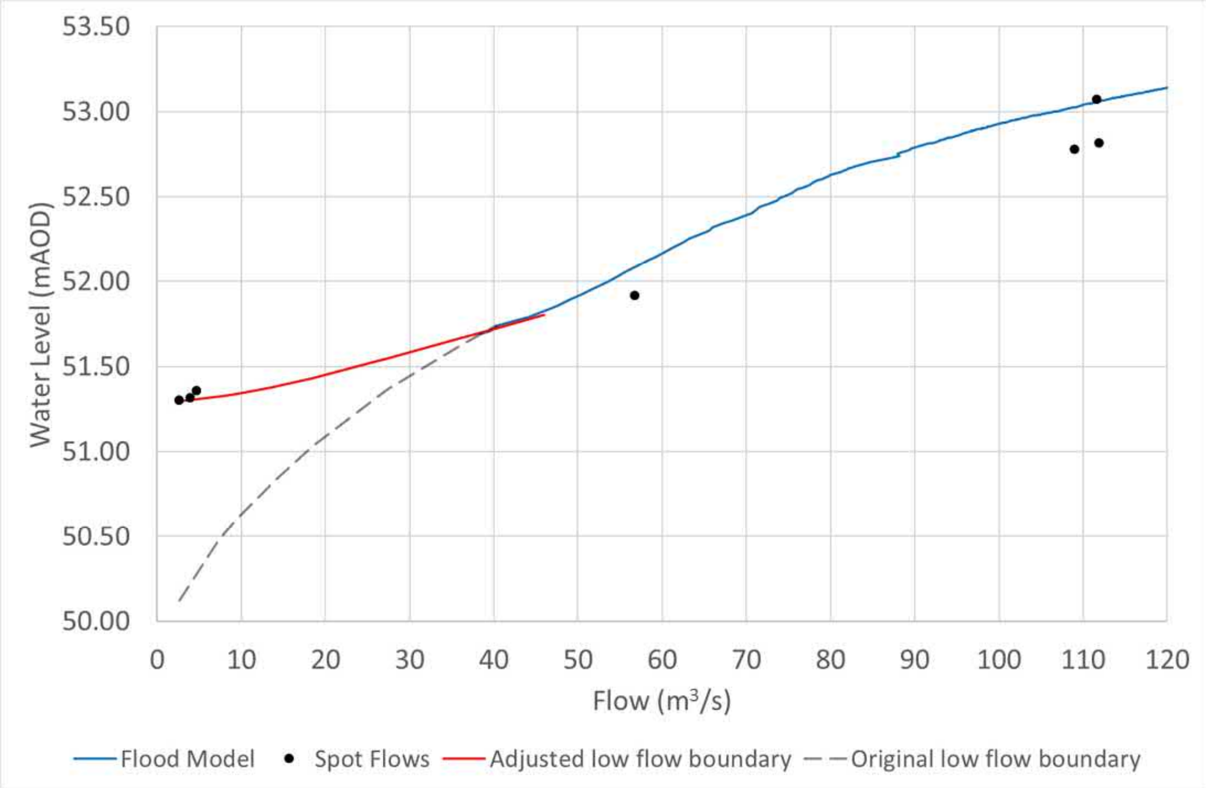


Figure 4.6: Downstream boundary check at Sandford Lock (Tail)

4.4 Temporary defences

The temporary defences which are deployed during flood events in Oxford have not been considered in the modelling results presented for the 2018 modelling.

4.5 Results

Peak water levels and comparison with the previous baseline modelling (at outline design stage) are detailed in Table 4.3 and Table 4.4 at the locations in Figure 4.7.

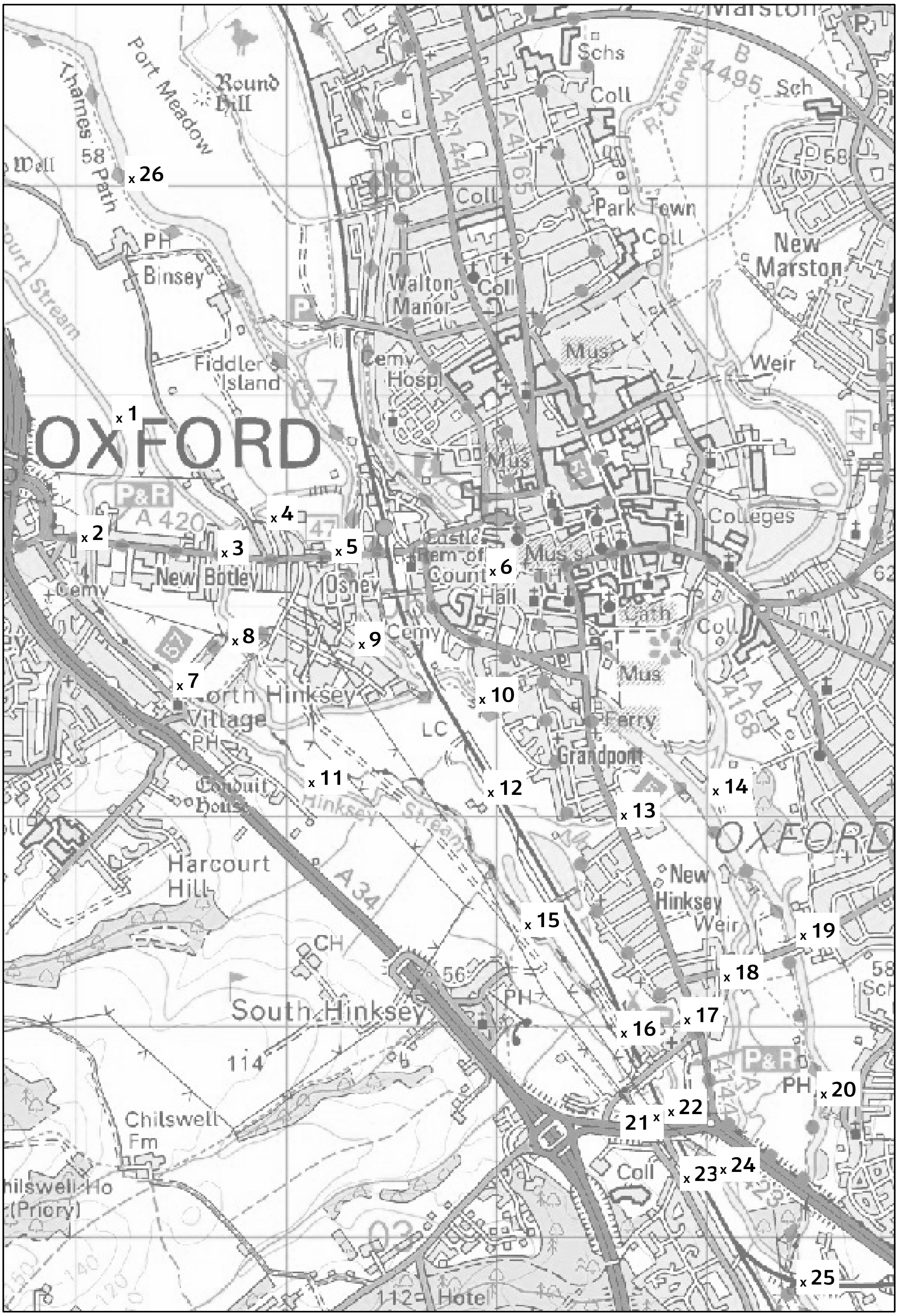


Figure 4.7: Model results node locations

Table 4.3: Do Minimum peak water levels and comparison

		50% AEP (2-year)			20% AEP (5-year)			10% AEP (10-year)			5% AEP (20-year)			2% AEP (50-year)			1.3% AEP (75-year)		
Re	Location	2015	2017	Diff	2015	2017	Diff	2015	2017	Diff	2015	2017	Diff	2015	2017	Diff	2015	2017	Diff
1	Seacourt/Botley Stream	56.93	56.89	-0.04	57.16	57.12	-0.05	57.30	57.27	-0.04	57.40	57.36	-0.03	57.50	57.47	-0.03	57.55	57.51	-0.03
2	Seacourt at Botley Road	56.84	56.70	-0.13	57.10	57.02	-0.09	57.24	57.17	-0.07	57.33	57.27	-0.07	57.44	57.37	-0.07	57.49	57.41	-0.07
3	Bulstake at Botley Road	56.68	56.65	-0.04	56.95	56.92	-0.03	57.08	57.05	-0.03	57.17	57.14	-0.02	57.26	57.24	-0.02	57.31	57.28	-0.03
4	Osney Ditch	56.77	56.73	-0.04	57.14	57.09	-0.05	57.28	57.25	-0.03	57.37	57.34	-0.03	57.47	57.44	-0.03	57.52	57.49	-0.03
5	Thames at Botley Road	56.77	56.77	0.00	56.86	56.84	-0.02	56.98	56.96	-0.03	57.07	57.04	-0.04	57.19	57.14	-0.05	57.24	57.18	-0.06
6	Castle Mill Stream	56.64	56.64	0.00	56.74	56.72	-0.02	56.83	56.81	-0.02	56.90	56.87	-0.02	56.98	56.96	-0.02	57.02	56.99	-0.02
7	Seacourt Willow Walk	56.26	56.29	0.03	56.46	56.52	0.06	56.55	56.62	0.07	56.64	56.70	0.06	56.72	56.77	0.05	56.76	56.80	0.04
8	Bulstake Willow Walk	56.35	56.31	-0.05	56.49	56.48	-0.02	56.58	56.57	0.00	56.71	56.71	0.00	56.80	56.79	0.00	56.83	56.83	-0.01
9	Thames d/s Osney	55.99	55.97	-0.02	56.21	56.19	-0.03	56.34	56.32	-0.02	56.42	56.41	-0.01	56.53	56.53	0.00	56.58	56.58	0.00
10	Thames	55.73	55.71	-0.02	55.94	55.92	-0.02	56.09	56.06	-0.02	56.19	56.18	-0.01	56.31	56.32	0.01	56.37	56.38	0.01
11	Hinksey Stream	55.85	55.83	-0.02	56.08	56.06	-0.02	56.22	56.20	-0.02	56.32	56.32	0.00	56.45	56.46	0.01	56.51	56.52	0.01
12	Eastwyke Ditch (west)	55.75	55.74	-0.01	56.00	55.98	-0.02	56.14	56.13	-0.02	56.23	56.23	0.00	56.34	56.35	0.01	56.39	56.40	0.01
13	Eastwyke Ditch Abingdon Rd	55.50	55.47	-0.04	55.69	55.66	-0.03	55.83	55.80	-0.03	55.92	55.91	-0.01	56.02	56.02	0.00	56.07	56.07	0.00
14	Thames (Cherwell Conf)	55.47	55.45	-0.02	55.68	55.65	-0.02	55.81	55.78	-0.02	55.90	55.89	-0.01	55.99	56.00	0.01	56.03	56.05	0.01
15	Devils Backbone	55.60	55.57	-0.03	55.96	55.92	-0.04	56.13	56.12	-0.02	56.25	56.25	0.01	56.39	56.41	0.02	56.44	56.46	0.02
16	Cold Harbour Bridges	55.38	55.30	-0.08	55.80	55.76	-0.03	56.05	56.05	0.00	56.19	56.20	0.02	56.34	56.37	0.03	56.40	56.42	0.03
17	Mayweed Bridge	55.05	55.12	0.07	55.51	55.60	0.09	55.82	55.88	0.06	55.98	56.03	0.04	56.18	56.17	-0.01	56.24	56.22	-0.02
18	Weirs Mill Stream (d/s Weirs)	54.93	54.90	-0.02	55.11	55.09	-0.02	55.21	55.21	0.00	55.30	55.31	0.01	55.45	55.47	0.02	55.52	55.54	0.03
19	Thames Donnington Road	55.20	55.19	-0.02	55.44	55.42	-0.03	55.59	55.56	-0.03	55.69	55.68	-0.01	55.79	55.79	0.00	55.82	55.83	0.01
20	Thames Iffley Lock u/s	55.03	55.02	-0.01	55.29	55.26	-0.02	55.43	55.41	-0.02	55.54	55.53	-0.01	55.65	55.66	0.00	55.69	55.70	0.01
21	A423 West (Hinksey Ditch)	54.81	54.84	0.03	55.06	55.12	0.06	55.22	55.29	0.07	55.33	55.40	0.06	55.50	55.53	0.04	55.56	55.59	0.03
22	A423 East (Hinksey Stream)	54.87	54.88	0.02	55.16	55.17	0.01	55.35	55.33	-0.02	55.48	55.42	-0.05	55.62	55.52	-0.09	55.67	55.57	-0.10
23	Mundays Bridge	54.73	54.74	0.01	54.93	54.95	0.02	55.05	55.08	0.02	55.15	55.18	0.02	55.32	55.32	0.00	55.39	55.38	-0.01
24	End of Weirs Mill Stream	54.72	54.72	0.00	54.92	54.90	-0.01	55.04	55.02	-0.02	55.15	55.11	-0.04	55.28	55.23	-0.05	55.35	55.29	-0.06
25	Thames d/s Hinksey Stream	54.55	54.55	0.00	54.74	54.74	0.00	54.83	54.83	0.00	54.91	54.91	0.00	55.01	55.01	0.00	55.06	55.05	0.00
26	Thames Binsey/Port Meadow	57.55	57.55	0.00	57.62	57.62	0.00	57.67	57.67	-0.01	57.73	57.72	-0.01	57.81	57.79	-0.01	57.84	57.83	-0.01

Table 4.4: Do Minimum peak water levels and comparison

		1% AEP (100-year)			0.5% AEP (200-year)			0.1% AEP (1000-year)			1% AEP (100-year) +25%			1% AEP (100-year) +35%			1% AEP (100-year) +70%		
Re	Location	2015	2017	Diff	2015	2017	Diff	2015	2017	Diff	2015	2017	Diff	2015	2017	Diff	2015	2017	Diff
1	Seacourt/Botley Stream	57.58	57.55	-0.03	57.65	57.61	-0.03	57.81	57.78	-0.03	57.72	57.69	-0.03	57.79	57.76	-0.03	57.96	57.94	-0.02
2	Seacourt at Botley Road	57.52	57.44	-0.07	57.58	57.51	-0.07	57.74	57.67	-0.07	57.65	57.58	-0.06	57.71	57.65	-0.06	57.89	57.82	-0.07
3	Bulstake at Botley Road	57.34	57.31	-0.03	57.40	57.38	-0.02	57.58	57.52	-0.06	57.47	57.44	-0.02	57.52	57.50	-0.02	57.71	57.69	-0.02
4	Osney Ditch	57.55	57.52	-0.03	57.61	57.58	-0.03	57.76	57.73	-0.03	57.67	57.65	-0.03	57.74	57.71	-0.02	57.89	57.87	-0.02
5	Thames at Botley Road	57.28	57.21	-0.07	57.36	57.29	-0.07	57.51	57.46	-0.05	57.43	57.37	-0.07	57.49	57.44	-0.05	57.64	57.62	-0.02
6	Castle Mill Stream	57.04	57.02	-0.03	57.10	57.07	-0.02	57.23	57.20	-0.03	57.15	57.13	-0.02	57.21	57.19	-0.02	57.42	57.41	-0.01
7	Seacourt Willow Walk	56.79	56.83	0.04	56.85	56.88	0.03	57.01	57.02	0.01	56.92	56.94	0.02	56.99	57.01	0.01	57.17	57.18	0.01
8	Bulstake Willow Walk	56.86	56.85	-0.01	56.92	56.91	-0.01	57.07	57.06	-0.01	56.99	56.97	-0.01	57.05	57.04	-0.01	57.21	57.21	0.00
9	Thames d/s Osney	56.61	56.62	0.00	56.69	56.69	0.00	56.86	56.86	0.00	56.76	56.77	0.00	56.84	56.84	0.00	57.02	57.03	0.01
10	Thames	56.40	56.41	0.01	56.47	56.48	0.01	56.65	56.66	0.01	56.55	56.56	0.01	56.63	56.64	0.01	56.84	56.86	0.02
11	Hinksey Stream	56.54	56.55	0.01	56.62	56.62	0.01	56.78	56.79	0.00	56.69	56.70	0.01	56.77	56.77	0.00	56.95	56.96	0.01
12	Eastwyke Ditch (west)	56.43	56.43	0.00	56.50	56.50	0.00	56.68	56.69	0.00	56.58	56.58	0.00	56.66	56.67	0.00	56.86	56.88	0.02
13	Eastwyke Ditch Abingdon Rd	56.09	56.10	0.00	56.16	56.17	0.01	56.37	56.38	0.02	56.24	56.25	0.01	56.34	56.36	0.02	56.63	56.67	0.04
14	Thames (Cherwell Conf)	56.06	56.07	0.01	56.13	56.14	0.02	56.34	56.36	0.02	56.21	56.23	0.02	56.31	56.33	0.02	56.60	56.64	0.04
15	Devils Backbone	56.48	56.49	0.02	56.55	56.56	0.02	56.69	56.71	0.01	56.61	56.63	0.01	56.68	56.69	0.01	56.83	56.86	0.02
16	Cold Harbour Bridges	56.43	56.45	0.02	56.50	56.52	0.02	56.64	56.66	0.02	56.56	56.58	0.02	56.62	56.64	0.02	56.77	56.81	0.04
17	Mayweed Bridge	56.28	56.25	-0.03	56.34	56.30	-0.04	56.49	56.45	-0.04	56.41	56.36	-0.05	56.47	56.43	-0.04	56.66	56.67	0.01
18	Weirs Mill Stream (d/s Weirs)	55.57	55.60	0.02	55.70	55.72	0.02	56.02	56.04	0.02	55.85	55.87	0.02	55.99	56.01	0.02	56.35	56.37	0.03
19	Thames Donnington Road	55.85	55.85	0.01	55.90	55.91	0.01	56.08	56.09	0.01	55.95	55.96	0.01	56.06	56.06	0.01	56.38	56.40	0.02
20	Thames Iffley Lock u/s	55.73	55.74	0.01	55.79	55.80	0.01	56.01	56.02	0.01	55.87	55.88	0.01	55.98	55.99	0.01	56.33	56.35	0.02
21	A423 West (Hinksey Ditch)	55.61	55.64	0.03	55.73	55.74	0.01	56.00	56.01	0.01	55.86	55.86	0.01	55.97	55.98	0.01	56.18	56.24	0.06
22	A423 East (Hinksey Stream)	55.71	55.60	-0.11	55.79	55.67	-0.12	56.01	55.87	-0.14	55.88	55.75	-0.13	55.98	55.84	-0.14	56.26	56.17	-0.08
23	Mundays Bridge	55.44	55.43	-0.01	55.57	55.54	-0.03	55.86	55.82	-0.05	55.70	55.66	-0.04	55.83	55.79	-0.05	56.14	56.10	-0.04
24	End of Weirs Mill Stream	55.40	55.33	-0.07	55.51	55.42	-0.09	55.80	55.67	-0.12	55.64	55.54	-0.10	55.77	55.65	-0.12	56.12	55.97	-0.15
25	Thames d/s Hinksey Stream	55.09	55.09	0.00	55.17	55.17	0.00	55.38	55.37	0.00	55.26	55.26	0.00	55.35	55.35	0.00	55.62	55.62	0.00
26	Thames Binsey/Port Meadow	57.87	57.85	-0.02	57.93	57.92	-0.01	58.04	58.03	-0.01	57.99	57.98	-0.01	58.03	58.03	-0.01	58.13	58.12	-0.01

4.6 Model performance (Do Minimum)

The model runs well with no non-convergence for all events apart from the highest flow events (1000-year and 100-year +70%). Figure 4.8 details the convergence plots produced as part of the 1D model outputs.

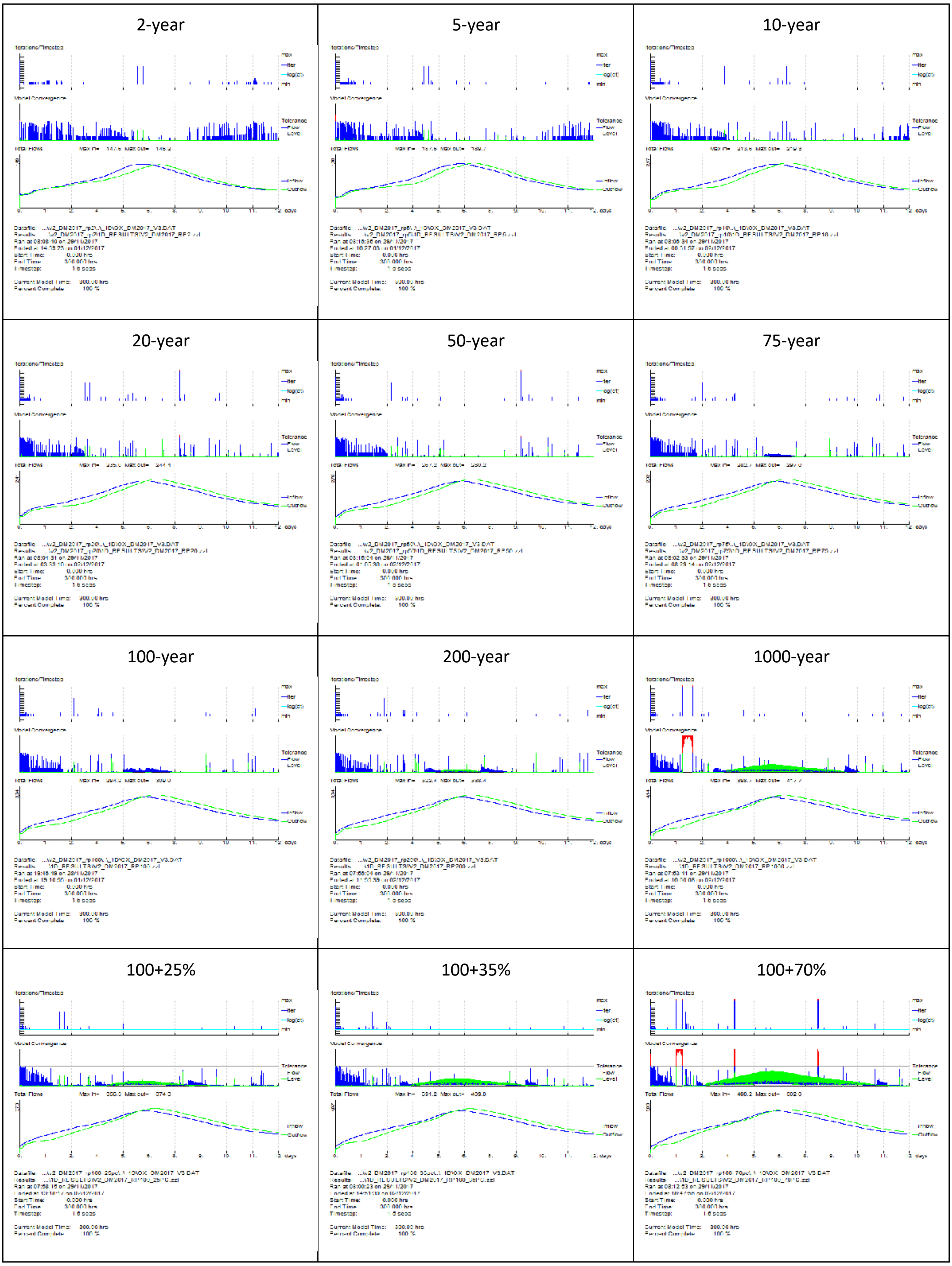


Figure 4.8: 1D convergence plots – Do Minimum

The area of non-convergence occurs at node OD01.014 (Osney Ditch, Helen Road footbridge) around 30-50 hours as detailed in Figure 4.9 (before peak water levels). During the larger flow events, when the capacity Osney Ditch is exceeded at Botley Road flows start to redistribute via Bulstake Stream causing negative flows around the footbridge which has been overtopped. For the 100-year +70% event there are attentional times of non-convergence at Binsey Bridge (Bulstake Stream BS01.056) which occur when the bridge enters orifice flow conditions. These instabilities also occur outside the time of peak water levels. The instabilities could be removed if the models are re-run in the future, Helen Road footbridge could be removed from the model as modelled water levels are similar upstream and downstream and a wider transition band for orifice flow could be added at Binsey Bridge.

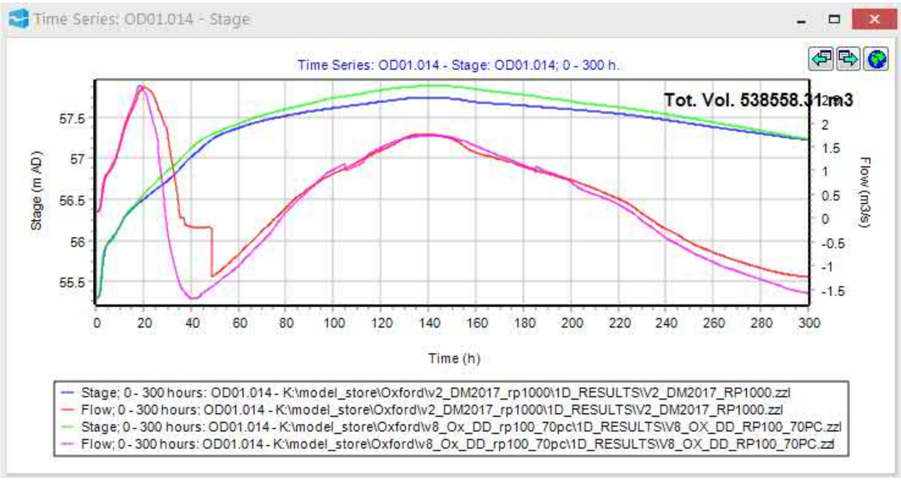


Figure 4.9: 1D Model non-convergence location

The 2D output of cumulative mass errors and dVol (smooth plots) are detailed in Figure 4.10. The cumulative mass errors are within +/- 1%.

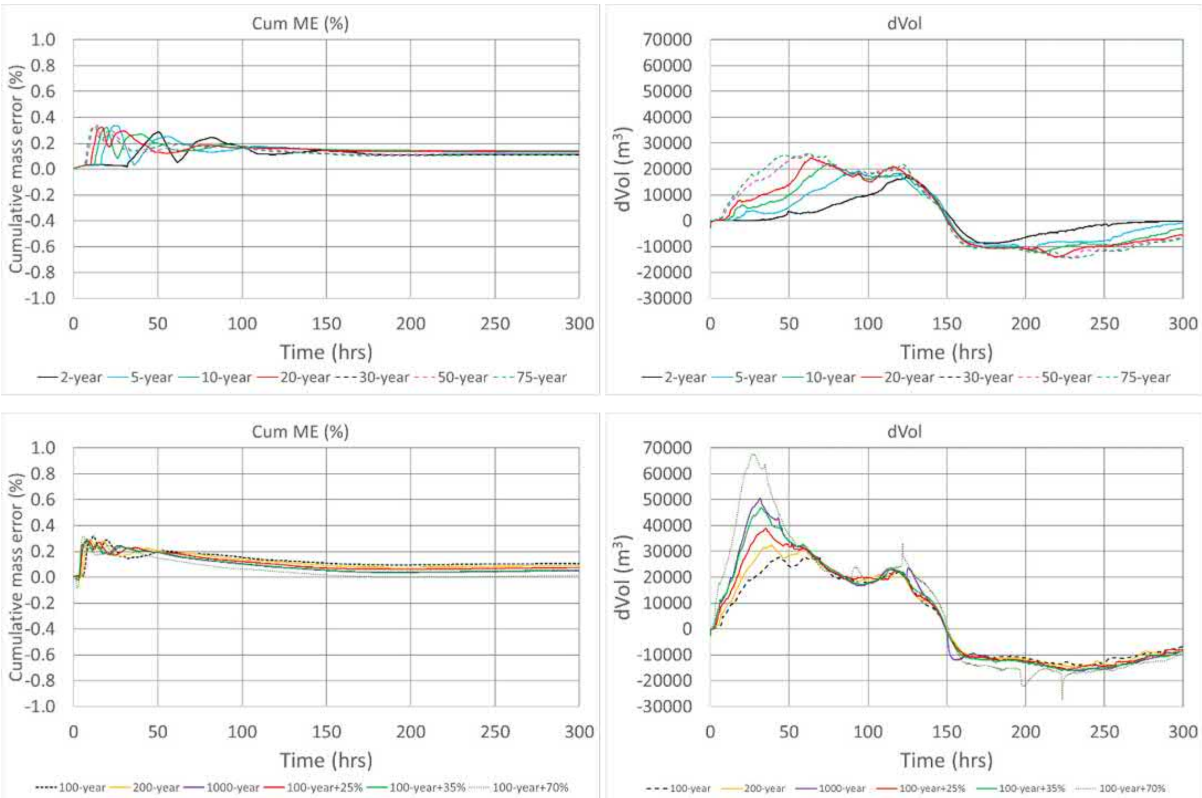


Figure 4.10: 2D Cumulative Mass Error and dVol (Do Minimum)

5. Main modelling stage: detailed design FAS model (2018)

5.1 Overview

The detailed design model was developed from the outline design model. The model incorporates all updated scheme elements, based on environmental/engineering design considerations and new survey. The resolution of the proposed channel has been increased with more cross sections. Figure 5.1 details the areas of the individual elements which make up the detailed design model (using the same area naming convention as the design drawings).

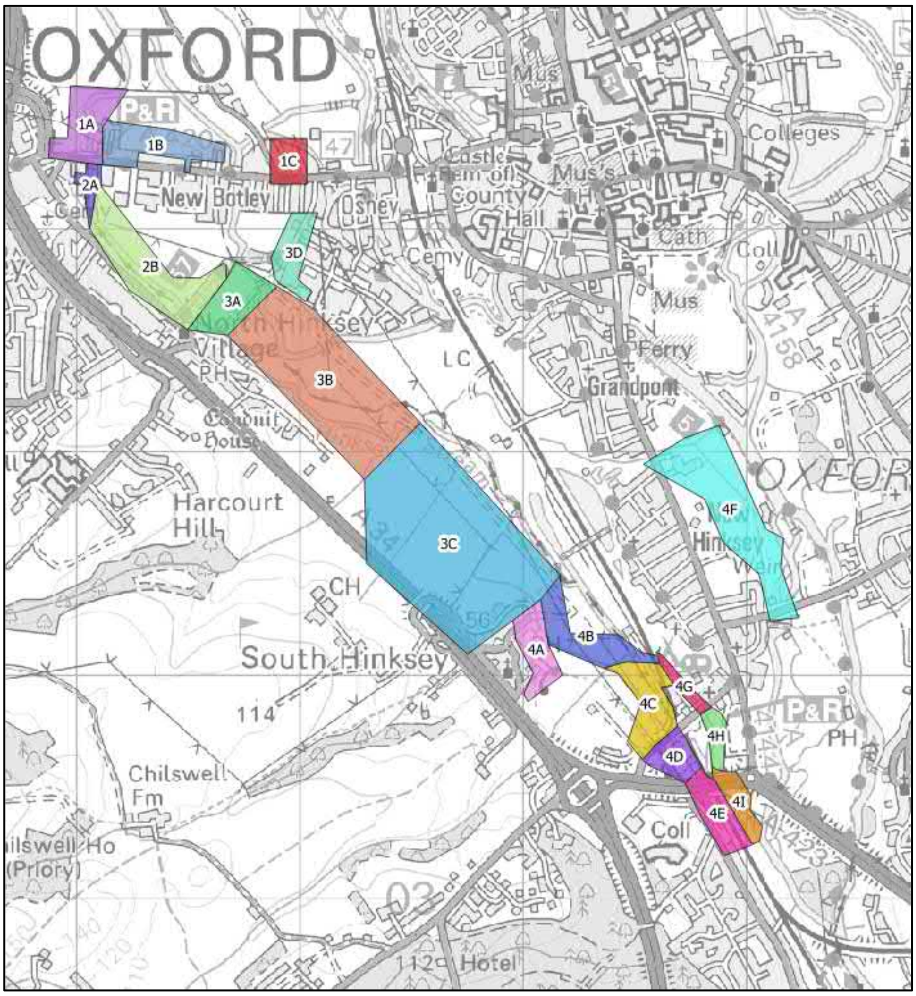


Figure 5.1: Overview of scheme areas

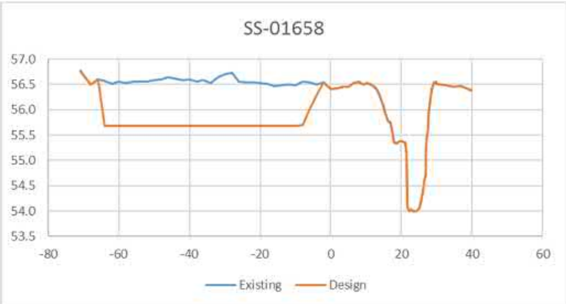
5.2 Model schematisation

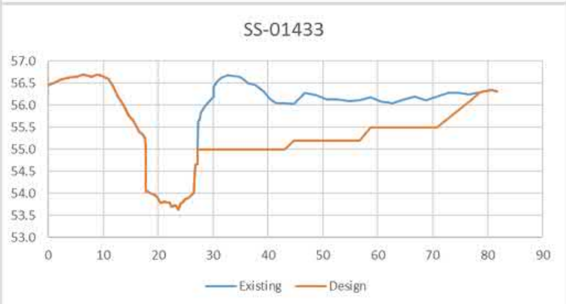
to Table 5.18 explain the schematisation in each area for detailed design model. Raised defences which will be set at 1% AEP event + 35% (100-year + 35%) peak level plus a freeboard allowance are currently set at 100mAOD (i.e. cannot be overtopped).

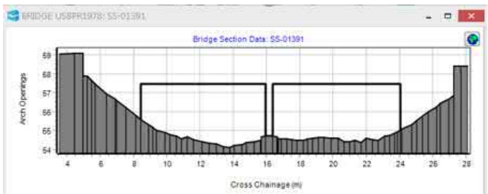
The roughness value for the proposed channel is set at 0.050. This is the same value as used in the baseline model for the existing Hinksey Stream channel and 2D floodplain.

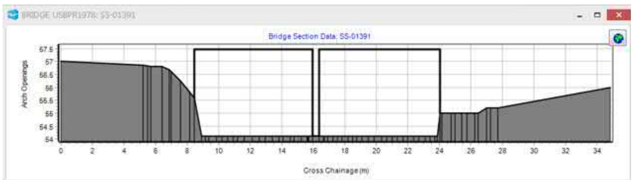
Table 5.1: Area 1A model schematisation

Seacourt Stream and defences to the west
A. 2-stage channel on Seacourt Stream left bank from nodes SS-01799 to SS-01541. Second stage 0.75m deep, area next to the bank as existing due to trees. No changes to original bed levels. B. Right bank stepped channel extending out to existing ground levels from nodes SS-01517 to SS-01391. Left bank no change, clearance to hard bed levels to Botley Road Bridge (Node SS-01517 to SS-01391). C. Full clearance of Botley Road Bridge. D. Embankment upstream of Botley Road on right bank (2d_zsh_FAS_Raised_Defences_v1.shp). Crest level set at 100.0mAOD
Example channels in reach A (top) and reach B (bottom)









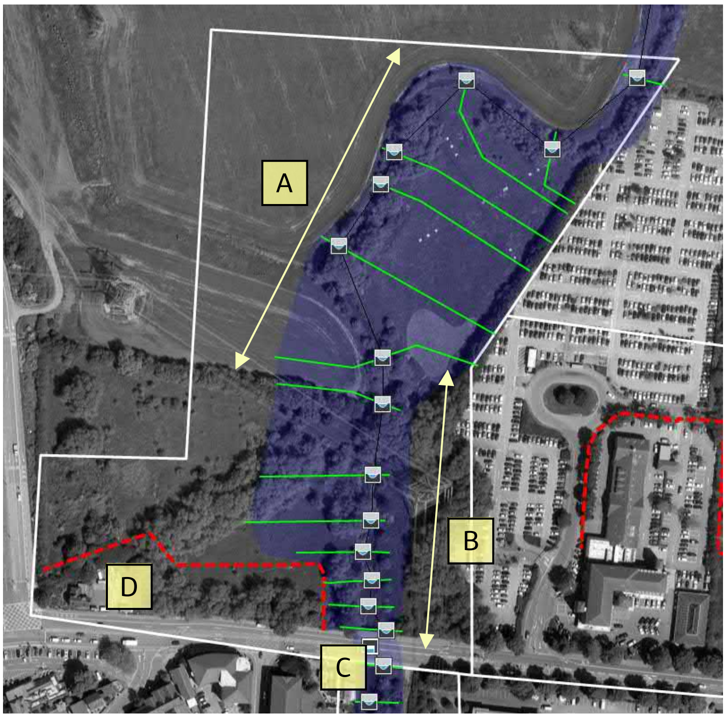


Table 5.2: Area 1B model schematisation

Raised defences to the east of Seacourt Stream
A. Embankment adjacent to Park and Ride and properties u/s Botley Road (2d_zsh_FAS_Raised_Defences_v1.shp). Crest level set at 100.00mAOD

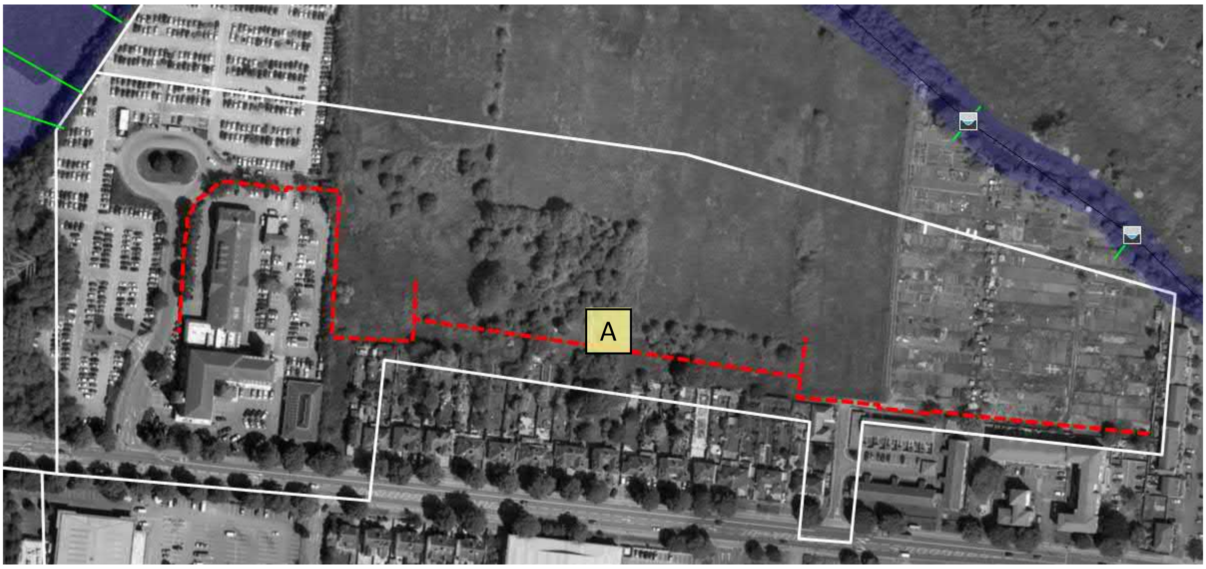
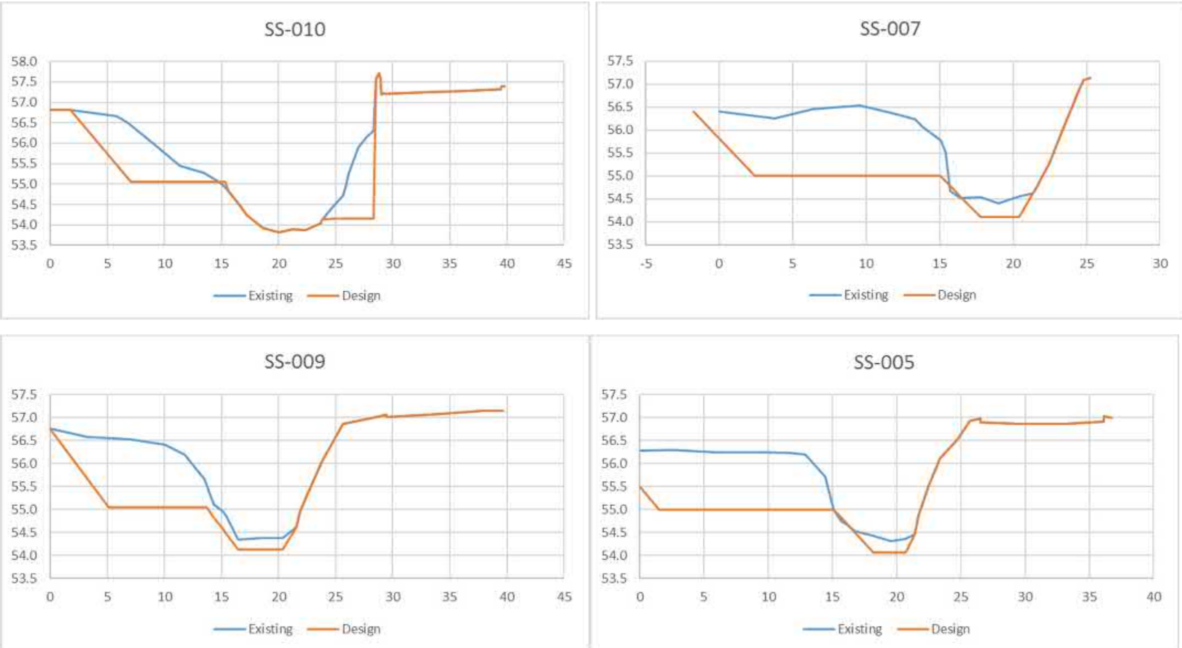


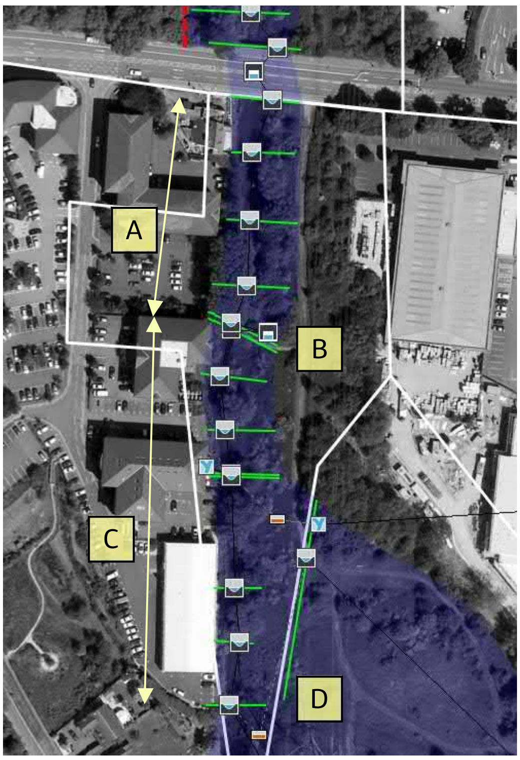
Table 5.3: Area 1C model schematisation

Flood Gates at Henry and Helen Road
A. Embankment adjacent to Park and Ride and properties u/s Botley Road (2d_zsh_FAS_Raised_Defences_v1.shp). Crest level set at 100.00mAOD
B. Low level defence at Allotment entrance. Crest level set at 57.25mAOD (2d_zsh_FAS_Allotment_v0.shp)

Table 5.4: Area 2A model schematisation

Downstream of Botley Bridge to spillway
A. Channel widening of left bank, with 1 in 3 slopes. Clearance of right bank adjacent to existing wall then right bank remains as existing. B. New Bridge at Minn's Estate, existing channel through right arch. C. Channel widening of left bank, with 1 in 3 slopes. right bank remains as existing. D. End of channel works, Seacourt Stream as existing.
Example channels in reach A (left) and reach C (right)





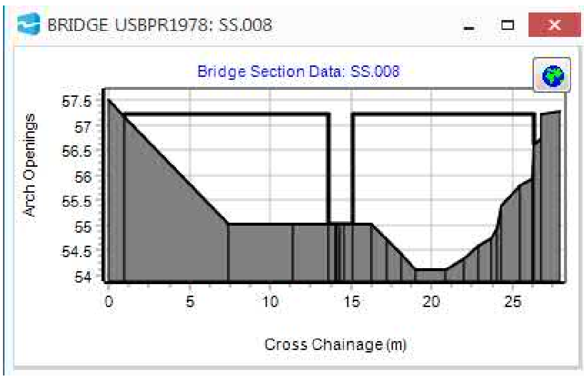
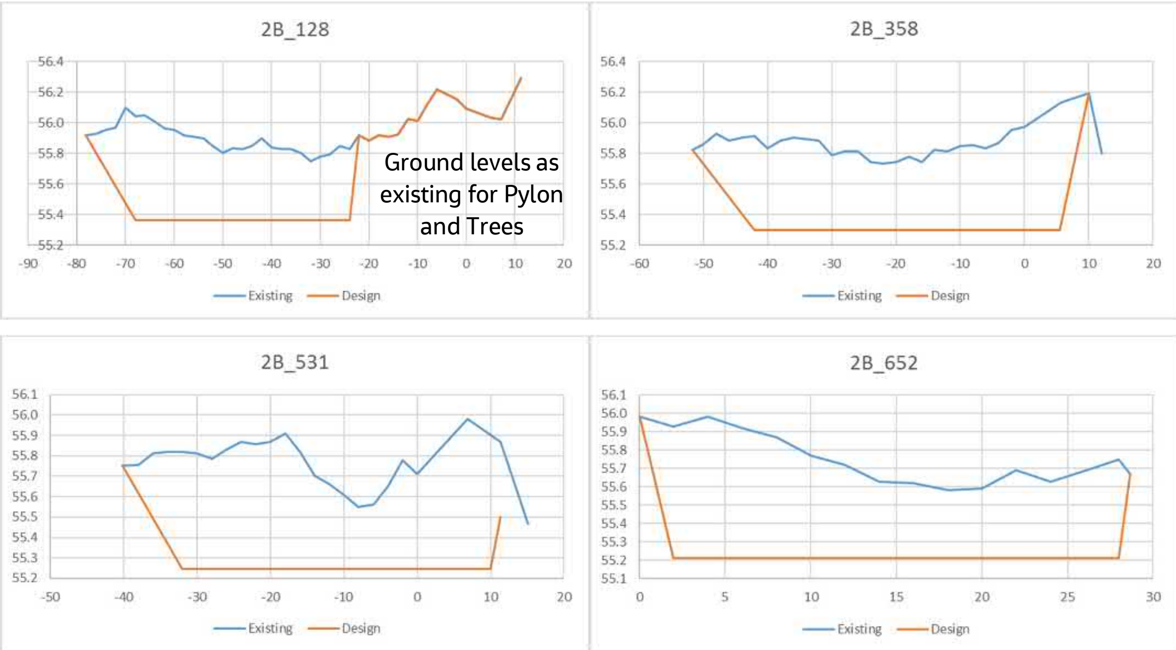


Table 5.5: Area 2B model schematisation

Spillway to Willow Walk
A. Spillway to new channel across access track, (2B_000su) crest level 55.50m AOD B. New channel, bed level 55.4mAOD to 55.2mAOD (Nodes 2B_000 to 2B_698), existing ground retained adjacent to Pylon. Side slopes 1 in 5 adjacent to Seacourt Stream and 1 in 10 on left bank. Channel will be dry under normal flow conditions. Seacourt Stream left bank lowered to 55.5m (spills 2B_215sru to 2B_440sru) C. New channel bed drops to 54mAOD to the new Willow Walk Bridge acts as a backwater channel (2B_699 to 2B_000) D. New Bridge under Willow Walk (WW_bu), 19.1m wide, soffit 57.12mAOD E. Existing pipe culverts under Willow Walk removed (2 sets of 3 culverts)
Example channels in reach B



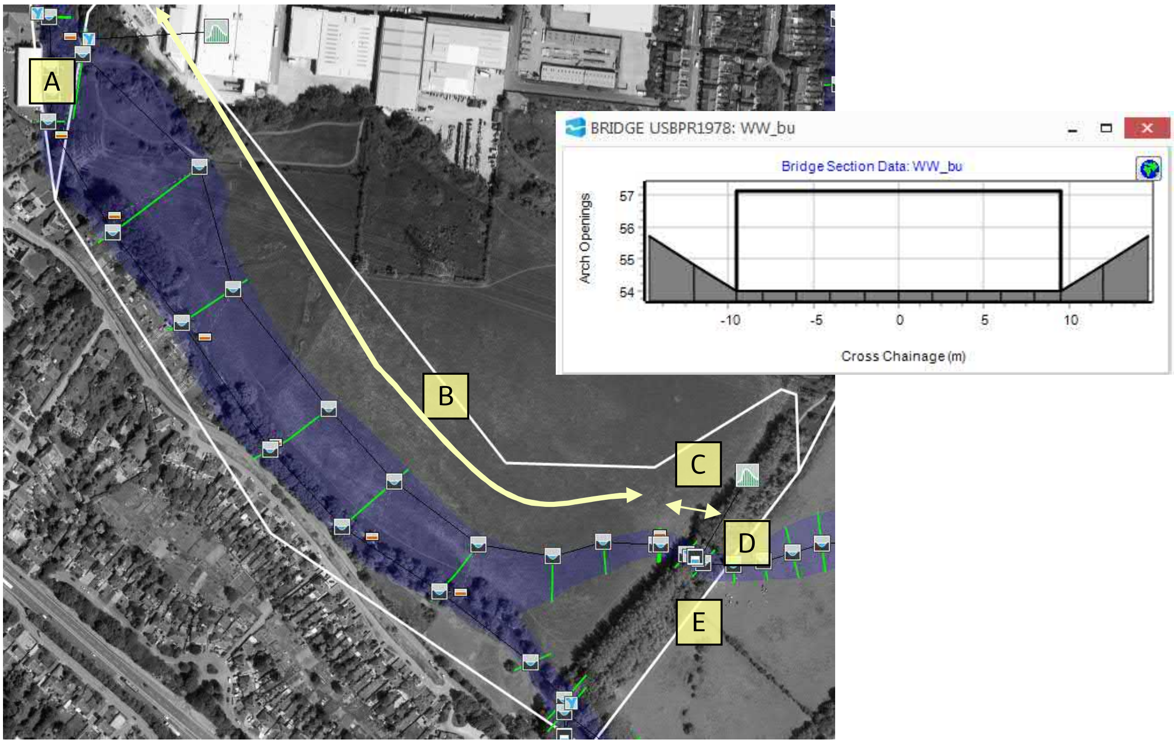
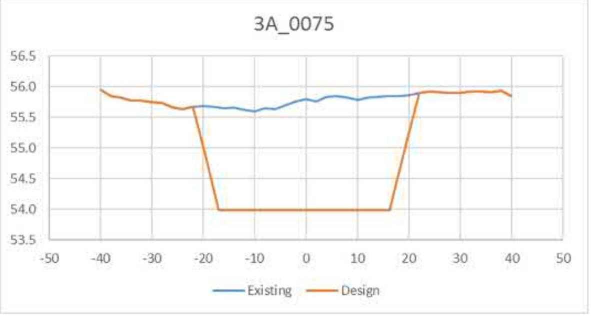


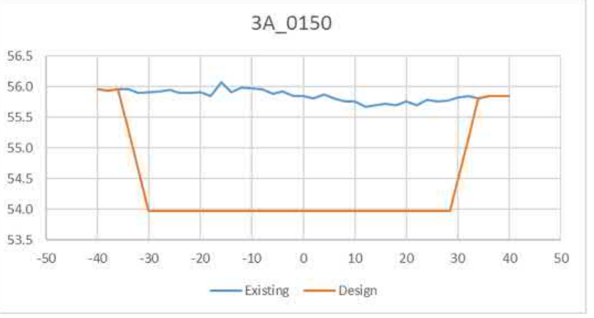
Table 5.6: Area 3A model schematisation

Willow Walk to Monks Causeway

A. New channel between Willow Walk and Monks Causeway, bed level 54mAOD side slopes 1 in 3 (3A_0000 to 3A_0200)
B. New Bridge (NH_bru), 23.05m wide, soffit 56.98mAOD.

Example channels in reach A





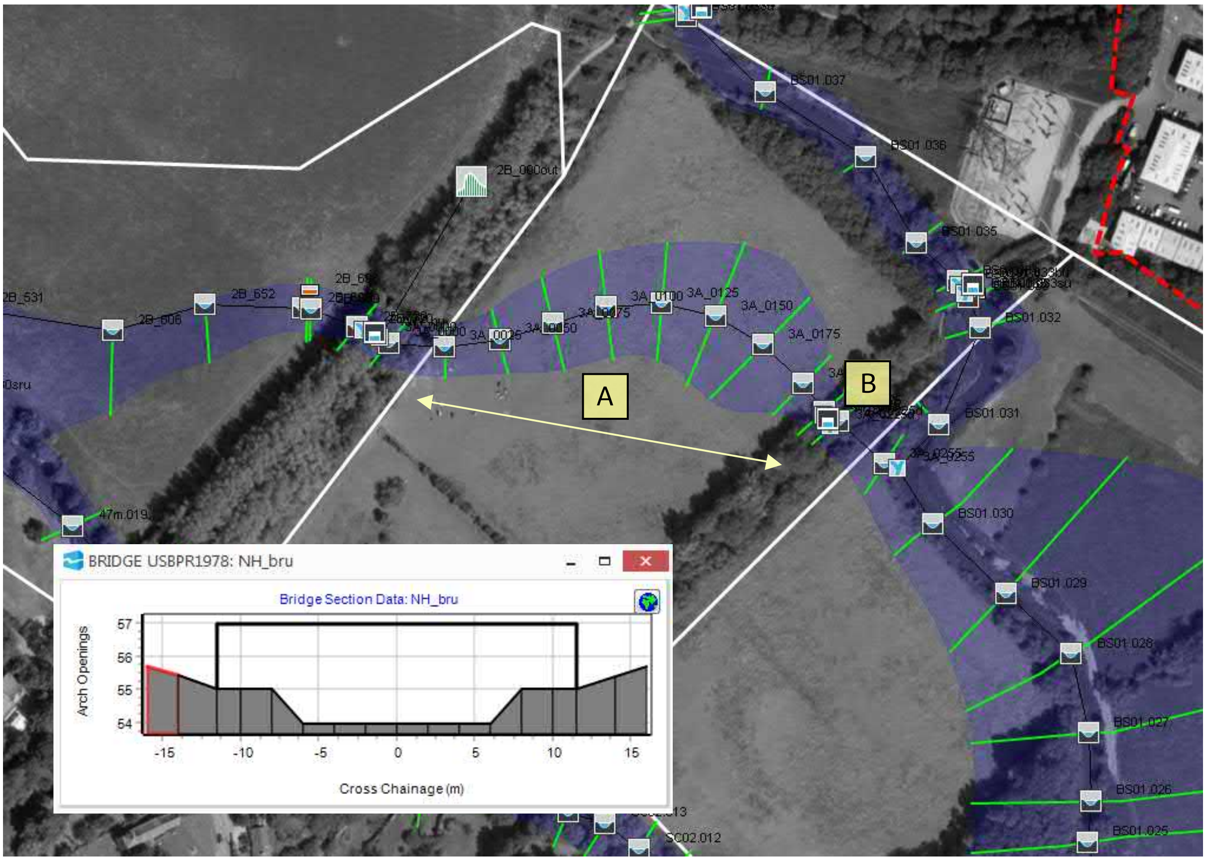


Table 5.7: Area 3B model schematisation

Monks Causeway to bifurcation from Hinksey Stream
A. Bulstake Stream retained, second stage at 55.00mAOD to 54.92mAOD, side slopes 1 in 20 (BS01.030 to BS01.022).
B. In-line weir to Bulstake Stream, crest level 54.85mAOD (BS01.016u).
C. Ditch link between Seacourt and Bulstake removed, weir level 55.2mAOD (47m.013B)
D. New Bridge (Bul_bu), 8.00m wide, soffit 55.04mAOD. Bypassed in second stage channel 54.98mAOD (Bul_SU)
E. New channel (WC578 to WC740) with pools/riffles, typically 8-9m wide in first stage, second stage at 54.92mAOD to 54.90mAOD, side slopes 1 in 20.
F. Hinksey Stream retained, second stage at 54.90mAOD to 54.81mAOD, side slopes 1 in 20 (HS2.037 to HS2.027).
G. In-line weir to Hinksey Stream, crest level 54.78mAOD (HS2.026u).
H. Within reach A and D, 4 low flows weirs (3 in A and 1 weir in reach d). Weirs to maintain Q_{95} water levels in Bulstake Stream

Example channels in reach A

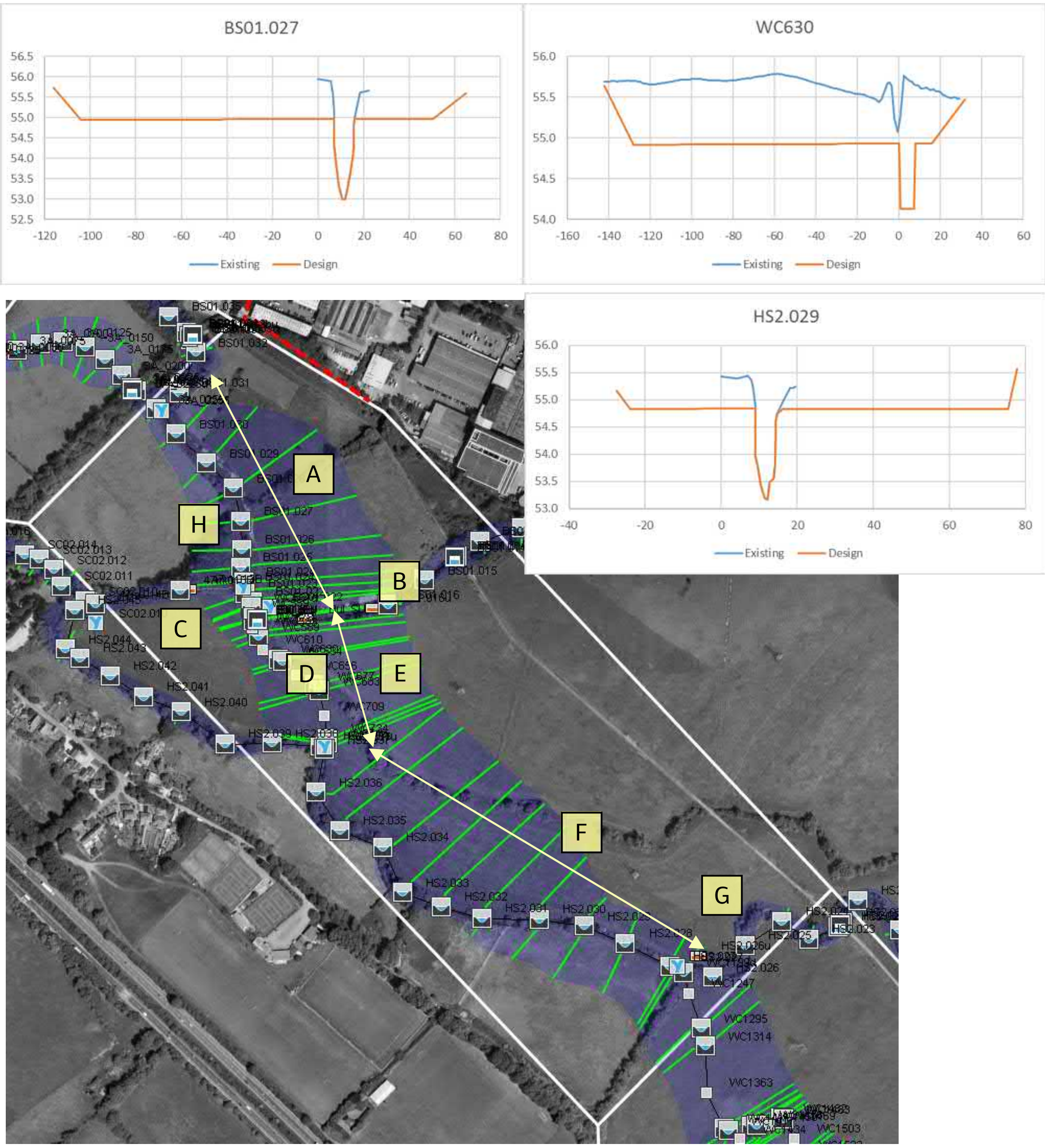


Table 5.8: Area 3C model schematisation

Hinksey Stream bifurcation to Devils Backbone
A. New channel (WC1199d to WC420) with pools/riffles, typically 14-15m wide in first stage, second stage at 54.81mAOD to 54.60mAOD, side slopes 1 in 20.
B. New ford crossing (Ford1570)
C. New Bridge at Devils Backbone(DB_bru), 19.10m wide, soffit 56.92mAOD. replaces existing culverts.
D. Adjustment applied to cross section relative path lengths

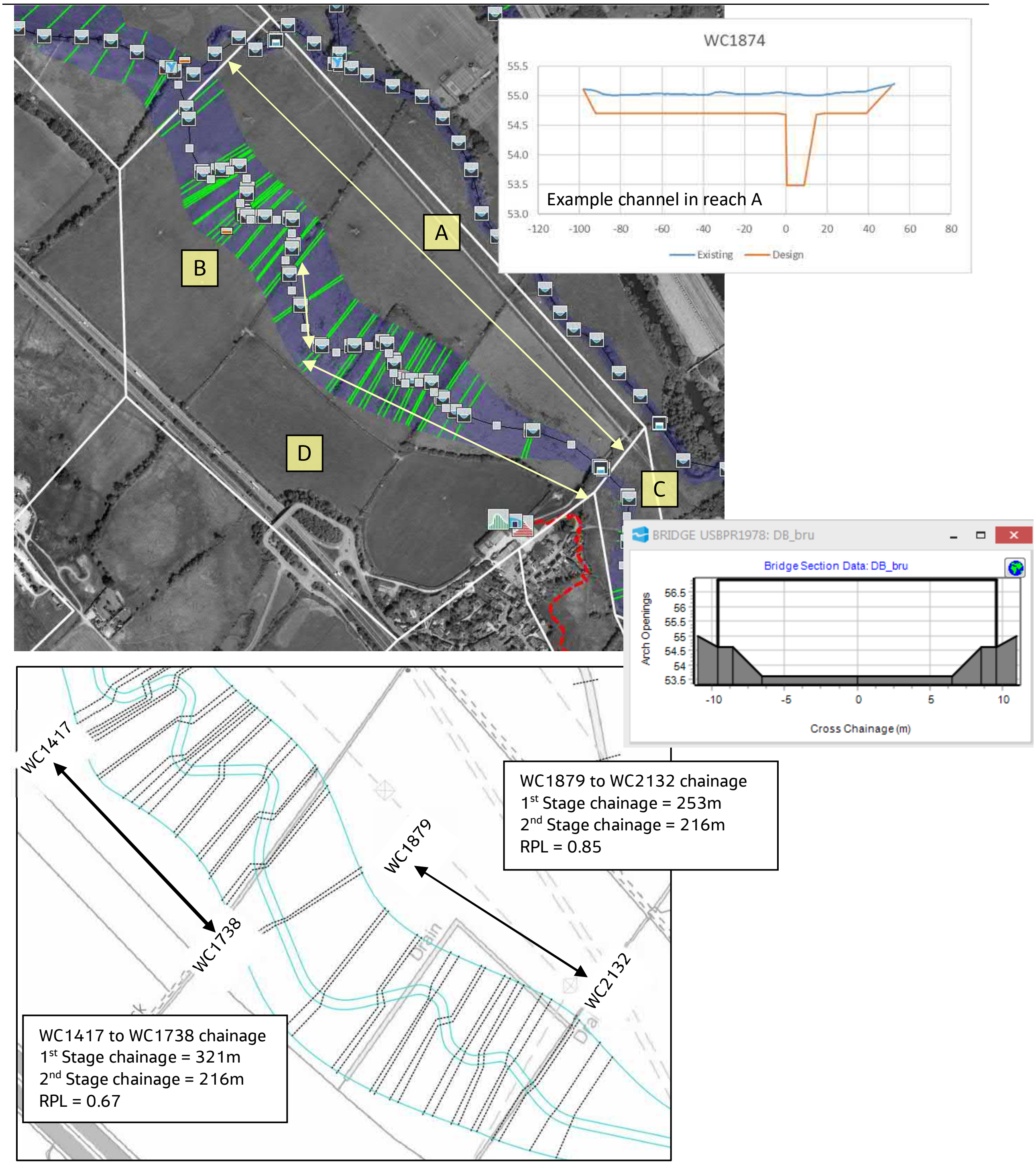


Table 5.9: Area 3D model schematisation

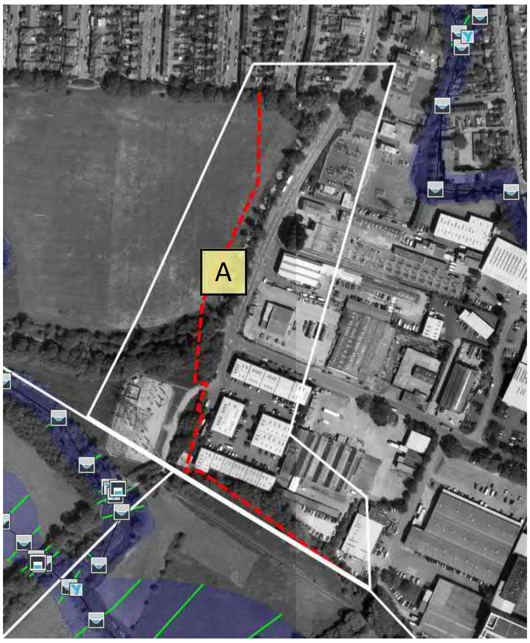
Raised Defences at Ferry Hinksey Road
A. Embankment/wall adjacent to Ferry Hinksey Road (2d_zsh_FAS_Raised_Defences_v0.shp). Crest level set at 56.70mAOD to tie in with existing access track levels.


Table 5.10: Area 3E model schematisation

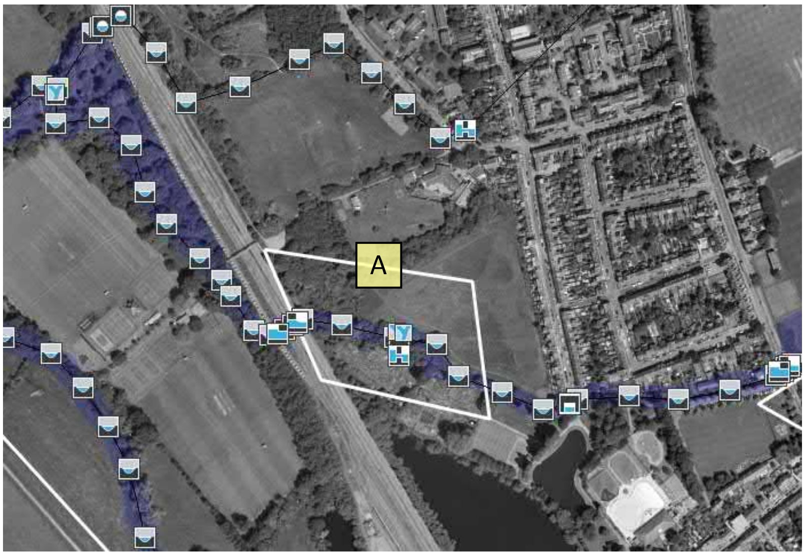
Eastwyke Ditch
A. Control structure (tilting gate) east of the railway to restrict flow to the Thames (Node EW01.020fd). Modelled as flapped orifice unit to ensure flow is restricted when levels on the western side of the railway are higher (so flap shuts). Bank levels set to 56.50m AOD between the railway and structure to prevent bypassing. The structure will also be used to regulate low flows to ensure that Q95 flows remain in the River Thames. Appendix K provides as assessment to show the impacts of not closing the structure during a flood event.


Table 5.11: Area 4A model schematisation

Raised Defences at South Hinksey
A. Embankment/wall adjacent South Hinksey (2d_zsh_FAS_Raised_Defences_v0.shp). Crest level set at 100.00mAOD. B. Low level defence to prevent 100-year flooding around the edge of the raised defence (2d_zsh_South_Hinksey_Kerb_P.shp), level set at 56.62m (+0.3m)

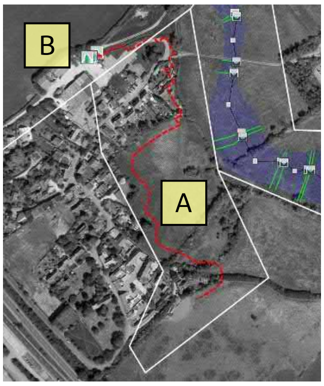
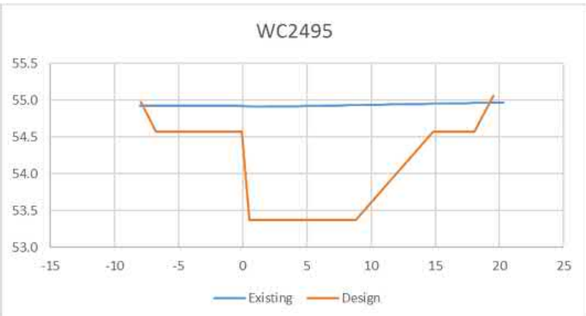
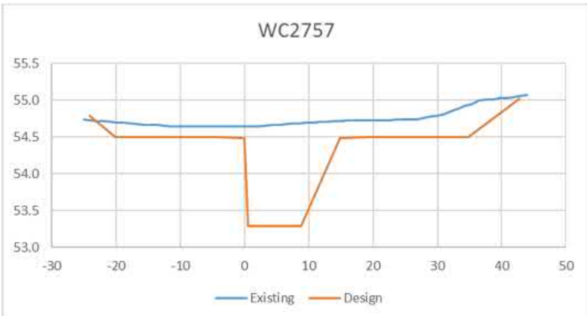


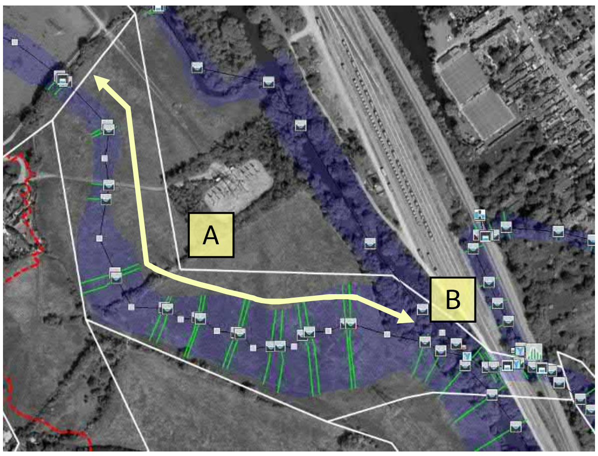
Table 5.12: Area 4B model schematisation

Devils Backbone to Hinksey Stream at Cold Harbour Railway Crossing
A. New channel (WC2420 to WC3018) with pools/riffles, typically 14-15m wide in first stage, second stage at 54.60mAOD to 54.40mAOD, side slopes 1 in 3 constrained sections and side slopes 1 in 20 for wider second stage. B. New Weir at the end of the existing pond in Hinksey Stream to maintain levels at normal/low flow conditions. Crest level 54.45mAOD (46g.020CC).

Example channels in reach A







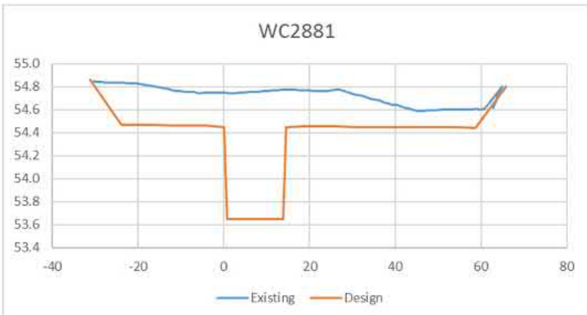
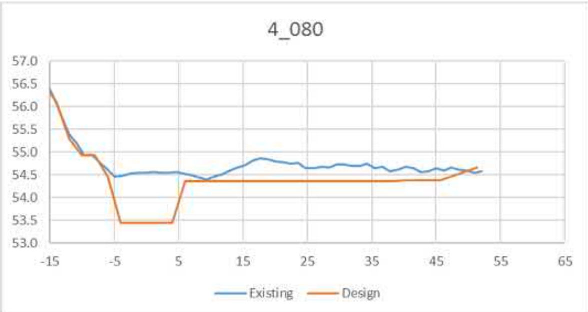
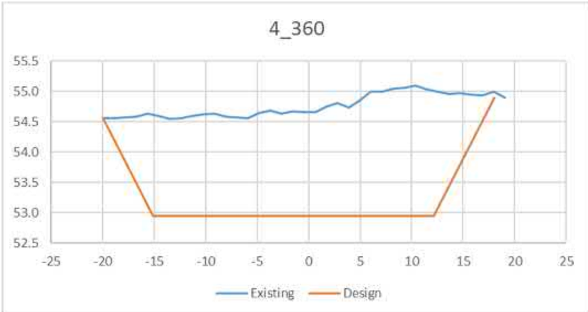


Table 5.13: Area 4C model schematisation

Hinksey Stream at Cold Harbour Railway Crossing to new bridge at Old Abingdon Road
A. New channel (4_000 to 4_240), typically 14m wide in first stage, second stage at 54.40mAOD to 54.30mAOD, side slopes 1 in 20 for wider second stage. B. New Weir to ensure low flows remain in Hinksey Stream (4_160wu), crest level 54.00mAOD C. New channel (4_260 to Ab_culu) with 1 in 3 side slopes D. Low level defence to prevent 100-year flooding via the Network rail access track (2d_zsh_AbingdonRd_v0.shp), level set at 56.30m. E. Orifice plate on Network Rail culvert removed
Example channels in reach A (left) and C (right)





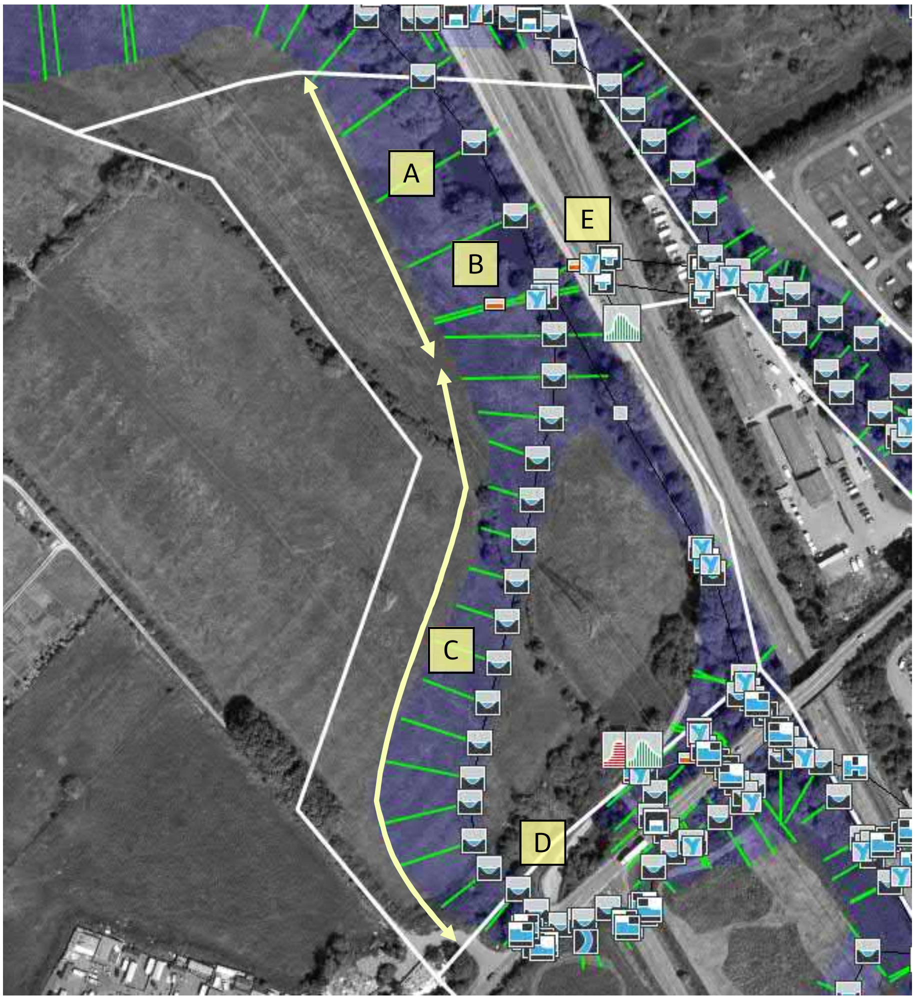


Table 5.14: Area 4D model schematisation

New bridge at Old Abingdon Road to A423

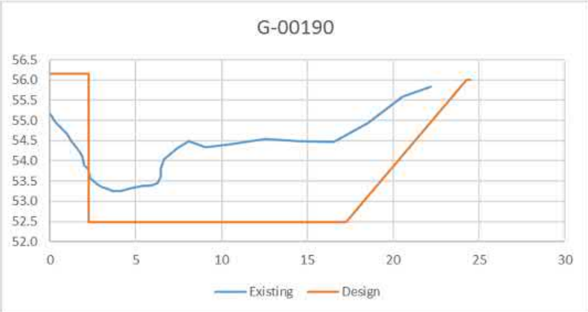
A. New channel and widening from Old Abingdon Road to new bypass culvert channel (Ab_culd to hin3b2u).

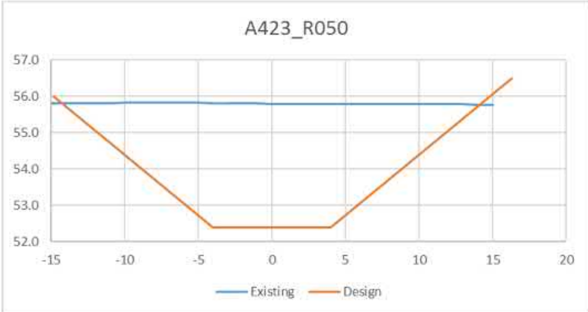
B. New Bridges at Old Abingdon Road and Kennington Road, modelled as twin rectangular culverts 10.8m wide, height varies 2.64 to 2.76m (old Abingdon Road) and 2.34 to 2.55m (Kennington Road) due to sloping soffit.

C. New channel (A423_R000 to A423_R138) with 1 in 3 side slopes

D. Existing Hinksey Ditch reach adjacent to the new culvert bypass remains as existing (hin3b2 to hin3b6u)

Example channels in reach A (left) and C (right)





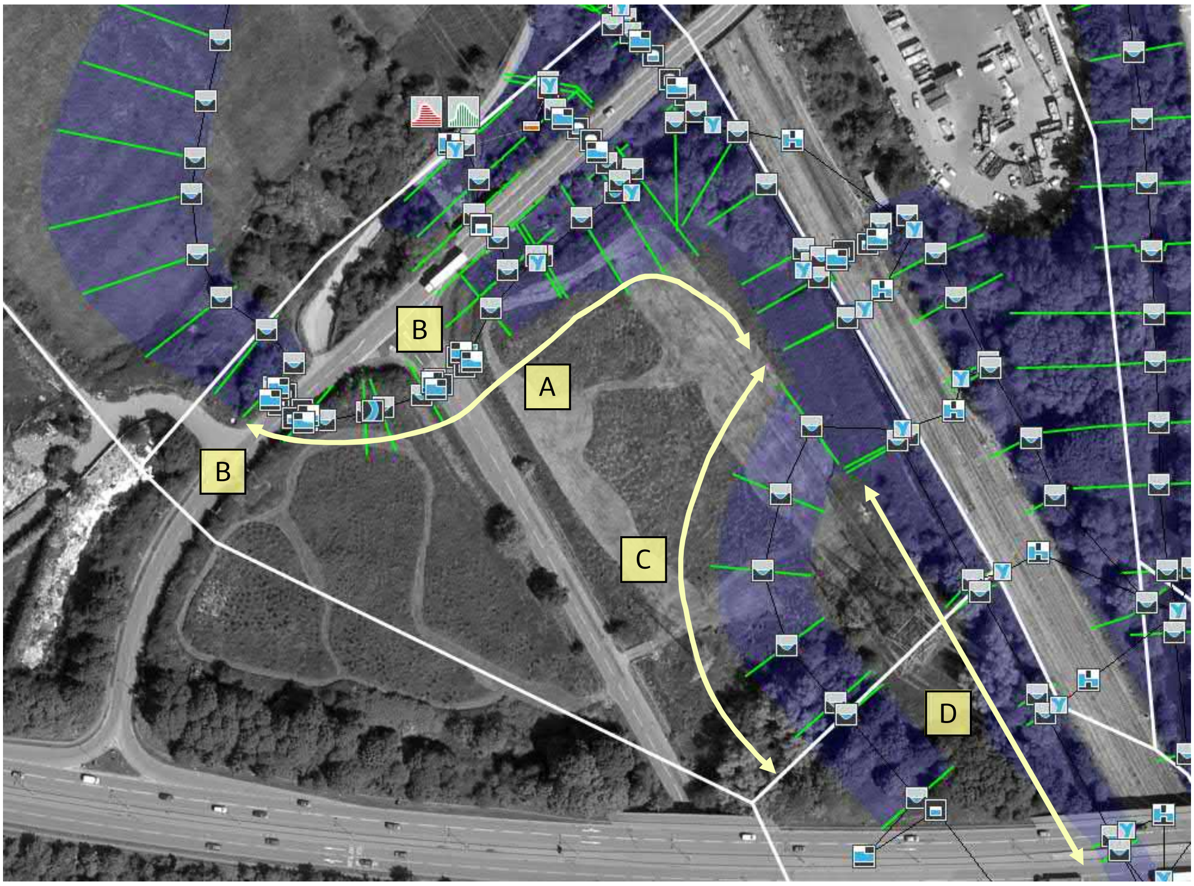


Table 5.15: Area 4E model schematisation

A423 to Mundays Bridge, including new west side culvert under A423

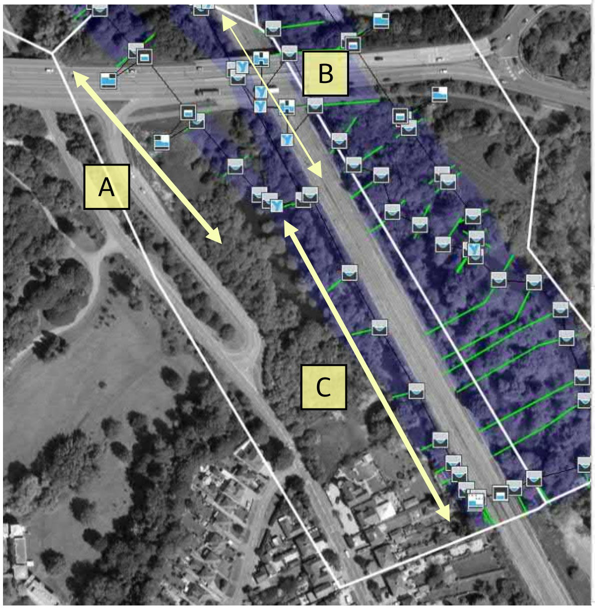
A. New culvert under A423 (A423_R138c to A423_R195c). Culvert 57m long, 8m wide, 3.7m high, invert level set at 52.34 to 52.27mAOD (1.5m depth of water at normal flows).

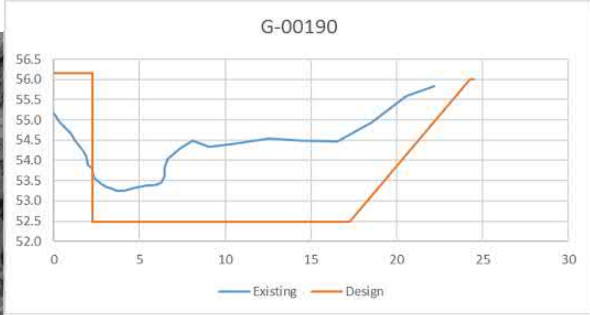
B. Existing Hinksey Ditch reach adjacent to the new culvert bypass remains as existing (hin3b2 to hin3b6u)

C. Re-profile of existing channel after new culver to Mundays Bridge (hin3b2 to K002). Channel width 11m adjacent to gardens upstream of Mundays Bridge

D. Clearance of Mundays Bridge to 52mAOD bed level (K001 to MU01.001)

Example channels in reach A (upper) and C (lower)





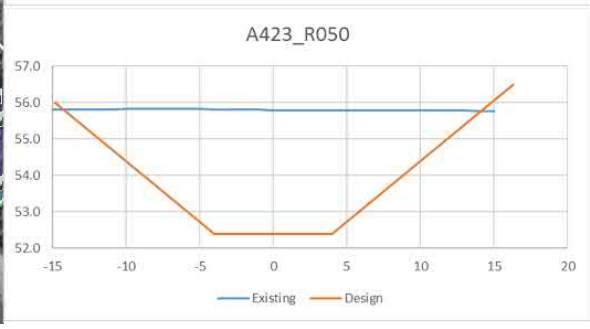


Table 5.16: Area 4F model schematisation

Raised Defences at New Hinksey

A. Embankment and flood walls (2d_zsh_FAS_Raised_Defences_v1.shp). Crest level set at 100.00mAOD.

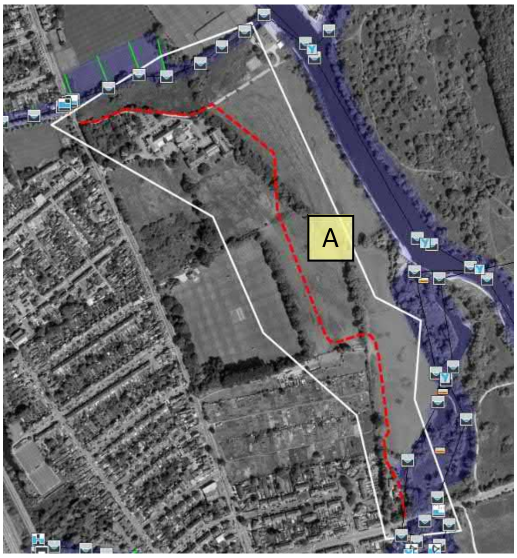
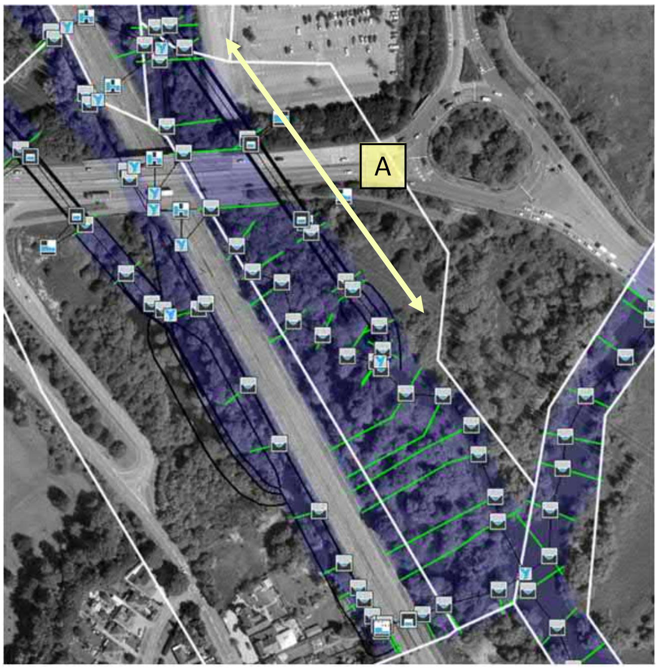


Table 5.17: Area 4G model schematisation

Raised Defences at New Hinksey
A. Removal of Towles Mill Weir (HKS.063wu) to improve fish passage

Table 5.18: Area 4H/4I model schematisation

New east side culvert under A423
A. New culvert under A423 (A423_L078c to A423_L137c). Culvert 59m long, 8m wide, 3.7m high, invert level set at 52.32 to 52.29 mAOD (1.5m depth of water at normal flows).



5.3 New channel sizing and flow control structures

Within areas 2B, 3B, 3C and 4B the design includes a combination of retaining existing channels and the sizing of new channel/control structures to allow the channel to function under low flows (Q_{95}) and flood flows, but also provide a sustainable channel under normal day to day flow conditions.

To test the normal day to day flow conditions, the model was run using the mean monthly flows detailed in Section 2.2 of this report. The flows are based on structure operations to maintain normal water levels at Kings/Osney Locks which control the flow rates over the weirs at the head of Seacourt and Bulstake Streams. Figure 5.2 details the new channels and locations of the control structures. The total mean monthly and Q_{95} flows in Seacourt and Bulstake Stream at Botley Road which can discharge into the new channel are detailed in Table 5.19.

The following features were considered, when sizing the channels and setting crest levels:

- Set spillway height into Area 2B to be active a late as possible to keep 2B channel dry (Structure 1, refer to Figure 5.2).
- Limit impact on groundwater levels, particularly in the MG4 grassland area (within Area 2B)
- Maximise flows within new channels, allow the Hinksey Stream to become a ‘pond’ at Q 95 flows, with fixed weirs at the start and end of the reach (Structures 5, 6 and 7, refer to Figure 5.2).
- Design cross sections representing pools and riffles.
- Keep mean monthly flows within the banks of the first stage channel, with second stage only active during flows predicted for the winter months.

Table 5.19: Seacourt and Bulstake Stream flows at Botley Road (m^3/s)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Q 95
Seacourt at Botley Road	1.1	1.0	0.8	0.6	0.5	0.5	0.5	0.4	0.4	0.5	0.6	0.9	0.3
Bulstake at Botley Road	5.0	4.1	2.8	1.9	1.4	1.3	1.1	1.0	1.0	1.2	2.0	3.3	0.5
Total u/s Botley Road	6.1	5.1	3.6	2.5	1.9	1.8	1.6	1.4	1.4	1.7	2.6	4.2	0.8
Flow Rank (low to high)	12	11	9	7	6	5	3	1	2	4	8	10	0

5.3.1 Spillway and new channel in Area 2B

The crest level to the spillway has been set at 55.50mAOD to be only active during flood events, modelling predicts a level of 55.43mAOD for January mean monthly flows. Appendix F details the water level records from July 2003 to July 2017 at Minns Estate, which indicate the spillway would have been active on approximately 55 occasions.

The new channel slopes from 55.40mAOD down to the new bridge at Willow Walk. The water levels at the new bridge are determined by the downstream levels in Bulstake Stream, which are predicted to be 55.14mAOD for the January flow. To keep the new channel dry through Area 2B, the bed level at the end of the channel is set at 55.20mAOD, dropping to 54.00mAOD at the bridge.

The spillway has been represented using spill unit with a coefficient of 1.0. The value of 1.0 was selected as the weir is not in-line and acts as lateral weir to the new channel. Sensitivity tests (Section 6.2) show negligible impacts in the model results due to the selection of the weir coefficient. The is due to the weir crest being set just above the bed of the downstream channel, which causes the weir the drown out as the downstream channel size is the control on water levels.

The bank level between the new channel and the existing Seacourt Stream has been set at 55.50mAOD from downstream of the pylon to Willow Walk. The spillway would become active first and then during flood conditions, spilling between the channels would occur. The bank spill coefficient between the channels are set at 0.5.

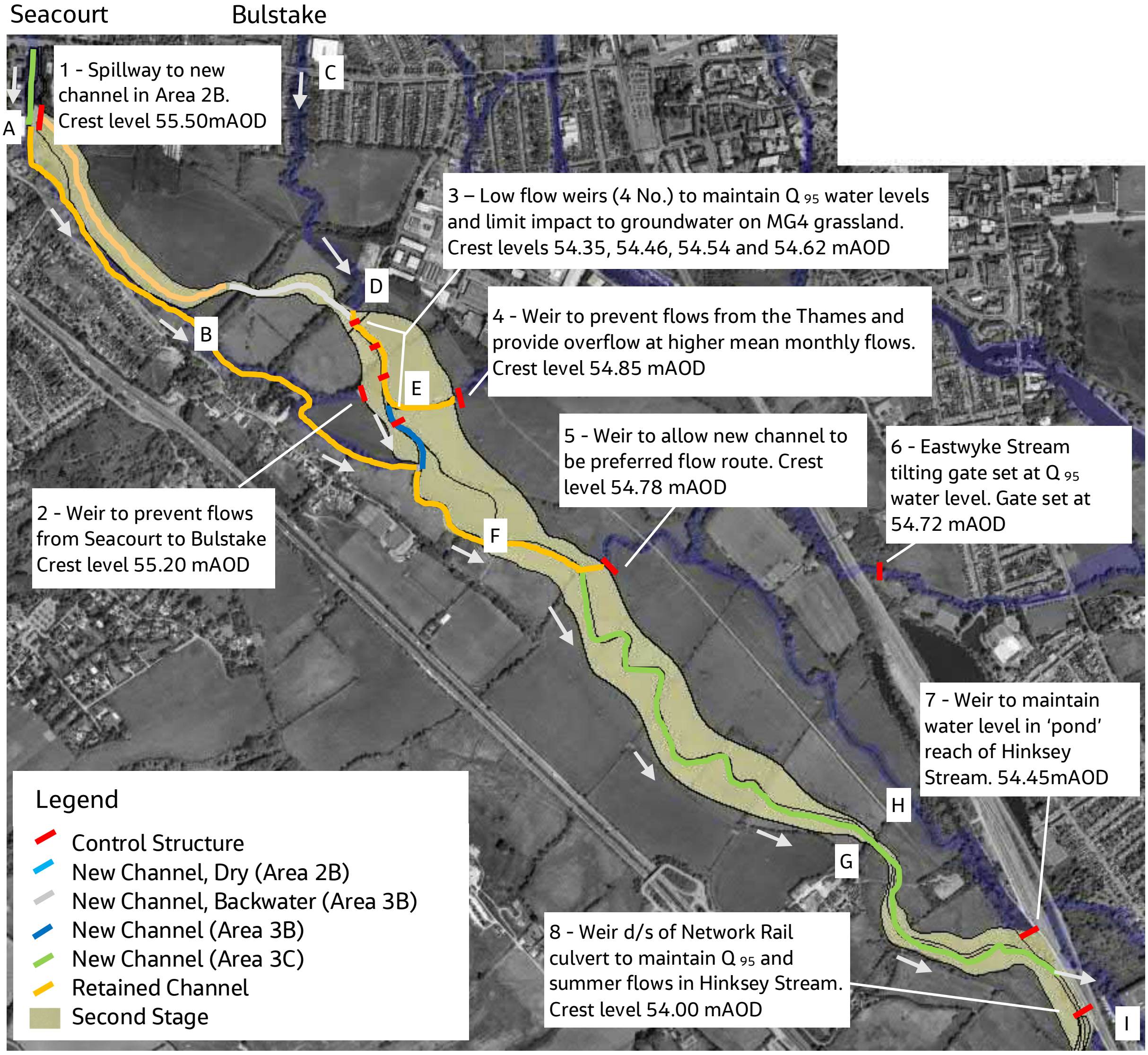
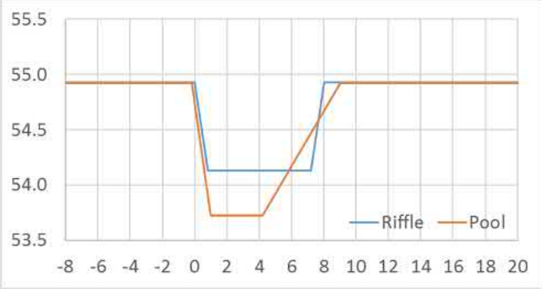


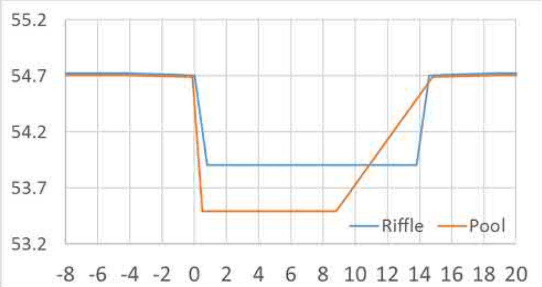
Figure 5.2: Channel types and flow controls

5.3.2 New channel in Area 3B and 3C

The new channel design in Area 3B and 3C are represented within the model as a series of riffle and pool cross sections. The sections have been sized to be able to transport sediments under the mean monthly flows. Design riffle/pool cross section are detailed in Figure 5.3. The long-section shows an extract from the new channel and highlights the change in bed levels for the riffle/pool schematisation.



Area 3B	Rifle	Pool
Depth (m)	0.8	1.0
Left Bank slope (1 in …)	1.0	1.0
Right Bank slope (1 in …)	1.0	4.0
Bed width (m)	6.4	3.2
Bank to bank width (m)	8.0	8.2



Area 3C	Rifle	Pool
Depth (m)	0.8	1.0
Left Bank slope (1 in …)	1.0	0.5
Right Bank slope (1 in …)	1.0	5.0
Bed width (m)	13.0	8.3
Bank to bank width (m)	14.6	13.8

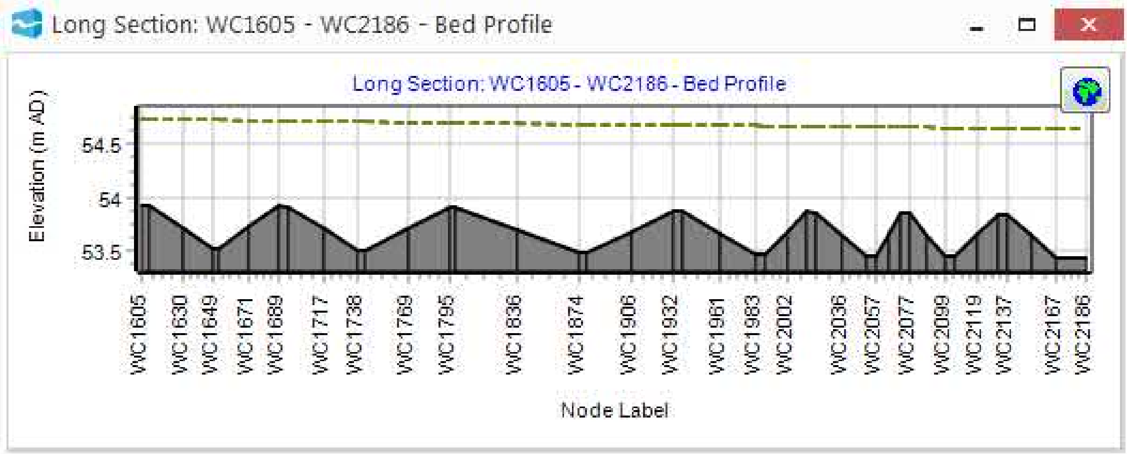


Figure 5.3: Design low flow channel sections

5.3.3 Control structures

Control structures are proposed at 8 locations, as detailed in Figure 5.2.

1) Spillway – refer to section 5.3.1.
2) Weir set to bank level to prevent in bank flow between Seacourt and Bulstake Stream.
3) 4 No. low flow weirs to maintain Q_{95} water levels at MG4 grassland.
4) Weir set below 2nd stage channel level. Structure to prevent flows from the Thames. discharging to the new channel and allow flows from Bulstake Stream to spill into the Thames at the higher mean monthly flows to keep the 2nd stage dry.

5) Weir set below 2nd stage channel level. Structure to prevent flow in the new channel from discharging into the Hinksey Stream. Weir would be active at the highest mean monthly flows to keep the 2nd stage dry.

6) Eastwyke Ditch control structure. Tilting gate level set above the Q_{95} water level to keep low flows within the Thames.

7) Weir at the end of the Hinksey Stream ponds, to maintain existing Q_{95} levels and minimal impact on groundwater at low flow.

8) Weir located downstream of the Network Rail culvert to ensure low summer month flows are retained in the Hinksey Stream.

5.4 Modelling results – mean monthly and Q_{95} flows

Mean monthly flows within the new channel and at control structures are detailed in Table 5.20 (locations detailed in Figure 5.2. At location D (highlighted), comparison of the flows shows the predicted increase in flow for Hinksey Stream due to the FAS.

Table 5.20: Flows in new channel and at control structures (m^3/s)

Flow Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Q 95
Total flow u/s Botley Road	6.1	5.1	3.6	2.5	1.9	1.8	1.6	1.4	1.4	1.7	2.6	4.2	0.8
1 – FAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2 - EXIST	-1.0	-0.9	-0.6	-0.5	-0.3	-0.3	-0.2	-0.1	-0.1	-0.3	-0.5	-0.7	0.0
2 - FAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 - EXIST	5.0	4.1	2.9	1.9	1.4	1.3	1.1	1.0	1.0	1.2	2.1	3.4	0.5
3 - FAS	5.0	4.2	2.8	1.9	1.4	1.2	1.1	1.0	1.0	1.2	2.0	3.3	0.5
4 - EXIST	4.0	3.3	2.2	1.4	1.1	1.0	0.9	0.9	0.9	0.9	1.6	2.6	0.6
4 - FAS	0.9	0.9	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.8	0.0
F - EXIST	2.1	1.8	1.4	1.0	0.8	0.8	0.7	0.5	0.5	0.7	1.1	1.6	0.2
F - FAS	5.2	4.2	2.9	2.3	1.9	1.8	1.6	1.4	1.4	1.7	2.4	3.4	0.8
Diff	3.1	2.4	1.5	1.3	1.2	1.0	0.9	0.9	0.9	1.0	1.3	1.8	0.6
5	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 - EXIST	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	-0.3
6 - FAS	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	0.0
G	4.7	4.0	2.9	2.3	1.9	1.8	1.6	1.4	1.4	1.7	2.4	3.3	0.8
H - EXIST	2.5	2.2	1.8	1.4	1.1	1.1	1.0	0.8	0.8	1.1	1.5	1.9	0.5
H - FAS	0.8	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.0
7 – EXIST	2.5	2.2	1.8	1.4	1.1	1.1	1.0	0.8	0.8	1.1	1.5	1.9	0.5
7 - FAS	0.8	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.0
8	1.8	1.3	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.8	0.0
I - EXIST	2.1	1.9	1.5	1.2	1.0	1.0	0.9	0.8	0.8	1.0	1.3	1.7	0.5
I – FAS	3.6	3.2	2.5	2.2	1.9	1.8	1.6	1.5	1.5	1.8	2.2	2.8	0.8

Table 5.21: Level comparison for mean monthly flows

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Q 95
A – Exist	55.4	55.3	55.2	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.2	55.3	55.0
A – FAS	55.4	55.3	55.2	55.2	55.1	55.1	55.1	55.1	55.1	55.1	55.2	55.3	55.0
Diff (m)	-0.01	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.01
B – Exist	55.3	55.3	55.2	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.2	55.0
B – FAS	55.3	55.3	55.2	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.2	55.0
Diff (m)	-0.01	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.01
C – Exist	55.4	55.3	55.2	55.0	54.9	54.9	54.8	54.8	54.8	54.9	55.0	55.2	54.7
C - FAS	55.4	55.3	55.2	55.0	55.0	54.9	54.9	54.9	54.9	54.9	55.1	55.2	54.8
Diff (m)	-0.05	-0.04	0.00	0.05	0.08	0.06	0.07	0.08	0.07	0.07	0.03	-0.02	0.07
D – Exist	55.2	55.1	55.0	54.9	54.8	54.8	54.8	54.7	54.7	54.8	54.9	55.1	54.7
D - FAS	55.1	55.1	55.0	55.0	54.9	54.9	54.9	54.8	54.8	54.9	55.0	55.0	54.8
Diff (m)	-0.11	-0.08	0.00	0.07	0.11	0.09	0.09	0.10	0.10	0.09	0.06	-0.03	0.08
E - Exist	55.2	55.1	55.0	54.9	54.8	54.8	54.8	54.7	54.7	54.8	54.9	55.0	54.7
E - FAS	55.1	55.0	54.9	54.9	54.8	54.7	54.7	54.6	54.6	54.7	54.9	55.0	54.5
Diff (m)	-0.09	-0.07	-0.03	-0.01	-0.03	-0.06	-0.09	-0.10	-0.11	-0.07	-0.02	-0.04	-0.18
F – Exist	54.9	54.8	54.7	54.6	54.5	54.5	54.5	54.5	54.5	54.5	54.6	54.7	54.4
F – FAS	55.0	54.9	54.8	54.7	54.6	54.6	54.5	54.5	54.5	54.6	54.7	54.8	54.3
Diff (m)	0.08	0.09	0.07	0.06	0.05	0.02	0.00	0.00	0.00	0.01	0.06	0.09	-0.06
H – Exist	54.6	54.6	54.5	54.5	54.5	54.5	54.4	54.4	54.4	54.5	54.5	54.6	54.4
H – FAS	54.5	54.5	54.4	54.4	54.4	54.4	54.4	54.4	54.4	54.4	54.4	54.4	54.4
Diff (m)	-0.11	-0.11	-0.10	-0.06	-0.03	-0.03	-0.02	0.00	0.00	-0.03	-0.07	-0.11	0.04
I – Exist	54.5	54.5	54.5	54.4	54.4	54.4	54.4	54.4	54.4	54.4	54.4	54.5	54.4
I – FAS	54.2	54.1	54.0	54.0	53.9	53.9	53.9	53.9	53.9	53.9	54.0	54.1	53.8
Diff (m)	-0.35	-0.38	-0.44	-0.47	-0.48	-0.51	-0.51	-0.51	-0.51	-0.51	-0.46	-0.42	-0.54

5.5 Model performance (mean monthly and Q_{95} flows)

The mean monthly and Q_{95} simulations are run using just the 1D model. The model runs with stepped inflows and model results taken at 100 hour intervals when steady conditions are achieved for each of the mean monthly flows (results taken from 100 hours to 1200 hours). For Q_{95}, the model results are taken at 1600 hours. Model files are detailed in Appendix D and Figure 5.4 details the convergence plots from the simulation.

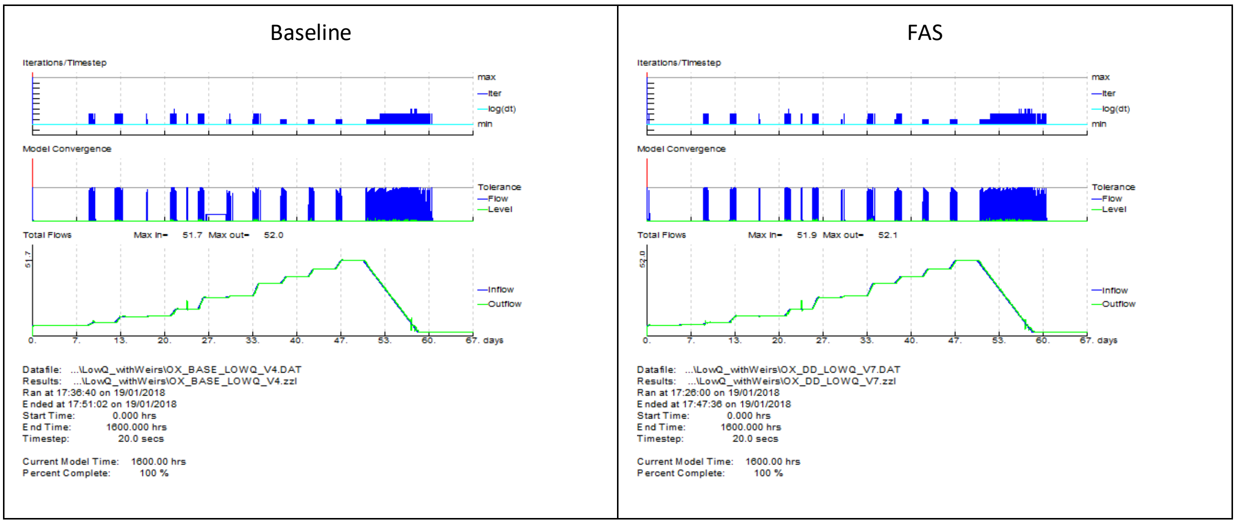


Figure 5.4: 1D convergence plots – Mean Monthly and Q 95 flows

5.6 Modelling results – design flood events

Peak water levels are detailed at the locations detailed in Figure 4.7 in Table 5.22 for the 50%, 20%, 10%, 5%, 2% and 1.3% AEP events (2, 5,10, 20, 50 and 75-year). Table 5.23 details the 1%, 0.5%, 0.1% AEP events (100, 200, 1000-year) and the 1% AEP event with climate changes for +25%, +35% and +70%. Comparison of the flood extents for the 1% AEP event (100-year) are detailed in Figure 5.5 which shows the impact of the FAS at a high level. Flood extent comparison for 20%, 5%, 2% and 1% AEP +35% (5, 20, 50 and 100-year +35%) are detailed in Appendix G.

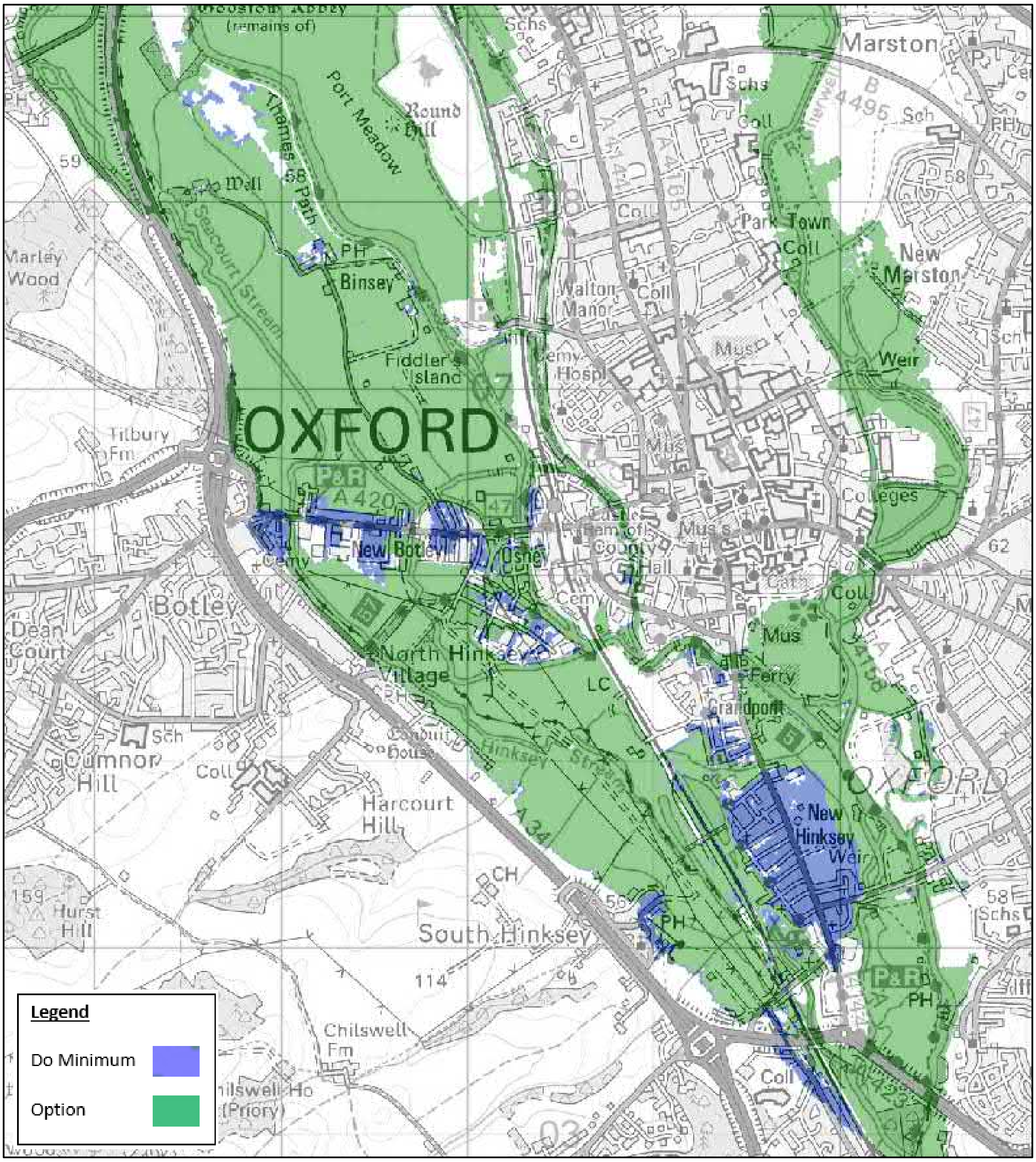


Figure 5.5: Comparison of 1% AEP (100-year) flood extents (2018 version)

Table 5.22: Peak water levels (mAOD) and comparison (m) (2018 version)

		50% AEP (2-year)			20% AEP (5-year)			10% AEP (10-year)			5% AEP (20-year)			2% AEP (50-year)			1.3% AEP (75-year)		
Re	**Location**	**Do Min**	**FAS**	**Diff**	**Do Min**	**FAS**	**Diff**	**Do Min**	**FAS**	**Diff**	**Do Min**	**FAS**	**Diff**	**Do Min**	**FAS**	**Diff**	**Do Min**	**FAS**	**Diff**
1	Seacourt/Botley Stream	56.89	56.81	-0.08	57.12	56.96	-0.16	57.27	57.05	-0.22	57.36	57.17	-0.20	57.47	57.32	-0.15	57.51	57.39	-0.13
2	Seacourt at Botley Road	56.70	56.26	-0.44	57.02	56.62	-0.39	57.17	56.86	-0.31	57.27	57.02	-0.24	57.37	57.19	-0.17	57.41	57.26	-0.15
3	Bulstake at Botley Road	56.65	56.58	-0.07	56.92	56.74	-0.17	57.05	56.84	-0.22	57.14	56.95	-0.19	57.24	57.09	-0.15	57.28	57.16	-0.13
4	Osney Ditch	56.73	56.65	-0.09	57.09	56.93	-0.16	57.25	57.04	-0.21	57.34	57.16	-0.18	57.44	57.31	-0.13	57.49	57.37	-0.11
5	Thames at Botley Road	56.77	56.78	0.01	56.84	56.78	-0.06	56.96	56.84	-0.11	57.04	56.90	-0.13	57.14	57.01	-0.13	57.18	57.06	-0.13
6	Castle Mill Stream	56.64	56.65	0.01	56.72	56.69	-0.04	56.81	56.73	-0.08	56.87	56.77	-0.10	56.96	56.86	-0.10	56.99	56.91	-0.09
7	Seacourt Willow Walk	56.29	55.92	-0.37	56.52	56.15	-0.36	56.62	56.30	-0.32	56.70	56.42	-0.28	56.77	56.57	-0.20	56.80	56.64	-0.16
8	Bulstake Willow Walk	56.31	56.23	-0.07	56.48	56.31	-0.16	56.57	56.37	-0.20	56.71	56.45	-0.26	56.79	56.58	-0.22	56.83	56.70	-0.13
9	Thames d/s Osney	55.97	55.87	-0.10	56.19	56.04	-0.15	56.32	56.17	-0.16	56.41	56.28	-0.14	56.53	56.40	-0.13	56.58	56.45	-0.13
10	Thames	55.71	55.61	-0.10	55.92	55.77	-0.15	56.06	55.91	-0.16	56.18	56.03	-0.16	56.32	56.19	-0.13	56.38	56.26	-0.12
11	Hinksey Stream	55.83	55.65	-0.18	56.06	55.88	-0.18	56.20	56.03	-0.18	56.32	56.15	-0.17	56.46	56.32	-0.14	56.52	56.39	-0.12
12	Eastwyke Ditch (west)	55.74	55.60	-0.14	55.98	55.85	-0.13	56.13	56.00	-0.12	56.23	56.12	-0.12	56.35	56.28	-0.07	56.40	56.36	-0.04
13	Eastwyke Ditch Abingdon Rd	55.47	55.37	-0.10	55.66	55.52	-0.14	55.80	55.66	-0.13	55.91	55.78	-0.13	56.02	55.93	-0.10	56.07	55.98	-0.09
14	Thames (Cherwell Conf)	55.45	55.37	-0.08	55.65	55.53	-0.12	55.78	55.67	-0.11	55.89	55.78	-0.11	56.00	55.92	-0.09	56.05	55.97	-0.08
15	Devils Backbone	55.57	55.31	-0.27	55.92	55.65	-0.27	56.12	55.86	-0.26	56.25	56.02	-0.23	56.41	56.22	-0.18	56.46	56.31	-0.16
16	Cold Harbour Bridges	55.30	55.12	-0.18	55.76	55.48	-0.29	56.05	55.70	-0.35	56.20	55.88	-0.32	56.37	56.12	-0.24	56.42	56.22	-0.20
17	Mayweed Bridge	55.12	54.97	-0.15	55.60	55.34	-0.26	55.88	55.57	-0.31	56.03	55.76	-0.27	56.17	55.98	-0.19	56.22	56.08	-0.14
18	Weirs Mill Stream (d/s Weirs)	54.90	54.88	-0.02	55.09	55.04	-0.05	55.21	55.16	-0.05	55.31	55.26	-0.05	55.47	55.39	-0.08	55.54	55.45	-0.09
19	Thames Donnington Road	55.19	55.12	-0.07	55.42	55.31	-0.11	55.56	55.45	-0.11	55.68	55.57	-0.11	55.79	55.71	-0.08	55.83	55.76	-0.07
20	Thames Iffley Lock u/s	55.02	54.97	-0.05	55.26	55.18	-0.09	55.41	55.32	-0.08	55.53	55.44	-0.09	55.66	55.59	-0.07	55.70	55.64	-0.06
21	A423 West (Hinksey Ditch)	54.84	54.84	0.01	55.12	55.13	0.01	55.29	55.31	0.02	55.40	55.46	0.06	55.53	55.66	0.13	55.59	55.74	0.15
22	A423 East (Hinksey Stream)	54.88	54.77	-0.11	55.17	54.98	-0.19	55.33	55.11	-0.22	55.42	55.21	-0.21	55.52	55.33	-0.19	55.57	55.39	-0.18
23	Mundays Bridge	54.74	54.77	0.03	54.95	54.98	0.03	55.08	55.12	0.04	55.18	55.24	0.07	55.32	55.42	0.10	55.38	55.49	0.10
24	End of Weirs Mill Stream	54.72	54.73	0.02	54.90	54.91	0.01	55.02	55.03	0.01	55.11	55.13	0.02	55.23	55.25	0.02	55.29	55.30	0.02
25	Thames d/s Hinksey Stream	54.55	54.55	0.00	54.74	54.73	0.00	54.83	54.83	0.00	54.91	54.91	0.00	55.01	55.01	0.00	55.05	55.05	0.00
26	Thames Binsey/Port Meadow	57.55	57.55	0.00	57.62	57.62	0.00	57.67	57.67	0.00	57.72	57.71	-0.01	57.79	57.76	-0.03	57.83	57.79	-0.04

Table 5.23: Peak water levels (mAOD) and comparison (m) (2018 version)

		1% AEP (100-year)			0.5% AEP (200-year)			0.1% AEP (1000-year)			1% AEP (100-year) +25%			1% AEP (100-year) +35%			1% AEP (100-year) +70%		
Re	Location	Do Min	FAS	Diff	Do Min	FAS	Diff	Do Min	FAS	Diff	Do Min	FAS	Diff	Do Min	FAS	Diff	Do Min	FAS	Diff
1	Seacourt/Botley Stream	57.55	57.43	-0.12	57.61	57.52	-0.09	57.78	57.74	-0.04	57.69	57.62	-0.07	57.76	57.71	-0.05	57.94	57.94	0.00
2	Seacourt at Botley Road	57.44	57.30	-0.14	57.51	57.39	-0.12	57.67	57.59	-0.08	57.58	57.48	-0.10	57.65	57.57	-0.08	57.82	57.79	-0.03
3	Bulstake at Botley Road	57.31	57.19	-0.12	57.38	57.27	-0.10	57.52	57.46	-0.06	57.44	57.36	-0.08	57.50	57.44	-0.07	57.69	57.67	-0.03
4	Osney Ditch	57.52	57.41	-0.10	57.58	57.50	-0.08	57.73	57.70	-0.03	57.65	57.59	-0.06	57.71	57.67	-0.04	57.87	57.87	0.00
5	Thames at Botley Road	57.21	57.10	-0.12	57.29	57.18	-0.11	57.46	57.40	-0.06	57.37	57.28	-0.09	57.44	57.38	-0.06	57.62	57.61	-0.02
6	Castle Mill Stream	57.02	56.94	-0.08	57.07	57.01	-0.06	57.20	57.17	-0.03	57.13	57.08	-0.05	57.19	57.15	-0.04	57.41	57.39	-0.02
7	Seacourt Willow Walk	56.83	56.68	-0.15	56.88	56.76	-0.12	57.02	56.93	-0.09	56.94	56.84	-0.10	57.01	56.91	-0.09	57.18	57.09	-0.09
8	Bulstake Willow Walk	56.85	56.73	-0.12	56.91	56.81	-0.10	57.06	56.98	-0.08	56.97	56.89	-0.08	57.04	56.96	-0.08	57.21	57.13	-0.08
9	Thames d/s Osney	56.62	56.49	-0.12	56.69	56.60	-0.09	56.86	56.80	-0.06	56.77	56.70	-0.07	56.84	56.78	-0.06	57.03	56.98	-0.05
10	Thames	56.41	56.31	-0.10	56.48	56.41	-0.08	56.66	56.60	-0.05	56.56	56.50	-0.06	56.64	56.58	-0.05	56.86	56.80	-0.06
11	Hinksey Stream	56.55	56.44	-0.11	56.62	56.55	-0.08	56.79	56.73	-0.05	56.70	56.64	-0.06	56.77	56.72	-0.05	56.96	56.91	-0.05
12	Eastwyke Ditch (west)	56.43	56.41	-0.02	56.50	56.52	0.01	56.69	56.70	0.01	56.58	56.61	0.02	56.67	56.68	0.02	56.88	56.85	-0.03
13	Eastwyke Ditch Abingdon Rd	56.10	56.02	-0.08	56.17	56.10	-0.07	56.38	56.31	-0.07	56.25	56.19	-0.06	56.36	56.29	-0.07	56.67	56.59	-0.08
14	Thames (Cherwell Conf)	56.07	56.00	-0.07	56.14	56.08	-0.07	56.36	56.28	-0.08	56.23	56.16	-0.06	56.33	56.26	-0.08	56.64	56.55	-0.09
15	Devils Backbone	56.49	56.36	-0.13	56.56	56.47	-0.09	56.71	56.65	-0.06	56.63	56.56	-0.06	56.69	56.63	-0.06	56.86	56.81	-0.05
16	Cold Harbour Bridges	56.45	56.28	-0.17	56.52	56.40	-0.12	56.66	56.58	-0.08	56.58	56.49	-0.09	56.64	56.56	-0.08	56.81	56.74	-0.07
17	Mayweed Bridge	56.25	56.14	-0.11	56.30	56.24	-0.06	56.45	56.39	-0.06	56.36	56.32	-0.05	56.43	56.38	-0.06	56.67	56.62	-0.06
18	Weirs Mill Stream (d/s Weirs)	55.60	55.50	-0.10	55.72	55.62	-0.10	56.04	55.97	-0.07	55.87	55.79	-0.08	56.01	55.94	-0.07	56.37	56.32	-0.06
19	Thames Donnington Road	55.85	55.79	-0.07	55.91	55.85	-0.06	56.09	56.01	-0.09	55.96	55.90	-0.06	56.06	55.98	-0.08	56.40	56.32	-0.08
20	Thames Iffley Lock u/s	55.74	55.68	-0.06	55.80	55.76	-0.05	56.02	55.96	-0.06	55.88	55.83	-0.05	55.99	55.93	-0.06	56.35	56.29	-0.06
21	A423 West (Hinksey Ditch)	55.64	55.79	0.15	55.74	55.90	0.16	56.01	56.10	0.09	55.86	56.00	0.14	55.98	56.08	0.10	56.24	56.29	0.05
22	A423 East (Hinksey Stream)	55.60	55.43	-0.16	55.67	55.53	-0.13	55.87	55.77	-0.09	55.75	55.64	-0.11	55.84	55.75	-0.09	56.17	56.08	-0.09
23	Mundays Bridge	55.43	55.53	0.10	55.54	55.64	0.11	55.82	55.87	0.06	55.66	55.75	0.09	55.79	55.85	0.07	56.10	56.13	0.03
24	End of Weirs Mill Stream	55.33	55.35	0.02	55.42	55.45	0.02	55.67	55.69	0.02	55.54	55.56	0.02	55.65	55.67	0.02	55.97	55.98	0.02
25	Thames d/s Hinksey Stream	55.09	55.09	0.00	55.17	55.17	0.00	55.37	55.38	0.00	55.26	55.27	0.00	55.35	55.36	0.00	55.62	55.62	0.00
26	Thames Binsey/Port Meadow	57.85	57.82	-0.04	57.92	57.88	-0.03	58.03	58.02	-0.01	57.98	57.95	-0.02	58.03	58.01	-0.01	58.12	58.12	0.00

5.7 Comparison of flows at Sandford (2018 version)

Comparison of the design event model outflows for do minimum and the preferred option are detailed in Figure 5.6 and Table 5.24. The modelling predicts that the scheme would result in a small reduction in peak flow for the events 20% to 1% AEP events (5-year to 100-year) and a slight increase for 50% AEP (2-year) and events greater than the 1% AEP event (100-year). The modelling predicts slightly higher flows in the rising limb of the hydrograph due to the increased conveyance provided by the scheme.

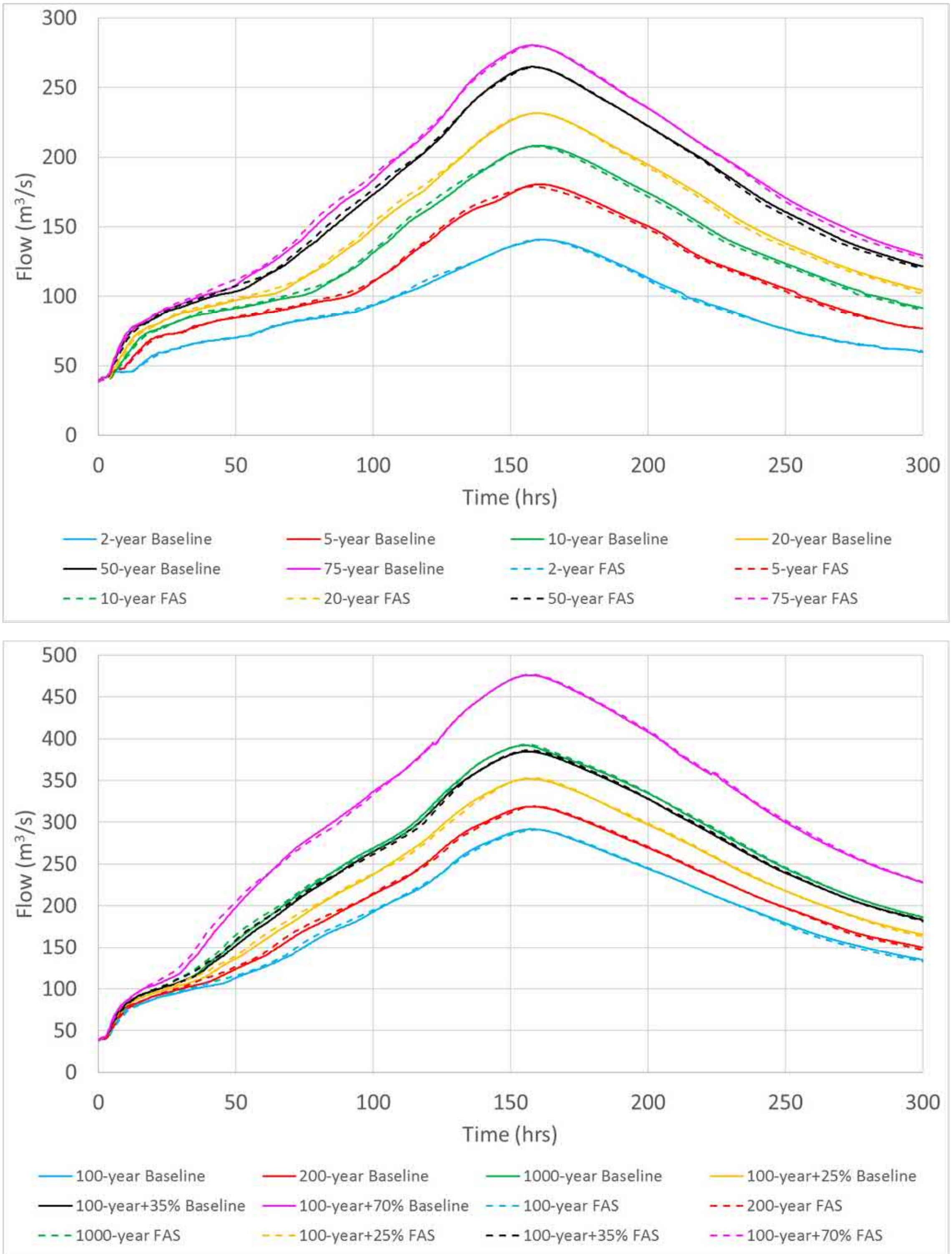


Figure 5.6: Comparison of flows at Sandford (2018 version)

Table 5.24: Model outflow comparison (2018 version)

	50% AEP (2-year)	20% AEP (5-year)	10% AEP (10-year)	5% AEP (20-year)	2% AEP (50-year)	1.3% AEP (75-year)
Do Minimum (m^3/s)	140.65	180.48	208.11	231.56	264.86	280.39
Detailed Design (m^3/s)	140.88	178.92	207.49	231.50	264.49	279.81
Difference (m^3/s)	0.23	-1.56	-0.61	-0.05	-0.37	-0.58
Difference (%)	0.16%	-0.87%	-0.29%	-0.02%	-0.14%	-0.21%

	1% AEP (100-year)	0.5% AEP (200-year)	0.1% AEP (1000-year)	1% AEP +25% (100-year)	1% AEP +35% (100-year)	1% AEP +70% (100-year)
Do Minimum (m^3/s)	291.59	318.83	392.04	351.88	384.68	476.14
Detailed Design (m^3/s)	290.82	318.92	393.04	353.07	386.03	476.76
Difference (m^3/s)	-0.77	0.09	1.01	1.18	1.35	0.62
Difference (%)	-0.26%	0.03%	0.26%	0.34%	0.35%	0.13%

Figure 5.7 compares the model outflows for the model using 2003 and 2007 calibration events. The model predicts small increases for both the 2003 and 20007 events (0.26% and 1.03%)

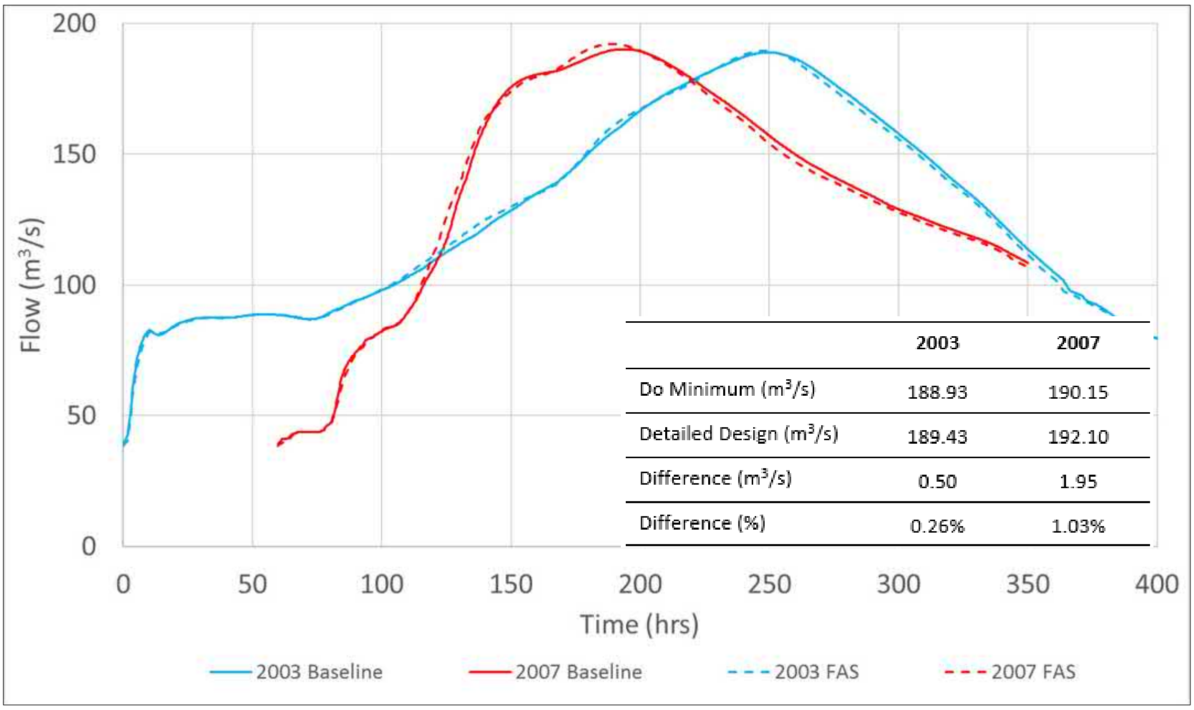


Figure 5.7: Comparison of flows at Sandford (2003 and 2007 event flows)

5.8 Model performance (detailed design 2018 version)

The model runs well with no non-convergence for the events simulated. Figure 5.8 details the convergence plots produced as part of the 1D model outputs.

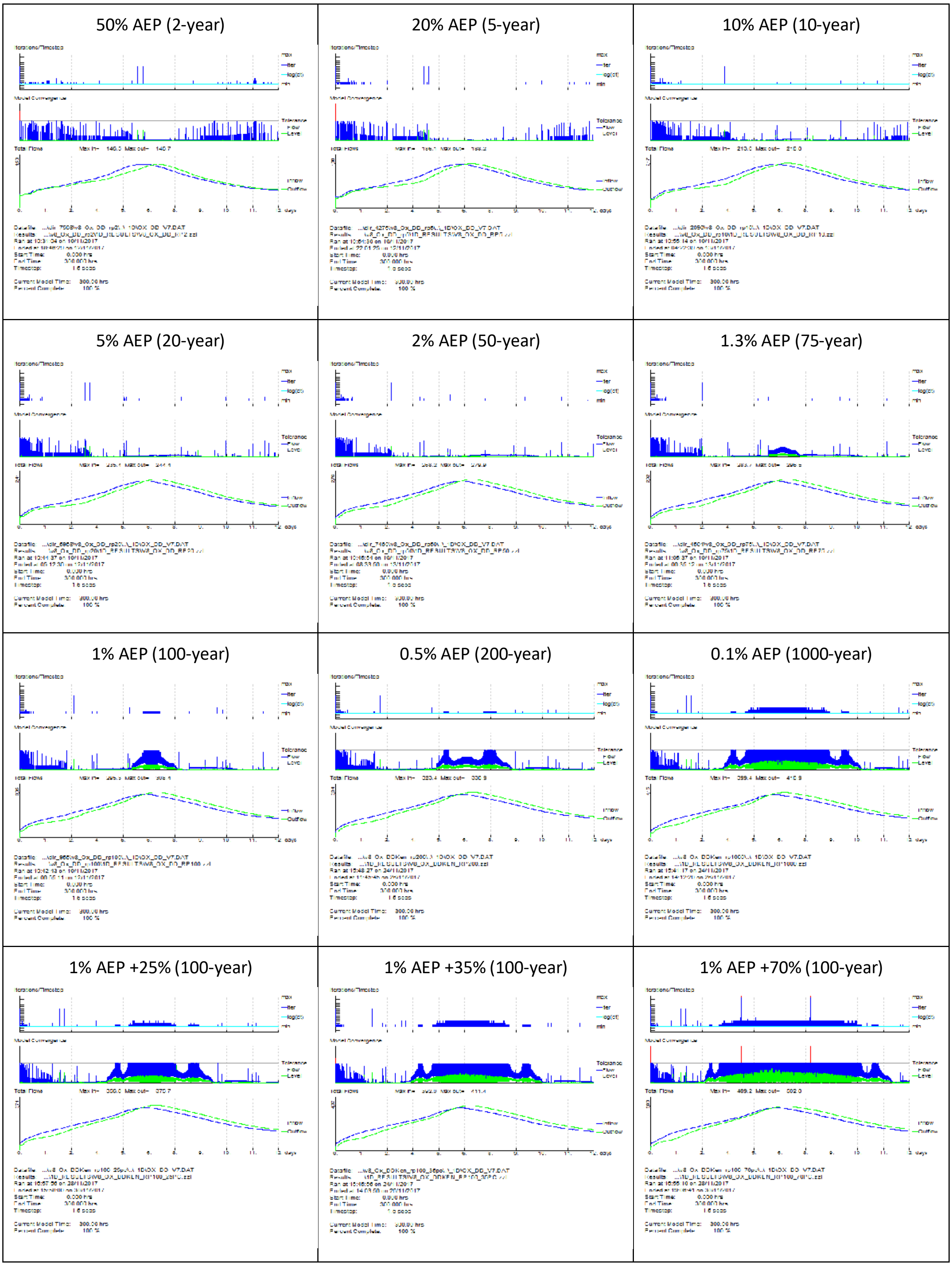


Figure 5.8: 1D convergence plots – Detailed Design FAS (2018 version)

The 2D output of cumulative mass errors and dVol (smooth plots) are detailed in Figure 5.9. The cumulative mass errors are within +/- 1% and on this basis are considered well with the acceptable tolerance.

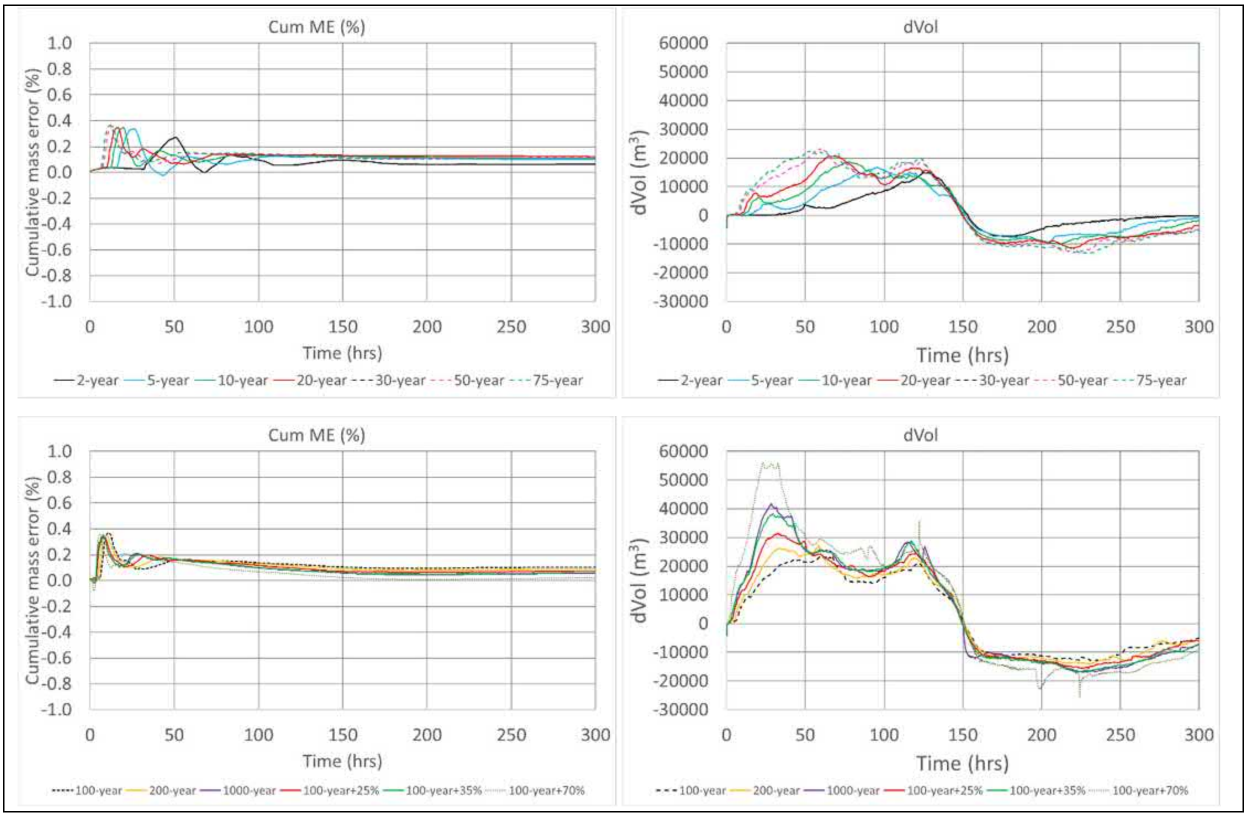


Figure 5.9: Cumulative Mass Error and dVol – Detailed Design FAS (2018 version)

6. Main modelling stage: model review and sensitivity tests (2018)

6.1 Model review

'Draft' versions of the updated baseline and detailed design were reviewed by Royal HaskoningDHV (November 2017). The model review comments and responses are included in Appendix H. Updates to both the baseline and detailed design versions of the model were applied following the review. The models and results reported in sections 4 and 5 use the updated review model.

6.2 Sensitivity tests

During the development of the hydraulic model for the detailed design, a number of assumptions to define model parameters, to some degree, remain uncertain. Whilst the calibration and validation of the model provides confidence that the baseline parameters we have adopted are realistic, we set up a suite of sensitivity tests to explore a wider and credible range of alternative parameter values (for example channel roughness) to understand how robust the performance of the scheme is.

In parallel to the model review it was agreed to run the tests for the 20%, 5% and 2% AEP events (5, 20 and 50-year), the 1% AEP event (100-year) was previously tested at the outline design stage. Note that the sensitivity tests and model results presented are based on the 'draft' version of the model.

The sensitivity tests detailed in Table 6.1 are for roughness and blockages to the new channels and structures. Further tests on a model global scale have been simulated for roughness (1D and 2D) as detailed in Table 6.2.

Table 6.1: Sensitivity test: scheme elements

Test	Parameter or Variable	Description of sensitivity test and purpose
1	1D Roughness (riverbed/banks) Only sections representing the new channel	Model run with (a) 20% increase and (b) 20% decrease in channel roughness. Purpose is to explore sensitivity of design to uncertainty in this partly subjective model parameter.
2	Bridge or Culvert blockages	Model run with 50% blockage at key structures. Purpose is to explore sensitivity of the model and the scheme to potential blockages at (a) Botley Road (Seacourt Stream) (b) Willow Walk (New Bridge) (c) Abingdon Road (New Culverts) (d) Mundays Bridge
5	Spillway coefficient	Model run reduced spillway coefficient (set to 1.0, was 1.5)

Table 6.2: Sensitivity test: global roughness parameters

Test	Parameter or Variable	Description of sensitivity test and purpose
3	1D Roughness (riverbed/banks) All model sections	Model run with (a) 20% increase and (b) 20% decrease (global) in channel roughness. Purpose is to explore sensitivity of design to uncertainty in this partly subjective model parameter.
4	2D Roughness (floodplain)	Model run with (a) 20% and (b) 50% increase and (c) 20% decrease (global) in floodplain roughness. Purpose is to explore sensitivity of design to uncertainty to this partly subjective model parameter and seasonal increases during summer.

Maximum, minimum and average changes in water level at all 1D river cross sections are detailed in Table 6.3, differences greater than +/-0.10m are highlighted. The outputs from the sensitivity tests are as expected.

Appendix I details the locations and changes in water level and Appendix J details the impacts on flood extents for the 5% AEP event (20-year) for each sensitivity test.

Table 6.3: Sensitivity test results

Test	Water level Change (m)	20% AEP 5-year	5% AEP 20-year	2% AEP 50-year	Comment
1a 20% increase for 1D channel roughness (scheme sections)	Maximum	0.05	0.05	0.05	As expected, raises levels (max 5cm) at the start of the scheme sections, as small reduction near the end
	Minimum	-0.02	-0.02	-0.02	
	Average	0.01	0.01	0.01	
1b 20% decrease for 1D channel roughness (scheme sections)	Maximum	0.02	0.02	0.02	As expected, reduced levels though the scheme area and watercourses joined to the scheme channel
	Minimum	-0.06	-0.06	-0.06	
	Average	-0.01	-0.01	-0.01	
2a 50% Blockage of Botley Road (Seacourt Stream)	Maximum	0.23	0.22	0.21	Raised levels u/s of Botley Road as water diverted via other channels. Reduced level downstream of blockage
	Minimum	-0.04	-0.16	-0.19	
	Average	0.00	0.01	0.01	
2b 50% Blockage of the New Willow Walk Bridge	Maximum	0.14	0.19	0.17	Raised levels u/s Willow Walk
	Minimum	-0.01	-0.01	-0.01	
	Average	0.00	0.00	0.00	
2c 50% Blockage of the New Abingdon Road Culverts	Maximum	0.03	0.04	0.06	Raised levels upstream of Old Abingdon Road and reduced levels downstream as lower flows
	Minimum	-0.02	-0.04	-0.06	
	Average	0.00	0.00	0.01	
2d 50% Blockage of Mundays Bridge	Maximum	0.10	0.17	0.16	Raised levels upstream, water diverted via other channels
	Minimum	0.00	0.00	0.00	
	Average	0.01	0.01	0.01	
3a 20% increase for 1D channel roughness (all sections)	Maximum	0.24	0.23	0.36	Overall increased water levels, some reduction at Kings/Wolvercote due to changes in flow distribution
	Minimum	-0.07	-0.05	-0.05	
	Average	0.11	0.12	0.13	
3b 20% decrease for 1D channel roughness (all sections)	Maximum	0.09	0.09	0.08	Overall decrease in levels
	Minimum	-0.30	-0.26	-0.27	
	Average	-0.13	-0.15	-0.15	
4a 20% increase for 2D roughness	Maximum	0.03	0.03	0.05	Small differences in levels and some increase noted in flood extents
	Minimum	-0.01	-0.01	0.00	
	Average	0.01	0.01	0.02	
4b 50% increase for 2D roughness	Maximum	0.07	0.11	0.11	Larger increase in levels throughout the model, increased flood extents
	Minimum	-0.01	0.00	0.00	
	Average	0.02	0.04	0.04	
4c 20% decrease for 2D roughness	Maximum	0.01	0.00	0.00	Small reductions in levels and some reductions noted in flood extents
	Minimum	-0.03	-0.05	-0.05	
	Average	-0.01	-0.02	-0.02	
5 Reduced spillway coefficient	Maximum	0.01	0.02	0.02	Slight rise in level u/s of the spillway
	Minimum	0.00	0.00	0.00	
	Average	0.00	0.00	0.00	

7. Final modelling stage: Do Minimum model (2021)

7.1 Minor updates

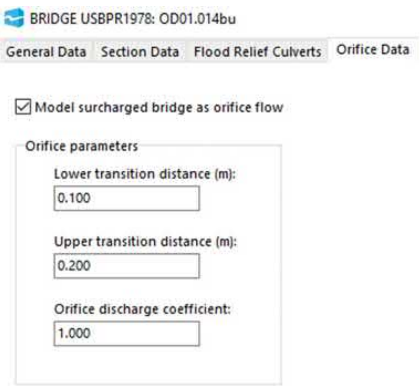
The final 2021 Do Minimum model is essentially the same as the 2018 version. Since that time there has been no capture of new detailed topographical data to update the model or significant flood events against which the model could have been calibrated or validated. The only minor updates to the model are detailed in Table 7.1 which have been aimed at addressing the non-convergence previously reported for the 2018 modelling of extreme events (refer to section 4.6).

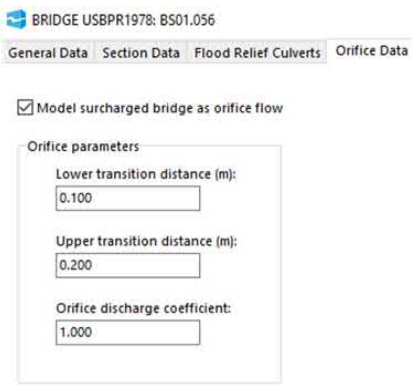
A newer LIDAR dataset (2020, 1m resolution) which partially covered the eastern half of the model was tested during the 2021 model update using the 2007 flood event. The modelling showed that using the original LiDAR, resulted in a better match to the 2007 event observed flood extents (refer to Section 10.2) when compared to using the newer LIDAR dataset. Therefore, the original LiDAR data within the model was retained. It should be noted that large areas of the LiDAR are replaced by topographic ground surveys, as detailed in Section 3 and 4.

Table 7.1: Update to Do Minimum model

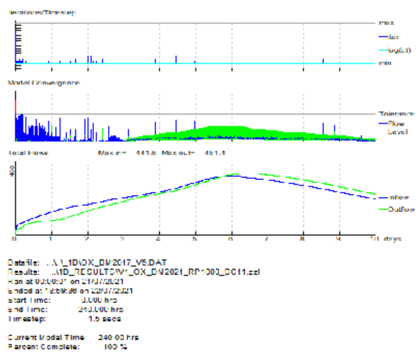
2021 1D Model “Ox_DM2017_v5.DAT” (2018 1D Model “Ox_DM2017_v3.DAT”)

Changes to the transition distances for switching to orifice for bridges OD01.014bu and BS01.056. The original model had 0m for the transition distances, set to 0.1m and 0.2m to smooth out change. The resulting changing have neglibible impacts in water levels and removed the non-convergence reported in 2018.





2021 model convergence



7.2 Testing of hedgerows

The Do Minimum model was used to investigate the effect of hedgerows on water levels, flows and velocities. Hedgerows will be located along the route of the proposed Oxford FAS bypass channel within the western floodplains between Botley Road and Abingdon Road.

Currently hedgerows are not explicitly represented within the modelled floodplains, the 2D floodplain element of the model is based on 1m LiDAR/topographic survey from which TUFLOW extracts elevations for the 10m cell size which is used for the model. Roughness within the floodplains is set at 0.055 (Manning’s n), with some highly vegetated areas set to 0.080/0.085 (dependent on MasterMap land use types). Given the 2D model cell size is 10m, it was decided that it was not feasible to reduce the 2D cell size due to the subsequent increased model run times (say 4 to 8 times longer to run, current run time approximately 48 hours).

Attempts to schematise the hedges at a smaller grid resolution with the latest TUFLOW technology versions of the TUFLOW HPC (finite volume method) solver and TUFLOW Quadtree (allows the user to vary the grid size) were trialled. The trial proved unsuccessful, the HPC method was able to complete a simulation using the same 10m cell size and showed significant run time improvement (approximately 10x faster).

The model using the TUFLOW HPC exhibited strange behaviours and unreliable performance. Using a reduced cell size of 5m, which was the aim of the trial, resulted in a model which would become unstable and crash. Running the model with HPC and Quadtree also proved unsuccessful. Use of the Quadtree method aimed at reducing the mesh cell size around hedgerow area. Despite multiple attempts, the Quadtree model crashed, inspection of the results showed that the model could crash before water had reached the adjusted cells within the Quadtree model.

Due to the uncertainties with the HPC modelling, the original model type approach (TUFLOW Classic) is retained knowing the models successfully run. There is no standard modelling guidance for representation of hedgerows. Therefore, a set of scenarios have been run to test modelling the hedgerows with 2D flow constriction cells, with only hedgerows along the route of the proposed route of the Oxford FAS bypass channel represented. The method used the TUFLOW '2d_fcsh layer' and assumed the 2D cell elevations at the hedgerows increased (by approximately 0.2m, based on experience (as no survey data was available). The modelling tested different blockage percentages applied above this elevation to restrict flows through the hedges (0%, 10%, 20%, 30% and 50%).

The modelling showed that the additional schematisation of the hedgerows led to negligible differences in the model results. This is as expected given that the flood depths are high and velocities very low in the floodplains.

Figure 7.1 shows an example of maximum flood depths and velocities for the 20% AEP and 1% AEP events. As shown in the figure, the flood depths at the hedgerows exceed 1m with velocities around 0.1m/s. The long section of floodplain maximum water levels (1% AEP) shows a very small water surface gradient (1 in 10,000), with localised changes in water levels at the floodplain constrictions at Willow Walk, Causeway and Old Abingdon Road.

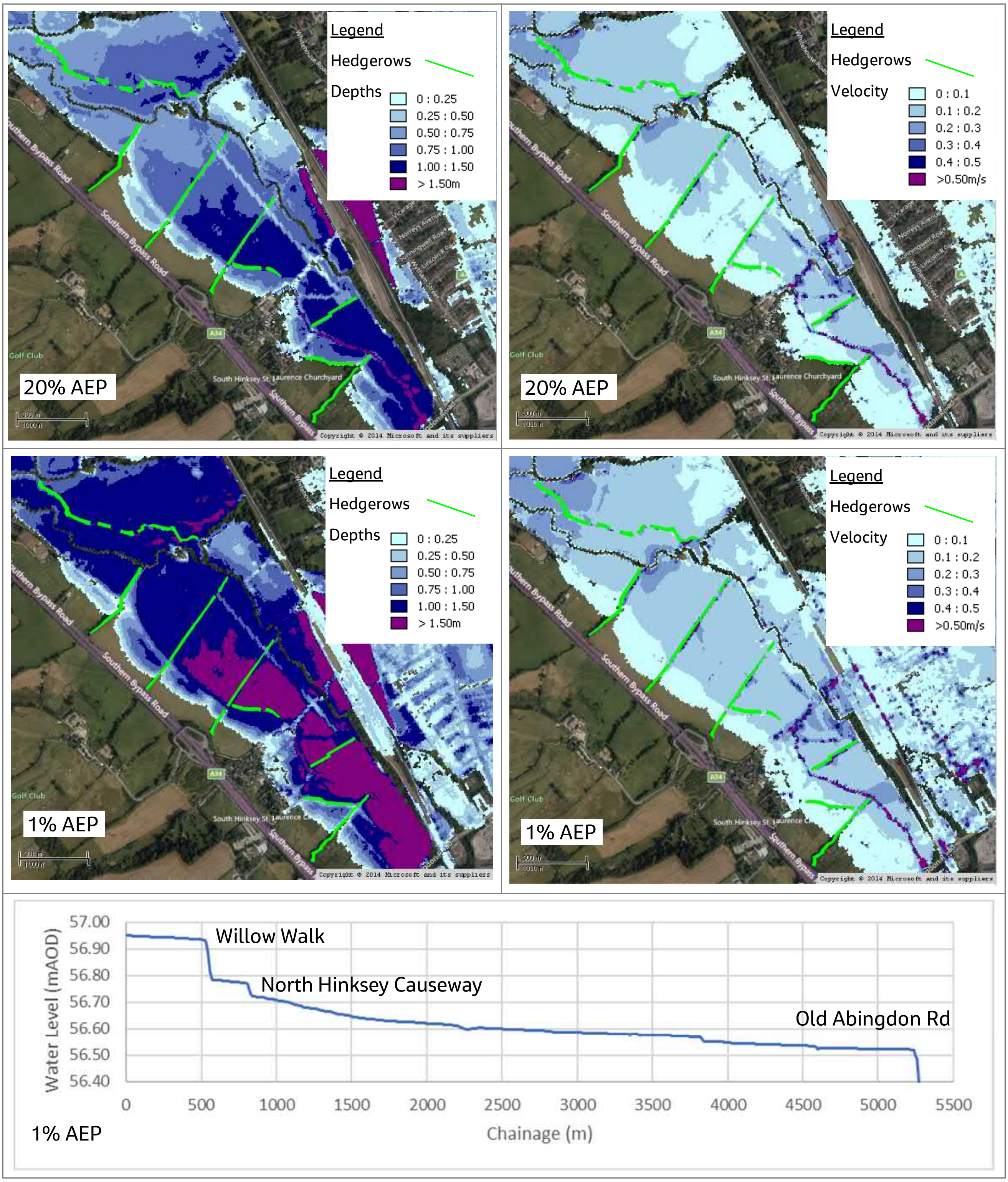


Figure 7.1: Flood depths and velocities

7.3 Comparison with previous study results

The 2021 Do Minimum model has been run for scenarios based on the latest climate change guidance which includes an uplift of +11%. The 1% AEP has also been run as a sensitivity test to provide a direct comparison to the 2018 model results and any potential impacts when running the model with the latest software versions of Flood Modeller and TUFLOW.

Figure 7.2 shows the maximum level differences between the 2021 model using old/new software versions and a comparison directly with the 2018 results. The comparison shows the software versions and model update to show negligible differences in the model results.

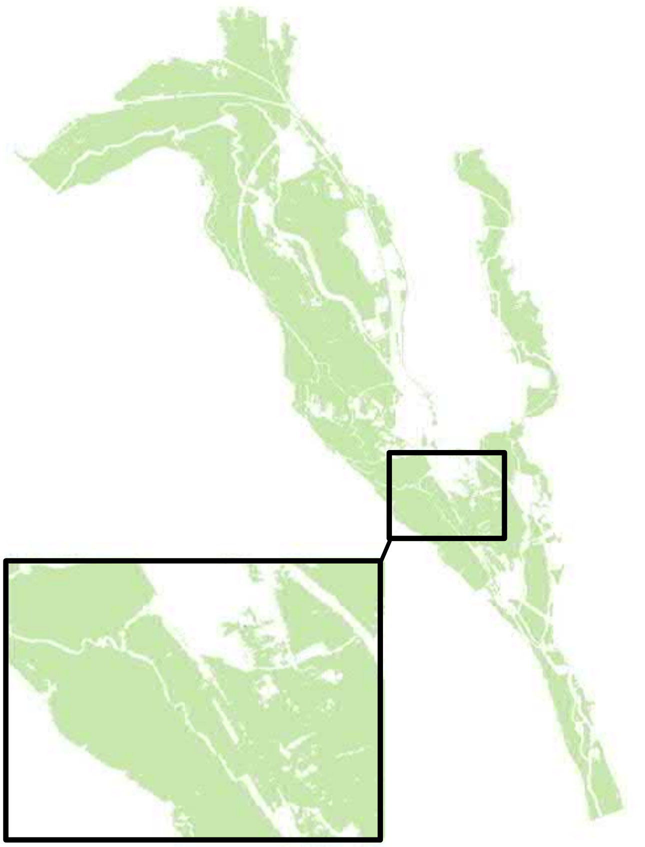
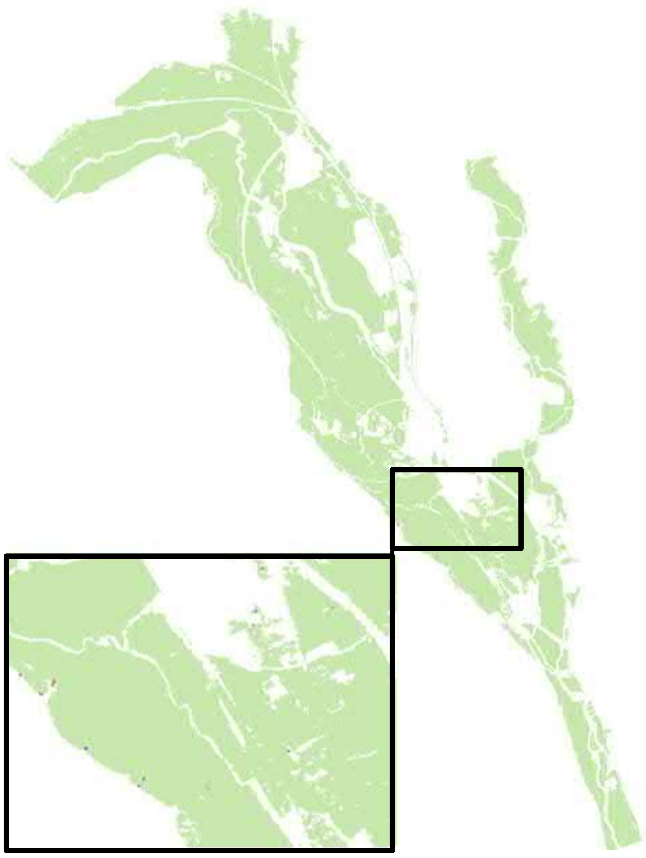
Maximum 1D and 2D water level differences using the 2021 model for software versions for Flood Modeller 4.3 to 5.0 and TUFLOW 2016-03-AE and 2020-10-AA. Tabulated 1D maximums show differences between the software versions of +/- 0.001m. The 2D maximum difference map below represents +/-0.01m (green shading)	Maximum 1D and 2D water level differences between the 2021 model using the latest software versions and including hedgerows with the 2018 modelling (older software version and no hedgerows) Tabulated 1D maximums show differences between +0.008m and -0.004m The 2D maximum difference map below represents +/-0.01m. There are some minor differences were the odd cell either becomes wet or does not flood.
	

Figure 7.2: 1% AEP comparison between 2018 and 2021 model

7.4 Sensitivity to catchment climate change allowances

The 20%, 5% and 1% AEP events for the 2020s and 2080s have been run to test the impacts to the choice of climate change uplifts. The uplift values applied for the sensitivity tests are detailed in Table 7.2

The baseline scenario used the Cotswolds catchment flow allowances for 11% (2020's) and 30% (2080's) uplifts to the model inflows. The sensitivity test used the uplifts from the corresponding management catchment for the relevant inflow, i.e., Cherwell based on the Cherwell and Ray catchment and minor inflows based on the Gloucester and the Vale catchment. For the 2080's the Thames inflow uplift has been based on the catchment area weighting between the Cotswolds and Gloucester and the Vale catchments.

At Sandford (model outflow), the change in peak flows are detailed in Table 7.3 and changes to the hydrographs presented in Figure 7.3 (2020's) and Figure 7.4 (2080's). The sensitivity test shows the peak flows to reduce by 1% to 1.5% (2020's) and 3.6% to 4% (2080s) for the 20%, 5% and 1% AEP's tested.

Table 7.2: Climate change sensitivity test - uplift factors

Model Node	Inflow	Climate change guidance Management Catchment	2020s uplift (%)		2080s uplift (%)	
			Baseline (1)	Sensitivity	Baseline (1)	Sensitivity
50.078Q	Thames	Cotswolds / Gloucester and the Vale	11(1)	11	30(1)	27.8(2)
CHER_A40	Cherwell and Ray	Cherwell and Ray	11(1)	6	30(1)	15
50.EVEN	Evenlode	Cotswolds	11(1)	11	30(1)	30
Sanug	Minor inflow	Gloucester and the Vale	11(1)	11	30(1)	26
Iffug	Minor inflow	Gloucester and the Vale	11(1)	11	30(1)	26
47.SL	Minor inflow	Gloucester and the Vale	11(1)	11	30(1)	26
HD07.023	Minor inflow	Gloucester and the Vale	11(1)	11	30(1)	26

(1) Baseline applied the Cotswold management catchment uplifts for all inflows

(2) uplift based on area weighting between the Cotswolds and Gloucester and the Vale catchments

Table 7.3: Climate change sensitivity test – peak flows at Sandford (model outflow)

Scenario	Peak Flows (m^3/s) 20% AEP		Peak Flows (m^3/s) 5% AEP		Peak Flows (m^3/s) 1% AEP	
	2020s uplift	2080s uplift	2020s uplift	2080s uplift	2020s uplift	2080s uplift
Baseline	201.19	236.12	256.14	299.51	322.97	373.81
Sensitivity	198.80	226.71	253.42	288.26	318.00	360.13
Difference (m^3/s)	-2.39	-9.41	-2.72	-11.25	-4.97	-13.68
Difference (%)	-1.19%	-3.99%	-1.06%	-3.76%	-1.54%	-3.66%

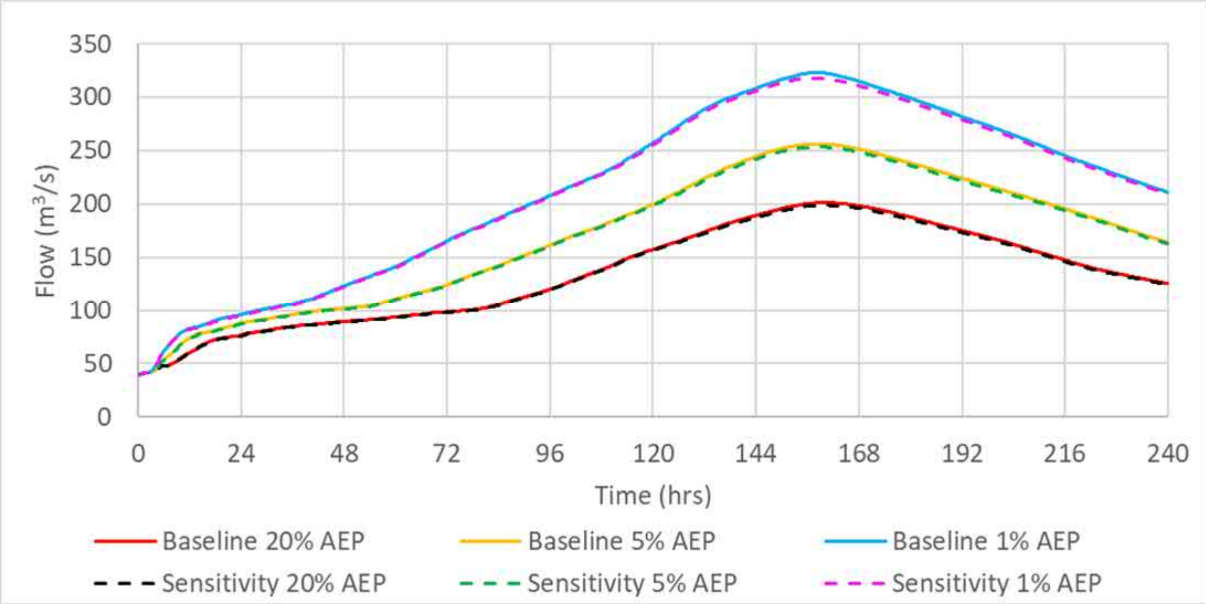


Figure 7.3: Climate change sensitivity test - flows at Sandford 2020s

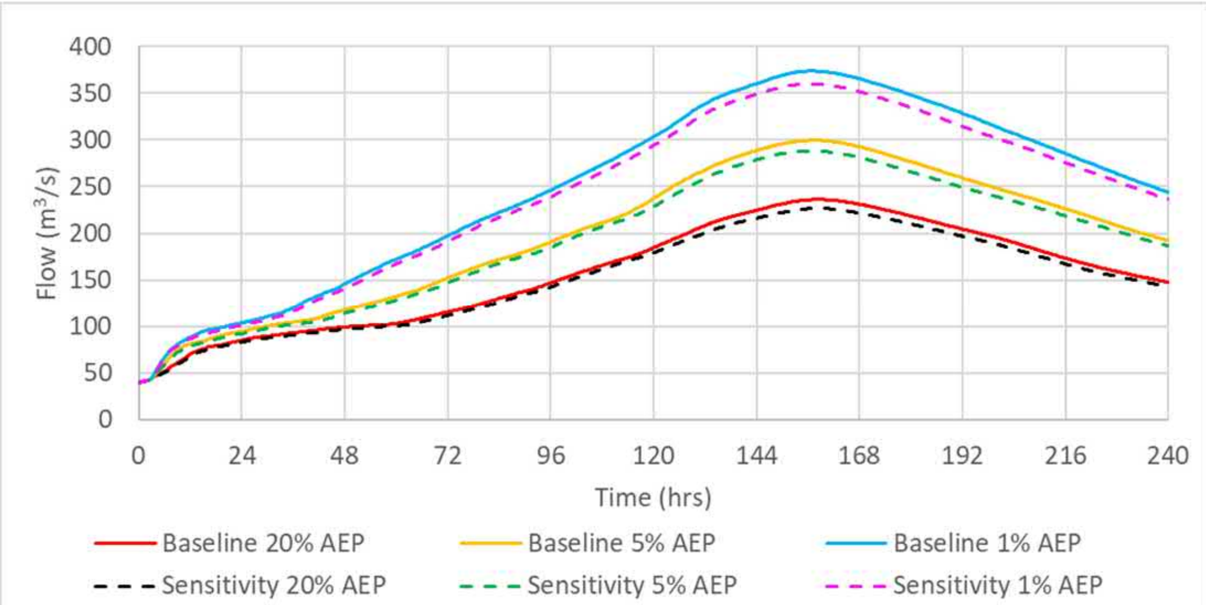


Figure 7.4: Climate change sensitivity test - flows at Sandford 2080s

Figure 7.5 (20% AEP), Figure 7.6 (5% AEP) and Figure 7.7 (1% AEP) compare the baseline flood extents (red shading) with the sensitivity test (green shading).

Figure 7.5: Climate change sensitivity test – flood extents (20% AEP)

Figure 7.6: Climate change sensitivity test – flood extents (5% AEP)

Figure 7.7: Climate change sensitivity test – flood extents (1% AEP)

8. Final modelling stage: detailed design FAS model (2021)

Elements of the Oxford FAS design have changed since the 2018 design proposals. The main differences are downstream of Old Abingdon Road around the A423 and minor elevations/alignments changes to some of the proposed raised defences. Figure 8.1 shows an overview map of where changes have been made. Section 5 should still be referred to details of the scheme which have not changed since the 2018 submission.

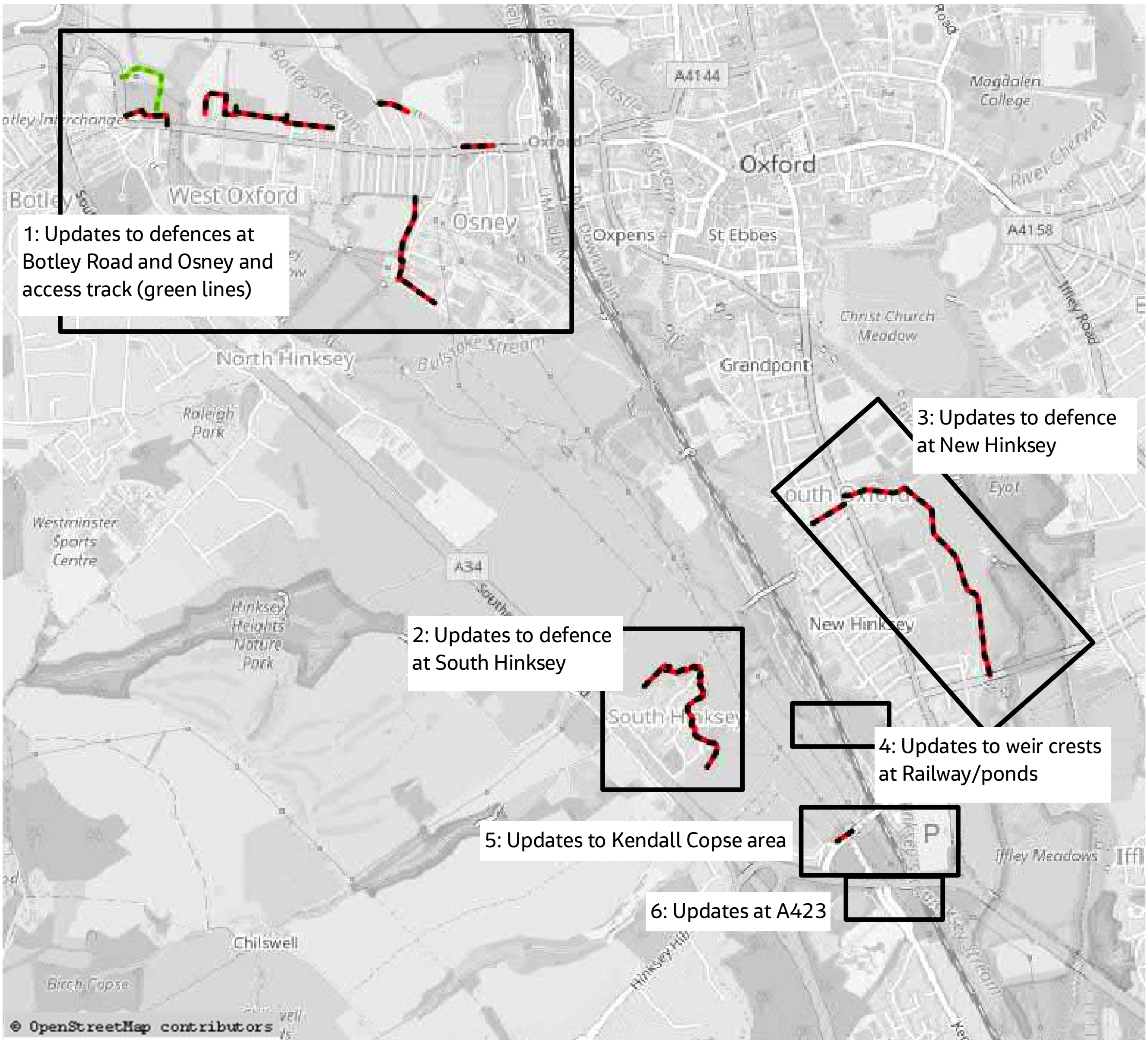


Figure 8.1: Locations of Oxford FAS model updates

8.1 Updated model schematisation

Details on the model updates to represent the latest FAS proposal for the 1D and 2D model elements are included in Table 8.1 to Table 8.6. This covers the updates to defences at Botley Road and Osney, defence at South Hinksey, defence at New Hinksey, weir crests at railway/pond, in the Kendall Copse area and A423.

Table 8.1: Updates to defences at Botley Road and Osney

Defences at Botley Road, Henry/Helen Road and Allotments - 2d_zsh_FAS_Defence_Design_Level.shp

- Defence levels at Botley Road updated from 2018 to actual crest levels which include the freeboard allowance (where freeboard is included) instead of the glass wall approach. Lowest point of the defence is 57.40mAOD which is determined by existing ground levels at the park and ride (no freeboard)
- Henry/Helen Road, repairs/improvements to the right bank to provide a minimum level of 57.53mAOD
- Allotment defence levels raised from 57.25mAOD to 57.35mAOD (no freeboard)

Access Track upstream of Botley Road - 2d_zsh_AccessTrack_L.shp and 2d_zsh_AccessTrack_L.shp

- New access track to the western bank of Seacourt Stream. Note the access track is not a flood defence and will be inundated for all flood events (flooded at 50% AEP)

Osney Defence - 2d_zsh_FAS_Defence_OsneyV23.shp and 1d_nwk_estry_osney4_FAS.shp

- Osney defence crest set to 2 levels, 56.70mAOD (determine by existing topography i.e. no freeboard) on the upstream north/south alignment and 56.55mAOD for the southern alignment of the defence. Split level required to ensure water is not trapped behind the defence when they are overtopped. Design include 4x 500m flapped valves through the southern defence alignment to drain water following flood events (modelled as TUFLOW Estry culverts).

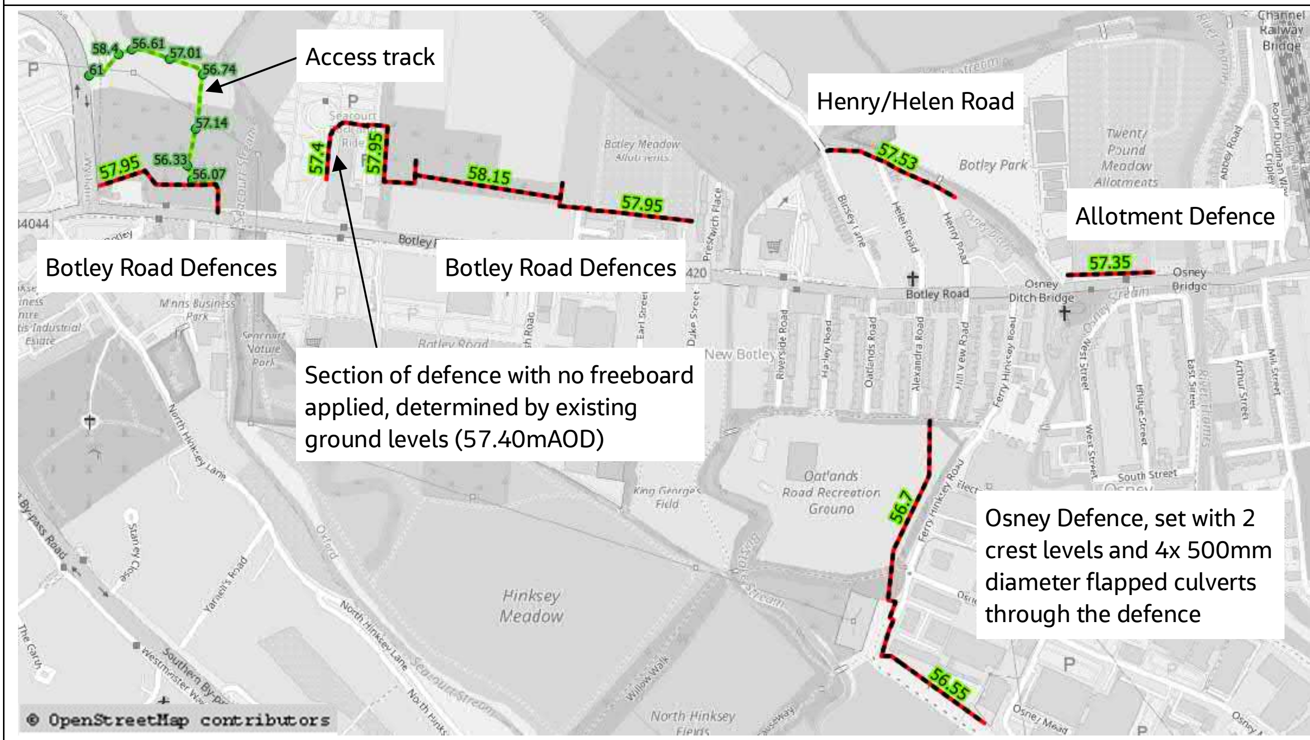


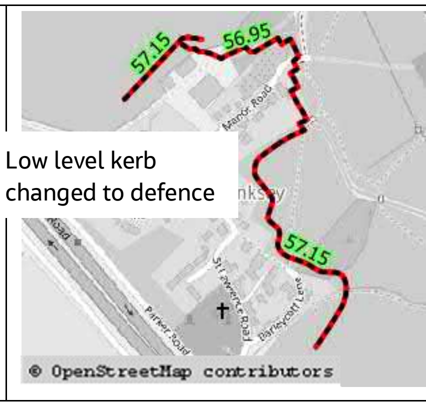
Table 8.2: Update to defence at South Hinksey

<table>
<tr>
<td>

<u>2d_zsh_FAS_Defence_Design_Level.shp</u>

- Defence levels updated from 2018 to actual crest levels which includes the freeboard allowance (where freeboard is included)
- 2018 modelling included a low level kerb set at 56.62mAOD, this is replaced with a defence set at 57.15mAOD.
- Minor change to defence alignment

</td>
<td>



</td>
</tr>
</table>

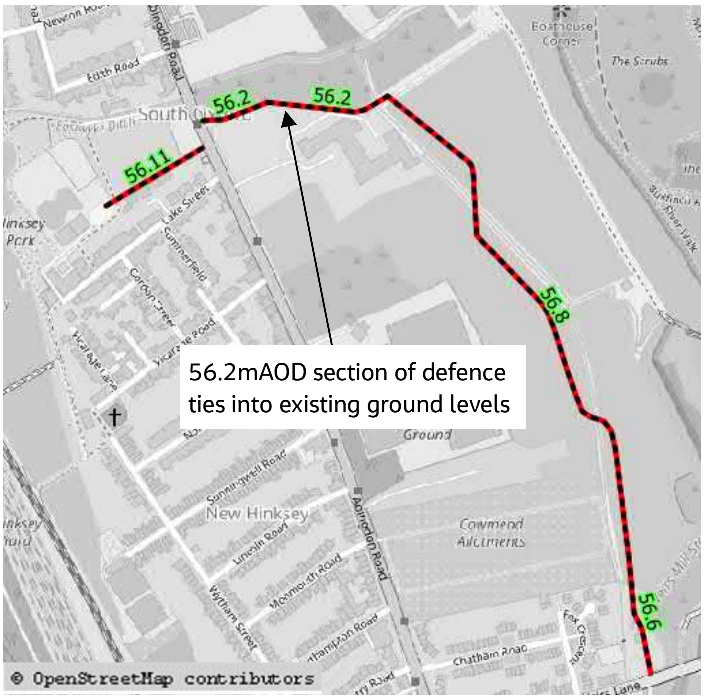
Table 8.3: Update to defence at New Hinksey

<table>
<tr>
<td>

<u>2d_zsh_FAS_Defence_Design_Level.shp</u>

- Defence levels updated from 2018 to actual crest levels which includes the freeboard allowance (where freeboard is included)
- Section of defence at Abingdon Road set at 56.20mAOD which is determined by existing ground levels (no freeboard)
- Minor change to defence alignment
- Defence at 56.11mAOD at the southern edge of the park represents the rear of the buildings and wall which would stop flow routes. Note this is not part of the Oxford FAS.

</td>
<td>



</td>
</tr>
</table>

Table 8.4: Update to weir crests at railway/pond

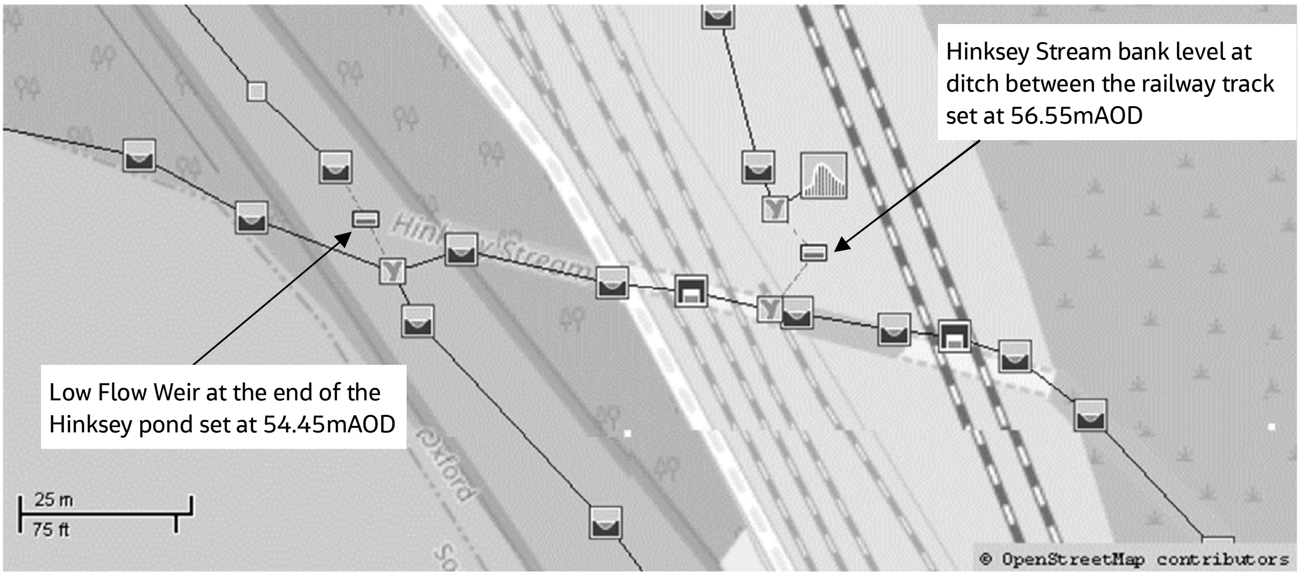
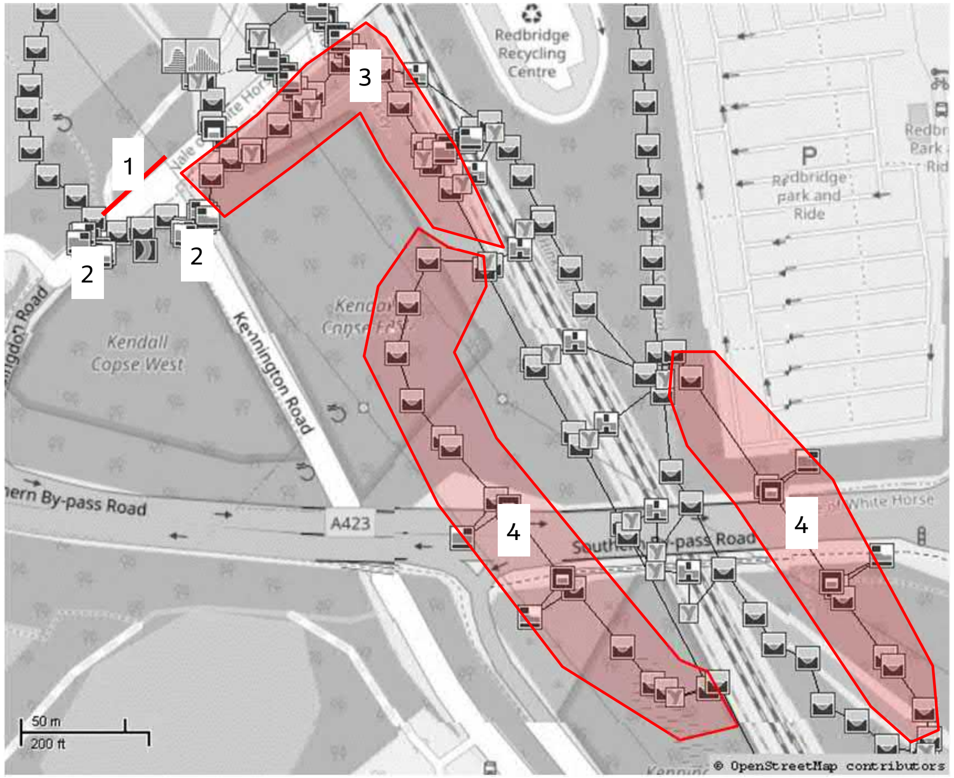
<u>Changes within 1D model (OxFAS_MedChannel_v6.dat)</u> ▪ New weir at the end of the existing pond in Hinksey Stream set at 54.45mAOD to maintain levels at normal/low flow conditions ▪ Hinksey Stream bank level at ditch between the railway track set at 56.55mAOD (previously glass walled)


Table 8.5: Updates in Kendall Copse area

Changes to 1D model schematisation (2018 model Ox_DD_v7.dat, updated 2021 model OxFAS_MedChannel_v6.dat)
1) Low level defence at Network rail access track was set at 56.30/56.55mAOD. Crest level set to 56.55mAOD (2d_zsh_AbingdonRd_v2.shp)
2) Culverts at Old Abingdon Road and Kennington Road same as 2018 version
3) Hinksey Ditch which was widened as part of the 2018 version, no change for 2021 version (i.e. as existing)
4) 8m wide culverts under A423 in the 2018 version not required for 2021 version (A423 bridge planned to be re-built)
5) New channel added in 2021 version (instead of widening the existing Hinksey Ditch) from the Kennington Road culvert to the A423, right bank 56.40mAOD



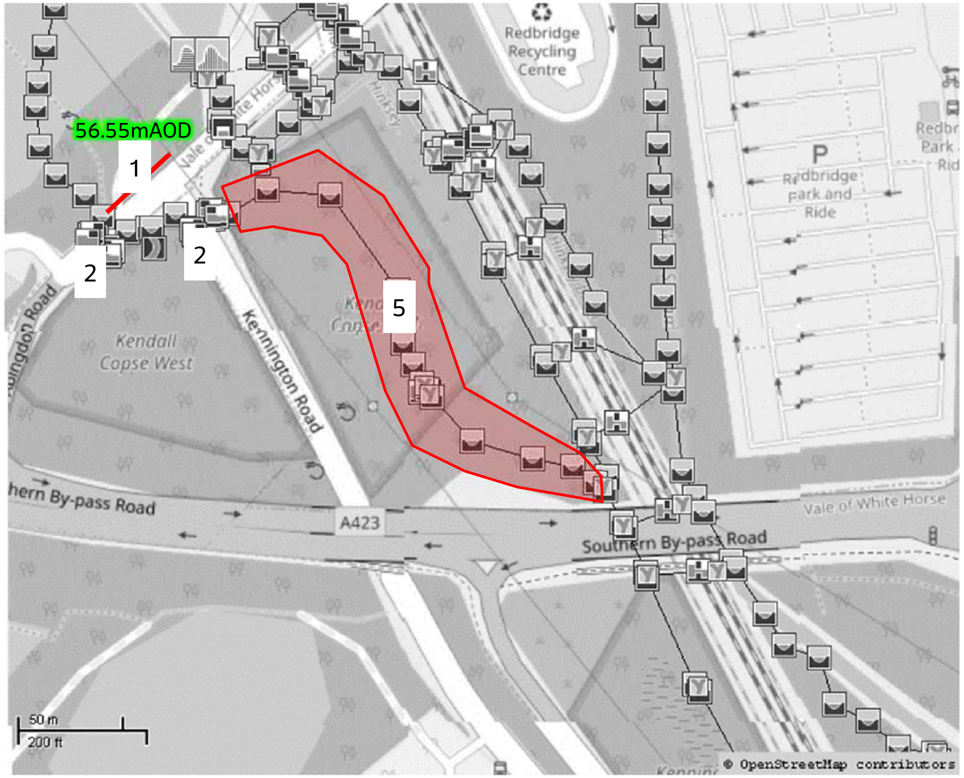
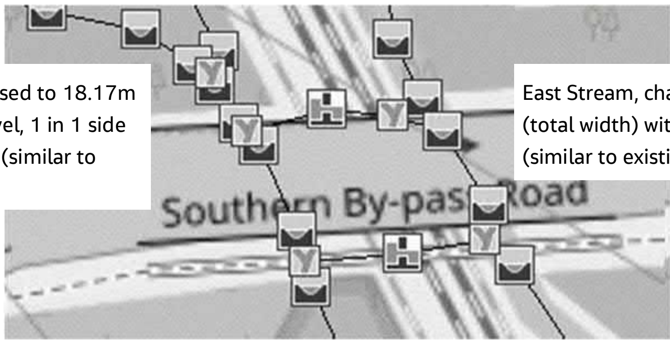
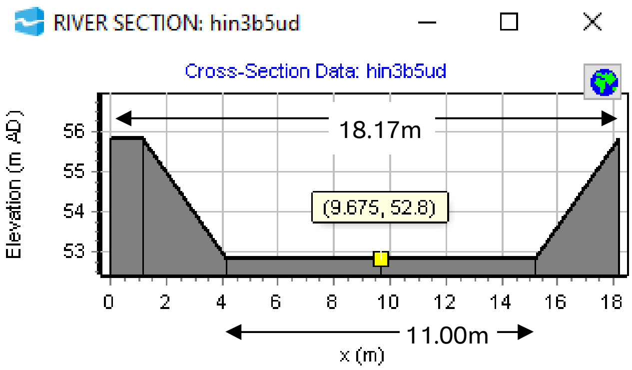
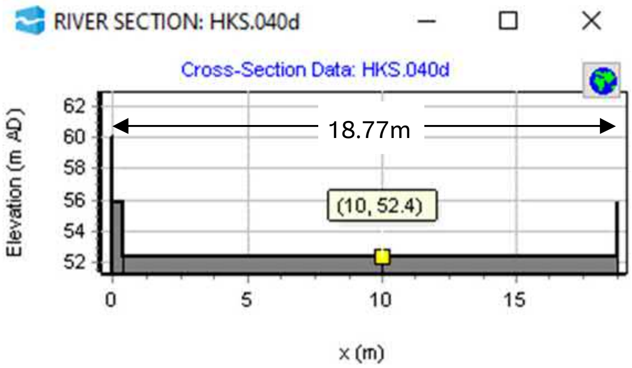
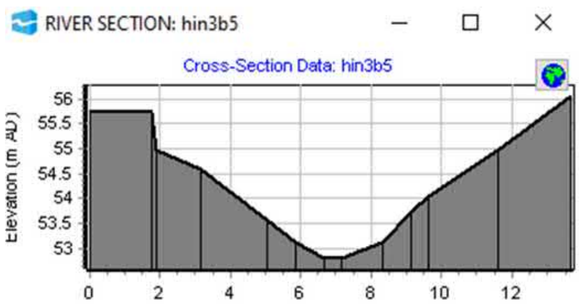
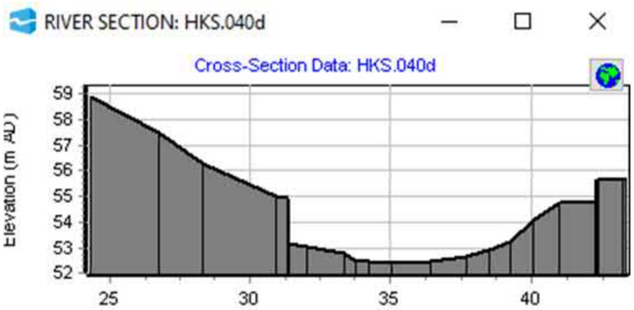


Table 8.6: Update to A423

<table>
<tr><td colspan="2"><u>Changes within 1D model (OxFAS_MedChannel_v6.dat)</u>
▪ 2018 version of the model retained the existing cross sections at the A423 as the 8m wide bypass culverts were part of the FAS (now removed from the FAS)
▪ A423 Bridge being re-built with enlarged cross sections</td></tr>
<tr><td colspan="2">West Stream, channel size increased to 18.17m and top level and 11m at bed level, 1 in 1 side slopes. Bed level at 52.80mAOD (similar to existing bed level)


East Stream, channel size increased to 18.77m (total width) with bed level at 52.40mAOD (similar to existing bed level)</td></tr>
<tr><td>Modified Section (west)

</td><td>Modified Section (east)

</td></tr>
<tr><td>Existing Section (west)

</td><td>Existing Section (east)

</td></tr>
</table>

8.2 Temporary defences

Figure 8.2 details the locations, lengths and heights for the temporary defences which are deployed at Osney Island and New Hinksey and included as part of the FAS detailed design.

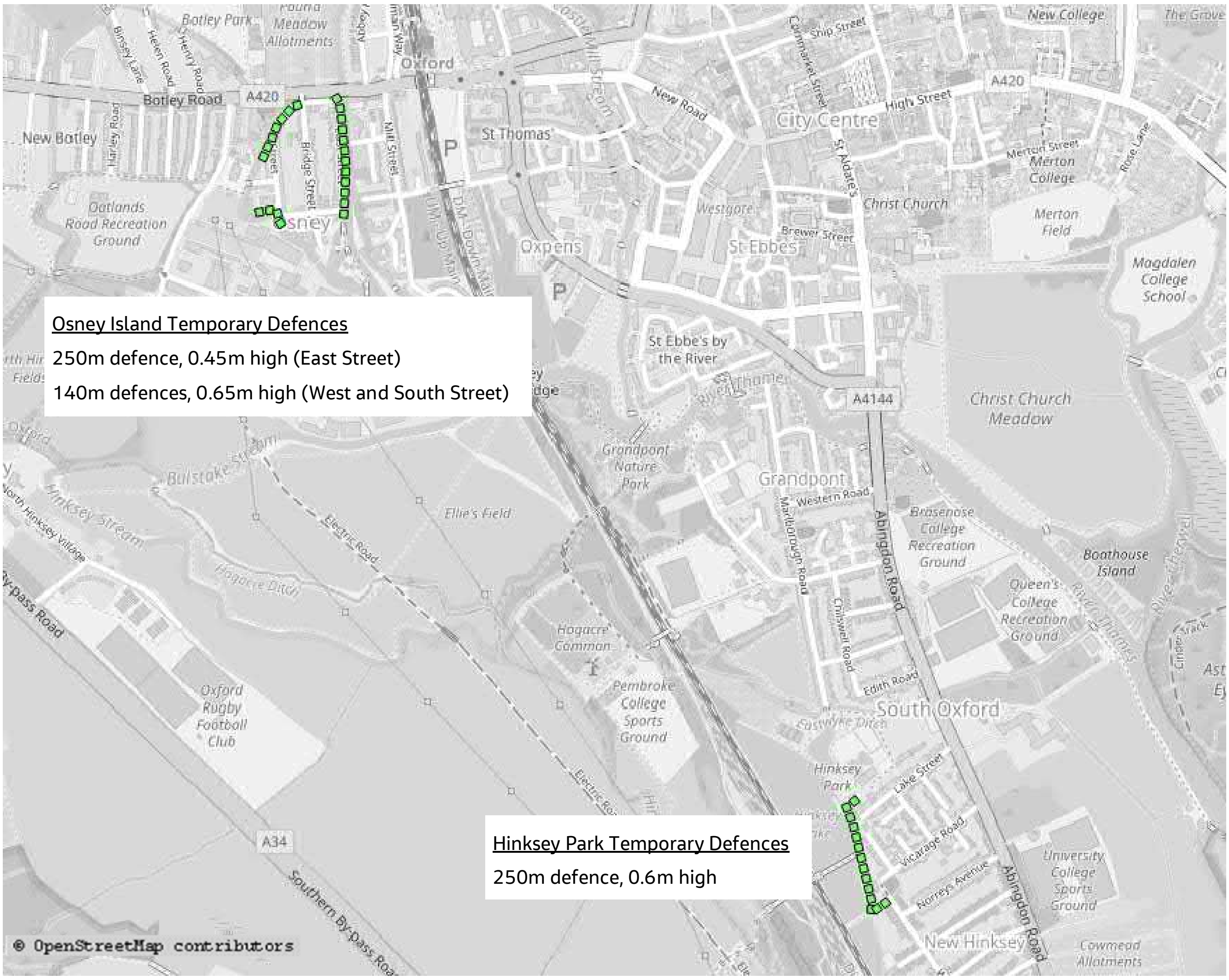


Figure 8.2: Temporary defences

8.3 Model results

Peak river water levels and comparison to Do Minimum are detailed in Table 8.7 for the 50%, 20%, 10%, 5%, 2% and 1.3% AEP events (2, 5,10, 20, 50 and 75-year). Table 8.8 details the peak levels for the 1%, 0.5%, 0.1% AEP events (100, 200, 1000-year) and the 1% AEP with climate change allowances of +13%, +30% and +82%. The Do Minimum scenario results do not include the deployment of the Oxford temporary defences.

The locations of the model nodes reported in the tables are indicated in Figure 4.7.

The model results show that the FAS reduces the maximum river flood levels between Binsey/Port Meadow to the Thames/Hinksey stream confluence (downstream of the A423). On the Bulstake Stream at Botley Road, the modelling predicts the peak levels to reduce by 0.09m to 0.21m between the 1% and 50% AEP events. At Mayweed Bridge (Old Abingdon Road) peak levels reduce by 0.08m to 0.34m between 1% and 50% AEP events.

Figure 8.3 shows an annotated map for the 1% AEP event, which presents the changes to the maximum water levels in the floodplains using the maximum 2D water levels grids for the FAS and Do Minimum scenario. Areas where there are no changes in maximum water levels are shaded light green and areas where flooding is removed due to the FAS are shaded black. Where maximum water levels are reduced the areas area shaded blues and dark green and any increases in water levels are shaded yellow/orange/purples.

Figure 8.4 to Figure 8.9 compare the flood extents for the FAS (blue shading) to the Do Minimum scenario (pink shading). The maps show large areas are protected by the FAS up to the 2% AEP event (50-year). At the 1.3% AEP event (75-year), flooding is predicted to start in the New Hinksey Area, the flooding spreads from Redbridge Stream. In this area where flooding is shown for the FAS, the depth of flooding compared to Do Minimum is reduced by 0.20m to 0.50m.

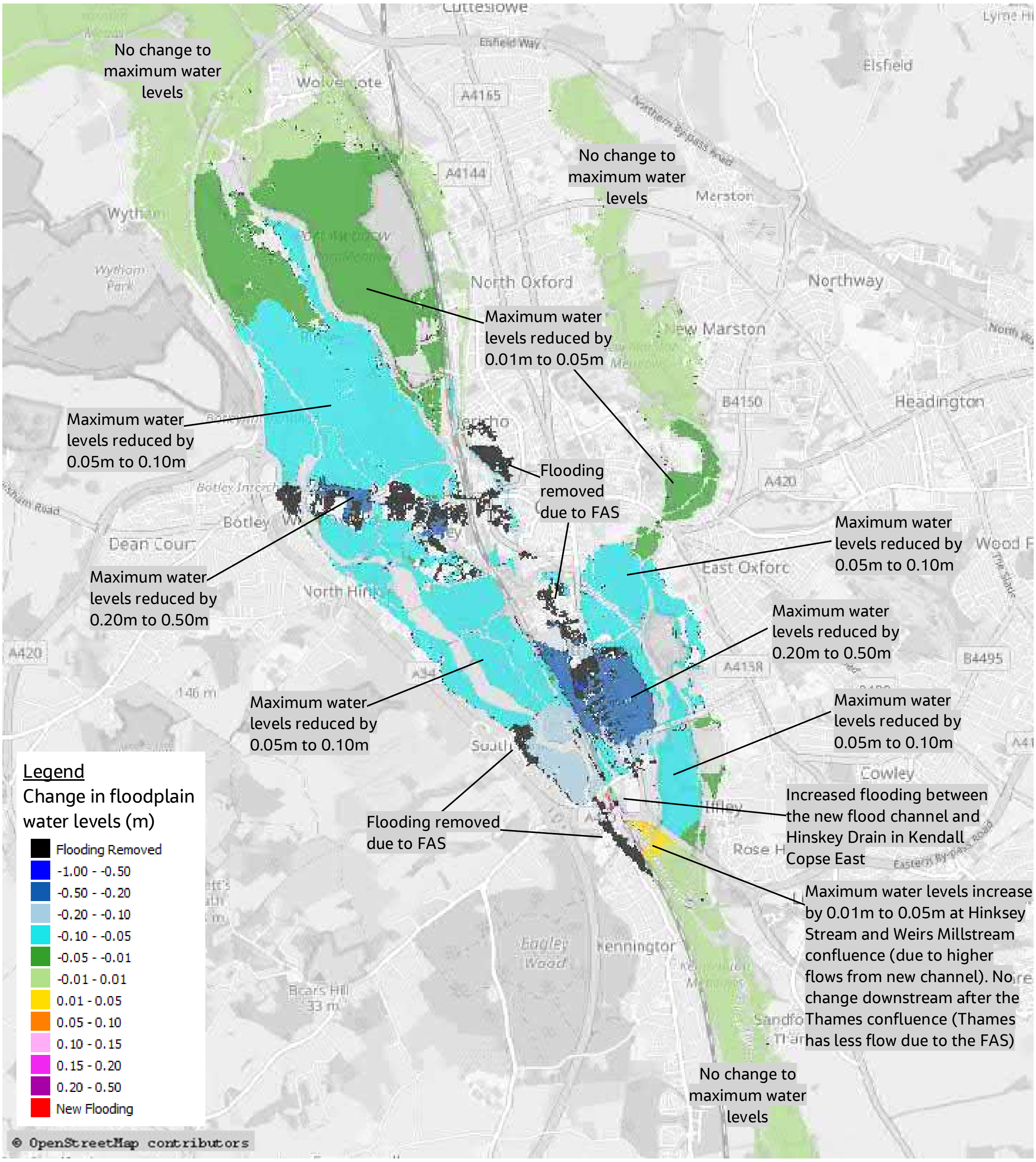


Figure 8.3: Difference maps (1% AEP)

Table 8.7: Peak water levels (mAOD) and comparison to Do Minimum (m)

		50% AEP (2-year)			20% AEP (5-year)			10% AEP (10-year)			5% AEP (20-year)			2% AEP (50-year)			1.3% AEP (75-year)		
Re	**Location**	**Do Min**	**FAS**	**Diff**	**Do Min**	**FAS**	**Diff**	**Do Min**	**FAS**	**Diff**	**Do Min**	**FAS**	**Diff**	**Do Min**	**FAS**	**Diff**	**Do Min**	**FAS**	**Diff**
1	Seacourt/Botley Stream	56.98	56.89	-0.09	57.23	57.02	-0.21	57.36	57.16	-0.20	57.44	57.28	-0.16	57.55	57.44	-0.11	57.59	57.50	-0.09
2	Seacourt at Botley Road	56.86	56.40	-0.46	57.14	56.78	-0.36	57.26	57.00	-0.26	57.34	57.14	-0.20	57.45	57.31	-0.14	57.49	57.37	-0.12
3	Bulstake at Botley Road	56.77	56.66	-0.11	57.02	56.81	-0.21	57.14	56.95	-0.19	57.22	57.06	-0.16	57.32	57.20	-0.12	57.36	57.26	-0.10
4	Osney Ditch	56.91	56.79	-0.12	57.21	57.01	-0.20	57.34	57.16	-0.18	57.42	57.27	-0.15	57.52	57.43	-0.09	57.56	57.49	-0.07
5	Thames at Botley Road	56.77	56.78	0.01	56.92	56.83	-0.09	57.03	56.90	-0.13	57.11	56.98	-0.13	57.22	57.11	-0.11	57.26	57.17	-0.09
6	Castle Mill Stream	56.67	56.66	-0.01	56.78	56.72	-0.06	56.87	56.77	-0.10	56.93	56.83	-0.10	57.02	56.95	-0.07	57.05	57.00	-0.05
7	Seacourt Willow Walk	56.41	56.02	-0.39	56.60	56.26	-0.34	56.70	56.42	-0.28	56.76	56.54	-0.22	56.83	56.69	-0.14	56.86	56.74	-0.12
8	Bulstake Willow Walk	56.39	56.28	-0.11	56.55	56.35	-0.20	56.71	56.45	-0.26	56.77	56.55	-0.22	56.86	56.74	-0.12	56.89	56.79	-0.10
9	Thames d/s Osney	56.07	55.95	-0.12	56.29	56.13	-0.16	56.42	56.27	-0.15	56.50	56.37	-0.13	56.62	56.49	-0.13	56.67	56.55	-0.12
10	Thames	55.80	55.68	-0.12	56.03	55.87	-0.16	56.19	56.03	-0.16	56.29	56.15	-0.14	56.41	56.31	-0.10	56.46	56.37	-0.09
11	Hinksey Stream	55.94	55.76	-0.18	56.17	55.99	-0.18	56.32	56.15	-0.17	56.43	56.27	-0.16	56.56	56.44	-0.12	56.60	56.51	-0.09
12	Eastwyke Ditch (west)	55.85	55.73	-0.12	56.09	55.96	-0.13	56.23	56.11	-0.12	56.32	56.23	-0.09	56.44	56.41	-0.03	56.48	56.48	0.00
13	Eastwyke Ditch Abingdon Rd	55.54	55.44	-0.10	55.76	55.63	-0.13	55.91	55.78	-0.13	56.00	55.90	-0.10	56.10	56.03	-0.07	56.15	56.08	-0.07
14	Thames (Cherwell Conf)	55.54	55.45	-0.09	55.75	55.64	-0.11	55.89	55.78	-0.11	55.98	55.89	-0.09	56.08	56.01	-0.07	56.12	56.06	-0.06
15	Devils Backbone	55.71	55.46	-0.25	56.06	55.78	-0.28	56.25	56.01	-0.24	56.37	56.16	-0.21	56.50	56.36	-0.14	56.54	56.43	-0.11
16	Cold Harbour Bridges	55.51	55.27	-0.24	55.97	55.62	-0.35	56.20	55.86	-0.34	56.33	56.04	-0.29	56.45	56.27	-0.18	56.49	56.35	-0.14
17	Mayweed Bridge	55.34	55.11	-0.23	55.82	55.48	-0.34	56.02	55.73	-0.29	56.14	55.90	-0.24	56.25	56.12	-0.13	56.28	56.20	-0.08
18	Weirs Mill Stream (d/s Weirs)	54.98	54.95	-0.03	55.18	55.13	-0.05	55.31	55.26	-0.05	55.43	55.35	-0.08	55.60	55.50	-0.10	55.68	55.57	-0.11
19	Thames Donnington Road	55.29	55.21	-0.08	55.52	55.42	-0.10	55.68	55.56	-0.12	55.77	55.68	-0.09	55.86	55.79	-0.07	55.89	55.83	-0.06
20	Thames Iffley Lock u/s	55.13	55.07	-0.06	55.37	55.29	-0.08	55.53	55.44	-0.09	55.63	55.55	-0.08	55.74	55.68	-0.06	55.78	55.73	-0.05
21	A423 West (Hinksey Ditch)	54.97	54.96	-0.01	55.25	55.25	0.00	55.39	55.44	0.05	55.50	55.60	0.10	55.64	55.79	0.15	55.70	55.87	0.17
22	A423 East (Hinksey Stream)	55.02	54.84	-0.18	55.29	55.04	-0.25	55.42	55.17	-0.25	55.50	55.27	-0.23	55.60	55.41	-0.19	55.64	55.47	-0.17
23	Mundays Bridge	54.83	54.86	0.03	55.04	55.09	0.05	55.17	55.25	0.08	55.28	55.40	0.12	55.44	55.57	0.13	55.50	55.64	0.14
24	End of Weirs Mill Stream	54.80	54.81	0.01	54.99	55.00	0.01	55.11	55.13	0.02	55.20	55.22	0.02	55.33	55.36	0.03	55.39	55.42	0.03
25	Thames d/s Hinksey Stream	54.64	54.64	0.00	54.81	54.81	0.00	54.91	54.91	0.00	54.98	54.98	0.00	55.09	55.09	0.00	55.14	55.14	0.00
26	Thames Binsey/Port Meadow	57.59	57.59	0.00	57.66	57.66	0.00	57.72	57.71	-0.01	57.77	57.74	-0.03	57.86	57.82	-0.04	57.90	57.86	-0.04

Table 8.8: Peak water levels (mAOD) and comparison to Do Minimum (m)

		1% AEP (100-year)			0.5% AEP (200-year)			0.1% AEP (1000-year)			1% AEP (100-year) +13%			1% AEP (100-year) +30%			1% AEP (100-year) +82%		
Re	Location	Do Min	FAS	Diff	Do Min	FAS	Diff	Do Min	FAS	Diff	Do Min	FAS	Diff	Do Min	FAS	Diff	Do Min	FAS	Diff
1	Seacourt/Botley Stream	57.62	57.54	-0.08	57.69	57.63	-0.06	57.86	57.84	-0.02	57.63	57.56	-0.07	57.73	57.68	-0.05	58.00	57.99	-0.01
2	Seacourt at Botley Road	57.52	57.41	-0.11	57.58	57.49	-0.09	57.75	57.68	-0.07	57.53	57.42	-0.11	57.62	57.54	-0.08	57.87	57.83	-0.04
3	Bulstake at Botley Road	57.38	57.29	-0.09	57.44	57.38	-0.06	57.63	57.58	-0.05	57.39	57.31	-0.08	57.48	57.42	-0.06	57.75	57.73	-0.02
4	Osney Ditch	57.59	57.52	-0.07	57.65	57.60	-0.05	57.80	57.79	-0.01	57.60	57.54	-0.06	57.69	57.65	-0.04	57.92	57.92	0.00
5	Thames at Botley Road	57.29	57.22	-0.07	57.37	57.31	-0.06	57.55	57.52	-0.03	57.31	57.23	-0.08	57.41	57.38	-0.03	57.68	57.66	-0.02
6	Castle Mill Stream	57.07	57.03	-0.04	57.13	57.09	-0.04	57.31	57.26	-0.05	57.09	57.04	-0.05	57.17	57.13	-0.04	57.49	57.46	-0.03
7	Seacourt Willow Walk	56.89	56.78	-0.11	56.94	56.85	-0.09	57.10	57.02	-0.08	56.90	56.79	-0.11	56.98	56.90	-0.08	57.26	57.18	-0.08
8	Bulstake Willow Walk	56.92	56.83	-0.09	56.98	56.90	-0.08	57.14	57.07	-0.07	56.93	56.84	-0.09	57.02	56.95	-0.07	57.28	57.21	-0.07
9	Thames d/s Osney	56.70	56.60	-0.10	56.77	56.69	-0.08	56.95	56.89	-0.06	56.71	56.61	-0.10	56.82	56.75	-0.07	57.11	57.05	-0.06
10	Thames	56.49	56.41	-0.08	56.56	56.50	-0.06	56.76	56.70	-0.06	56.50	56.43	-0.07	56.61	56.56	-0.05	56.95	56.89	-0.06
11	Hinksey Stream	56.63	56.55	-0.08	56.70	56.64	-0.06	56.88	56.82	-0.06	56.65	56.57	-0.08	56.75	56.69	-0.06	57.05	56.98	-0.07
12	Eastwyke Ditch (west)	56.51	56.52	0.01	56.59	56.61	0.02	56.78	56.78	0.00	56.53	56.54	0.01	56.64	56.66	0.02	56.97	56.92	-0.05
13	Eastwyke Ditch Abingdon Rd	56.18	56.11	-0.07	56.26	56.20	-0.06	56.52	56.44	-0.08	56.19	56.13	-0.06	56.33	56.26	-0.07	56.80	56.71	-0.09
14	Thames (Cherwell Conf)	56.15	56.09	-0.06	56.23	56.18	-0.05	56.50	56.41	-0.09	56.17	56.11	-0.06	56.30	56.23	-0.07	56.77	56.68	-0.09
15	Devils Backbone	56.57	56.47	-0.10	56.63	56.56	-0.07	56.78	56.72	-0.06	56.58	56.49	-0.09	56.67	56.60	-0.07	56.93	56.87	-0.06
16	Cold Harbour Bridges	56.52	56.39	-0.13	56.58	56.48	-0.10	56.73	56.64	-0.09	56.53	56.41	-0.12	56.62	56.53	-0.09	56.88	56.79	-0.09
17	Mayweed Bridge	56.31	56.23	-0.08	56.36	56.30	-0.06	56.56	56.48	-0.08	56.32	56.25	-0.07	56.41	56.34	-0.07	56.78	56.70	-0.08
18	Weirs Mill Stream (d/s Weirs)	55.74	55.63	-0.11	55.88	55.79	-0.09	56.21	56.14	-0.07	55.77	55.66	-0.11	55.96	55.89	-0.07	56.52	56.45	-0.07
19	Thames Donnington Road	55.91	55.85	-0.06	55.97	55.90	-0.07	56.25	56.15	-0.10	55.92	55.86	-0.06	56.03	55.95	-0.08	56.53	56.45	-0.08
20	Thames Iffley Lock u/s	55.81	55.76	-0.05	55.88	55.84	-0.04	56.19	56.12	-0.07	55.82	55.77	-0.05	55.95	55.90	-0.05	56.48	56.42	-0.06
21	A423 West (Hinksey Ditch)	55.75	55.91	0.16	55.86	56.01	0.15	56.14	56.20	0.06	55.77	55.93	0.16	55.94	56.06	0.12	56.32	56.34	0.02
22	A423 East (Hinksey Stream)	55.68	55.52	-0.16	55.75	55.62	-0.13	56.01	55.89	-0.12	55.69	55.54	-0.15	55.81	55.69	-0.12	56.30	56.19	-0.11
23	Mundays Bridge	55.55	55.69	0.14	55.67	55.80	0.13	55.97	56.04	0.07	55.57	55.71	0.14	55.74	55.86	0.12	56.20	56.24	0.04
24	End of Weirs Mill Stream	55.44	55.46	0.02	55.54	55.57	0.03	55.82	55.84	0.02	55.46	55.48	0.02	55.61	55.64	0.03	56.09	56.11	0.02
25	Thames d/s Hinksey Stream	55.18	55.18	0.00	55.26	55.27	0.01	55.50	55.51	0.01	55.20	55.20	0.00	55.32	55.33	0.01	55.72	55.73	0.01
26	Thames Binsey/Port Meadow	57.92	57.89	-0.03	57.98	57.96	-0.02	58.08	58.07	-0.01	57.93	57.91	-0.02	58.01	58.00	-0.01	58.15	58.15	0.00

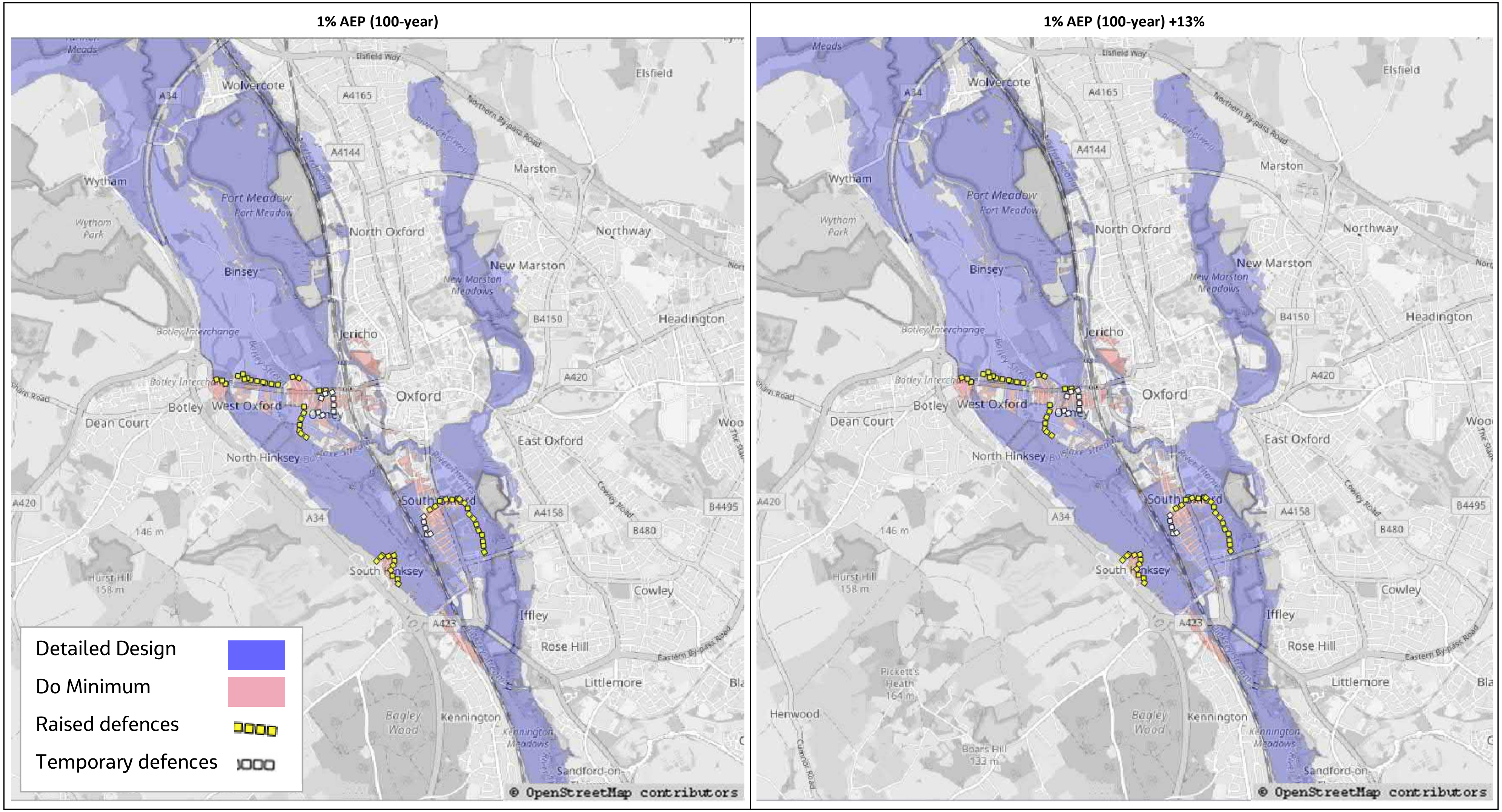


Figure 8.4: Difference maps (1% AEP and 1% AEP +13%)

1% AEP (100-year) +30% | **1% AEP (100-year) +82%**

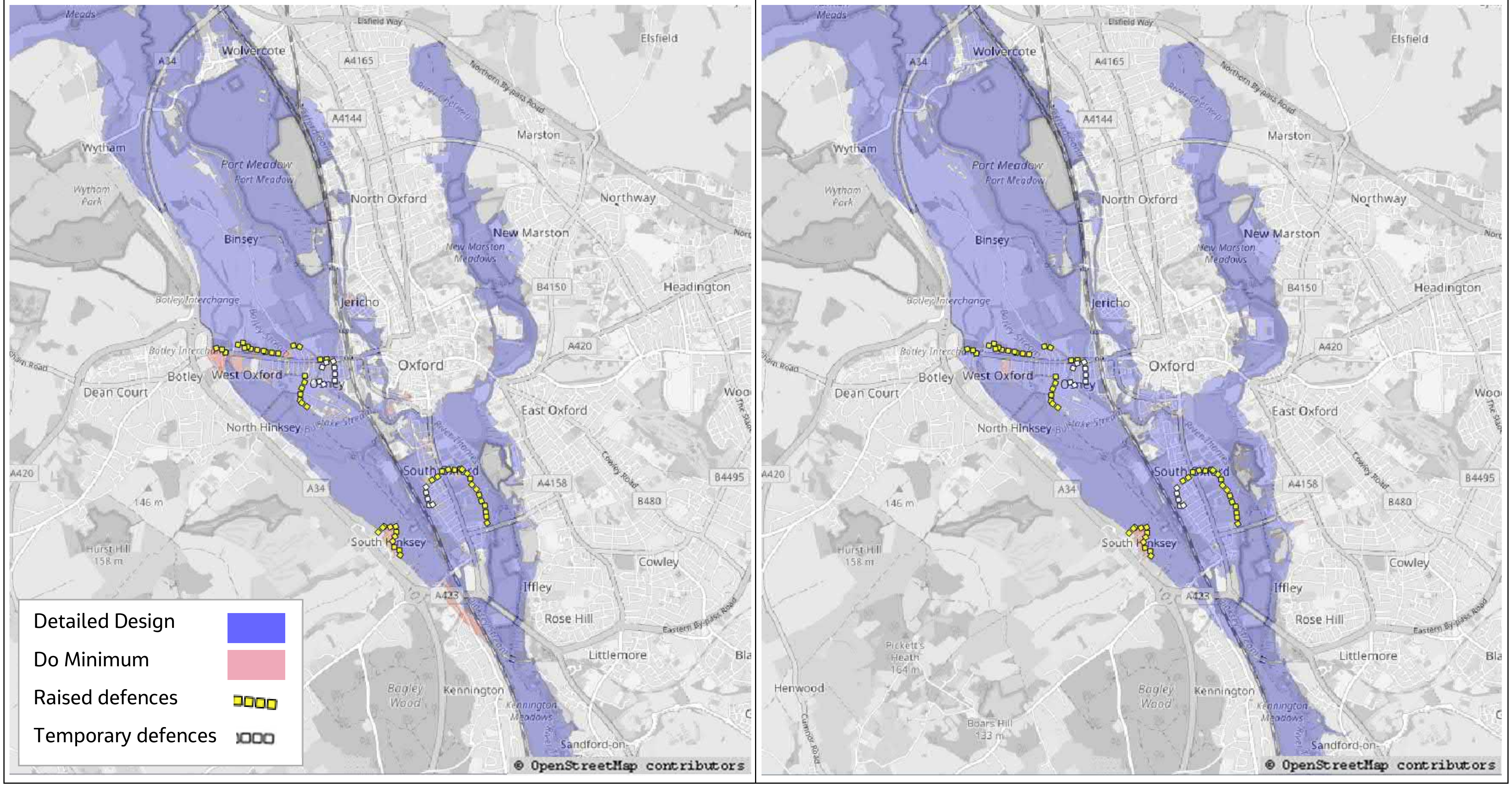


Figure 8.5: Difference maps (1% AEP +30% and 1% AEP +82%)

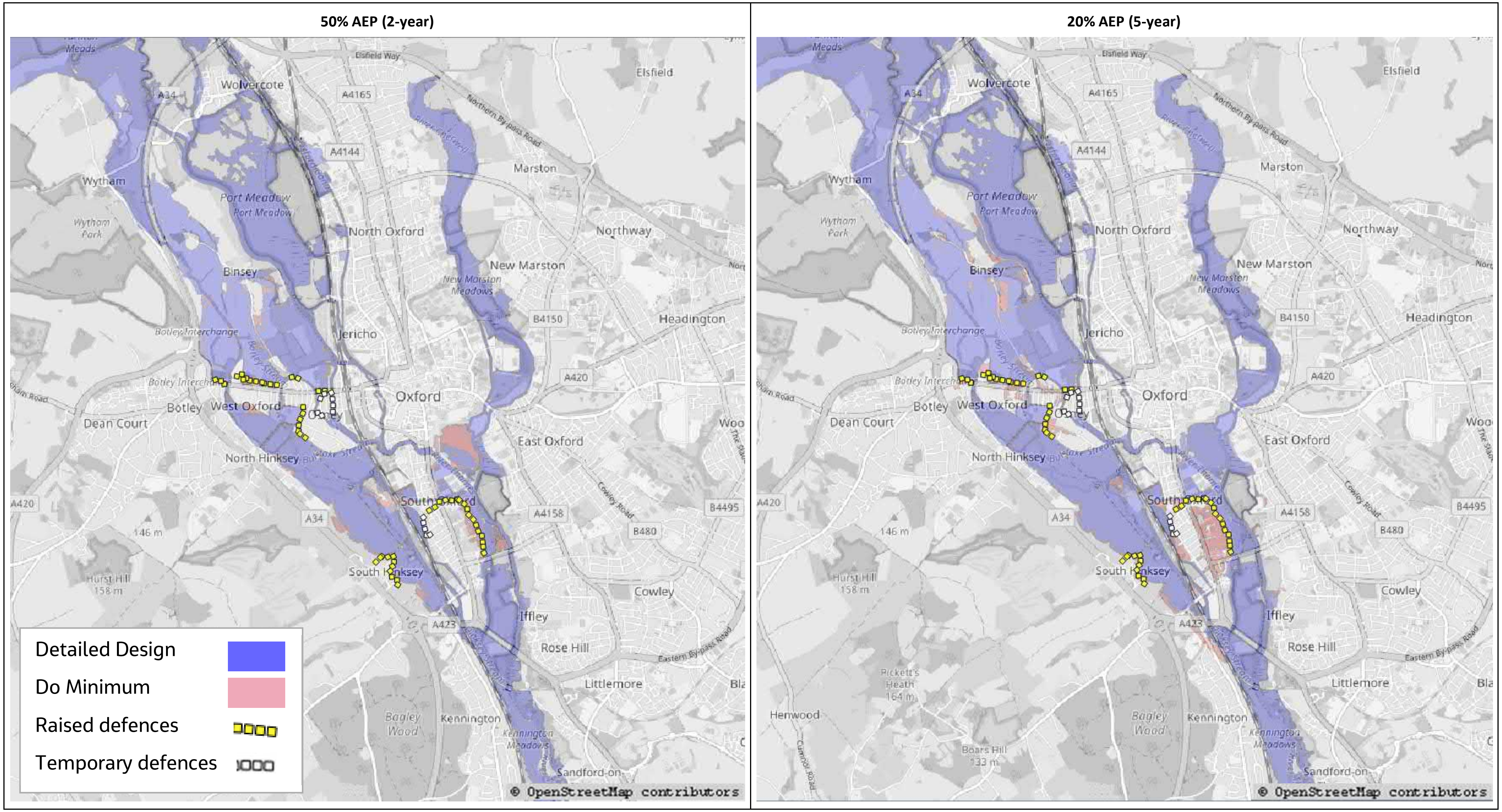


Figure 8.6: Difference maps (50% AEP and 20% AEP)

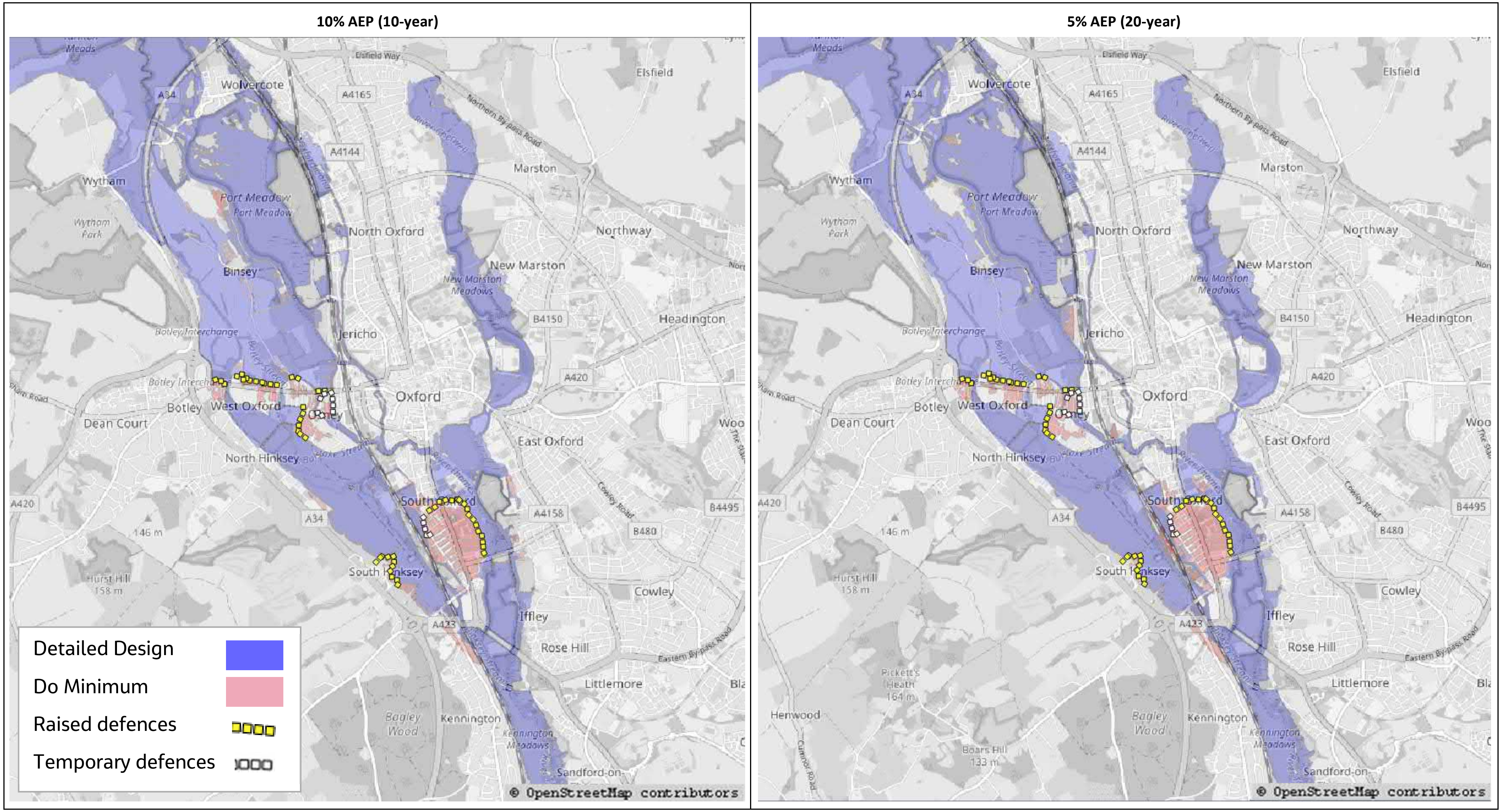


Figure 8.7: Difference maps (10% AEP and 5% AEP)

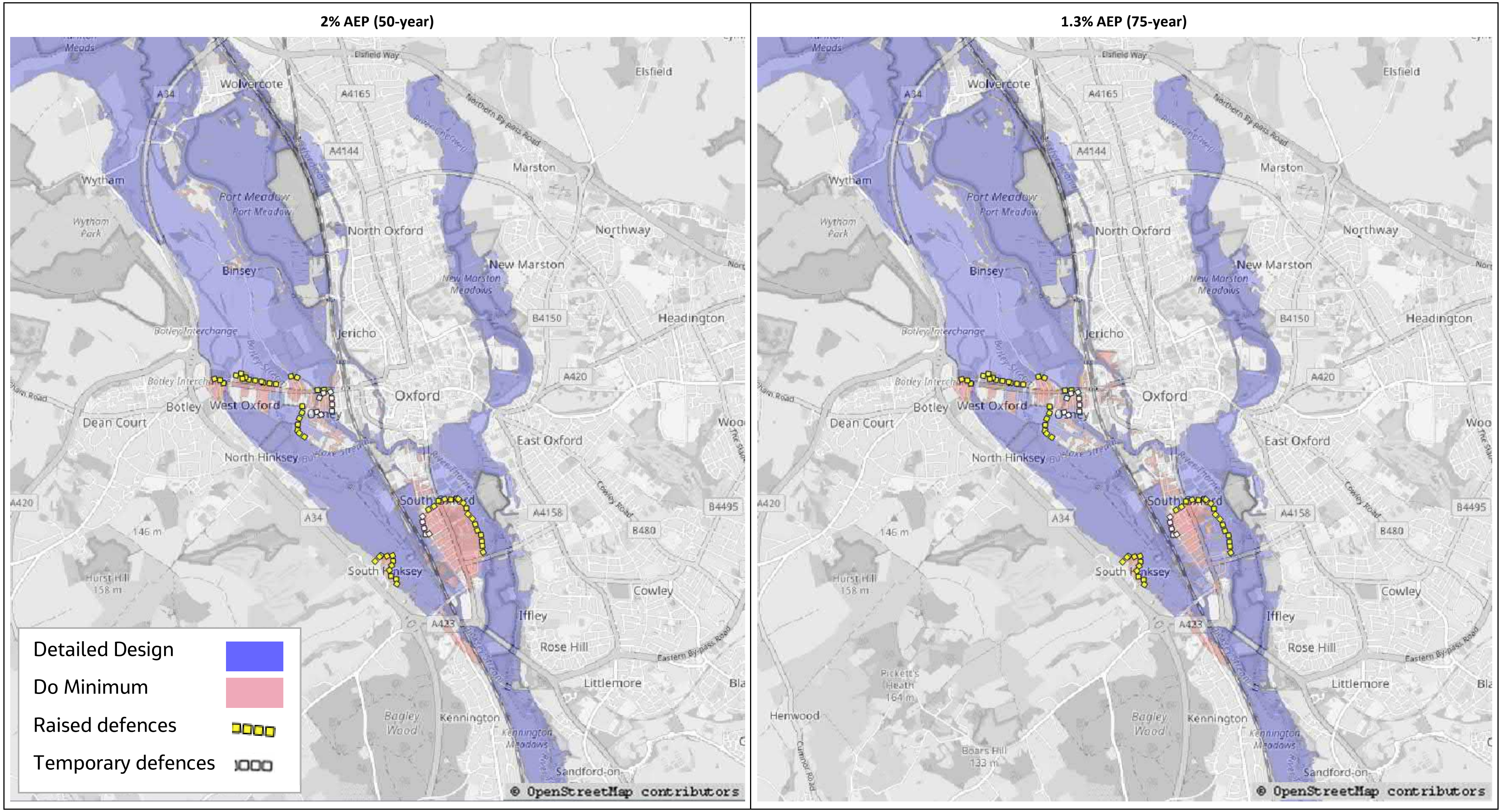


Figure 8.8: Difference maps (2% AEP and 1.3% AEP)

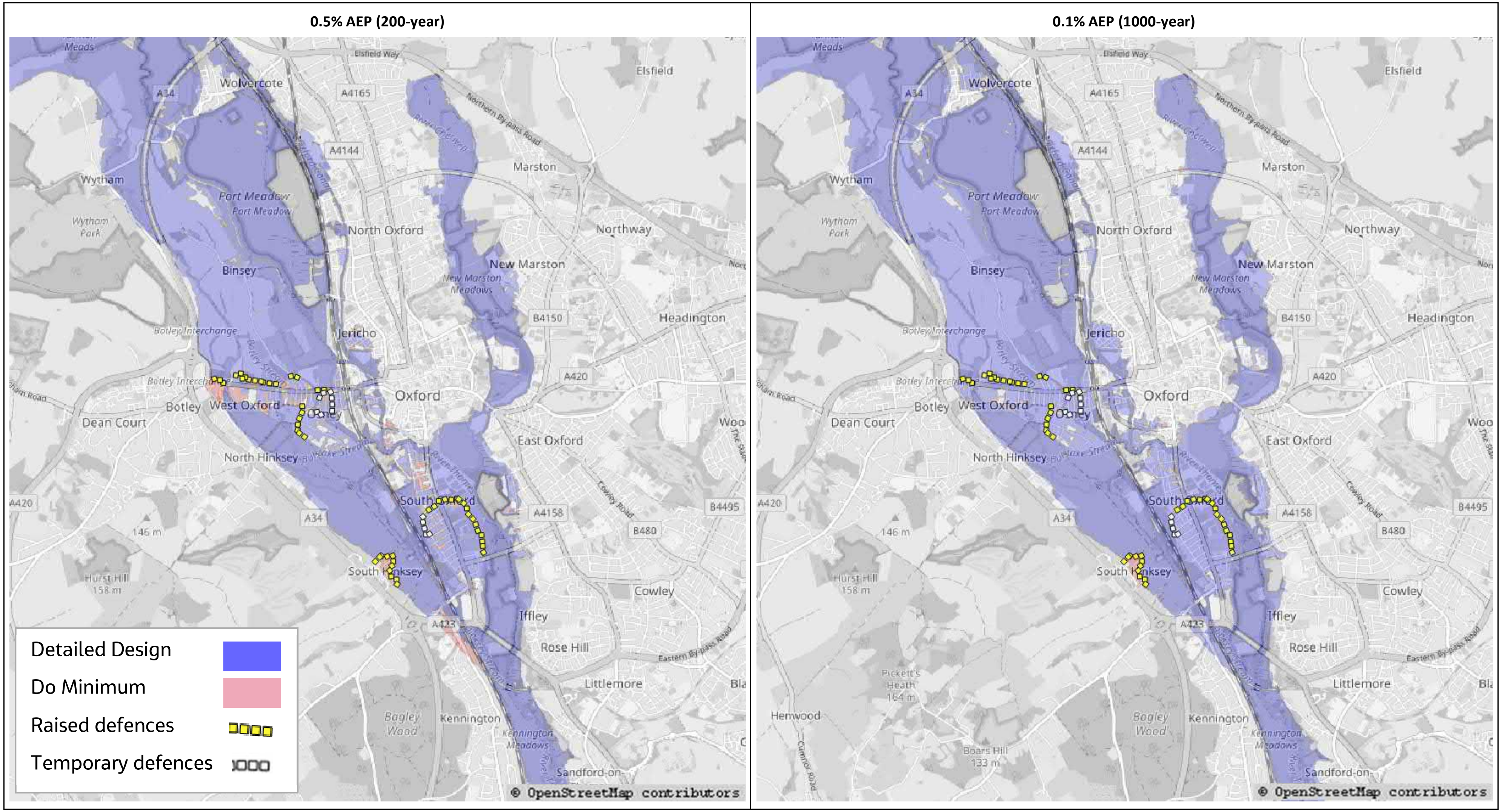


Figure 8.9: Difference maps (0.5% AEP and 0.1% AEP)

8.4 Comparison of flows at Sandford (2021 version)

Comparison of the design event model outflows for do minimum and the preferred option are detailed in Figure 8.11 and Table 8.9. The modelling predicts slightly higher flows in the rising limb of the hydrograph due to the increased conveyance provided by the scheme.

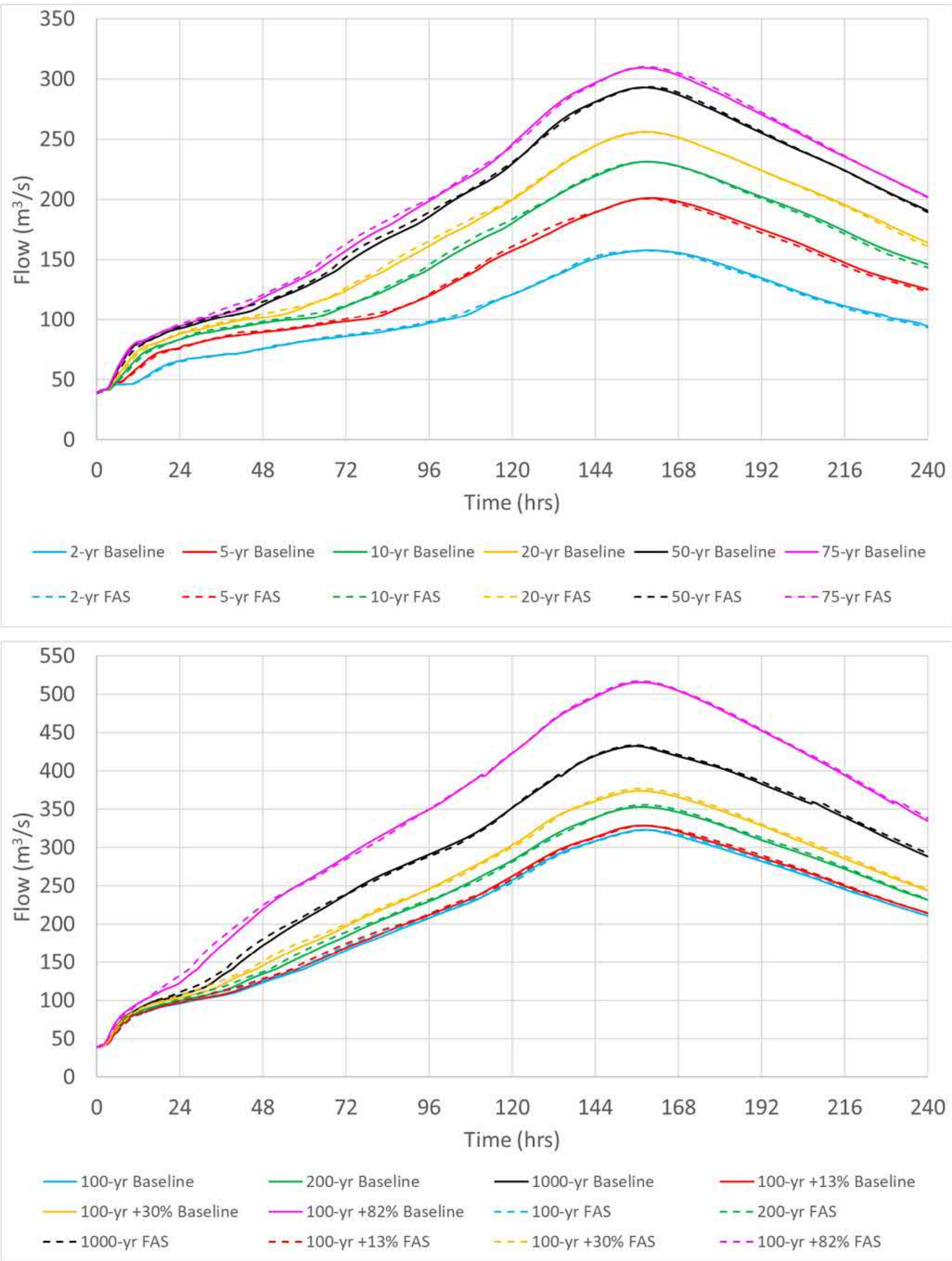


Figure 8.10: Comparison of flows at Sandford (2021 version)

Table 8.9: Model outflow comparison (2021 version)

	50% AEP (2-year)	20% AEP (5-year)	10% AEP (10-year)	5% AEP (20-year)	2% AEP (50-year)	1.3% AEP (75-year)
Do Minimum (m^3/s)	157.82	201.19	231.35	256.15	293.00	309.30
Detailed Design (m^3/s)	157.46	200.62	231.31	255.82	293.37	310.09
Difference (m^3/s)	-0.36	-0.57	-0.04	-0.33	0.37	0.79
Difference (%)	-0.23%	-0.28%	-0.02%	-0.13%	0.13%	0.26%

	1% AEP (100-year)	0.5% AEP (200-year)	0.1% AEP (1000-year)	1% AEP +13% (100-year)	1% AEP +30% (100-year)	1% AEP +82% (100-year)
Do Minimum (m^3/s)	322.97	352.81	432.38	328.58	373.81	515.48
Detailed Design (m^3/s)	322.81	355.68	433.57	328.39	376.91	517.02
Difference (m^3/s)	-0.16	2.87	1.19	-0.19	3.10	1.54
Difference (%)	-0.05%	0.81%	0.28%	-0.06%	0.83%	0.30%

8.5 Model performance (detailed design 2021 model)

The detailed design model runs well with no non-convergence for the events simulated. Figure 8.11 details the convergence plots produced as part of the 1D model outputs.

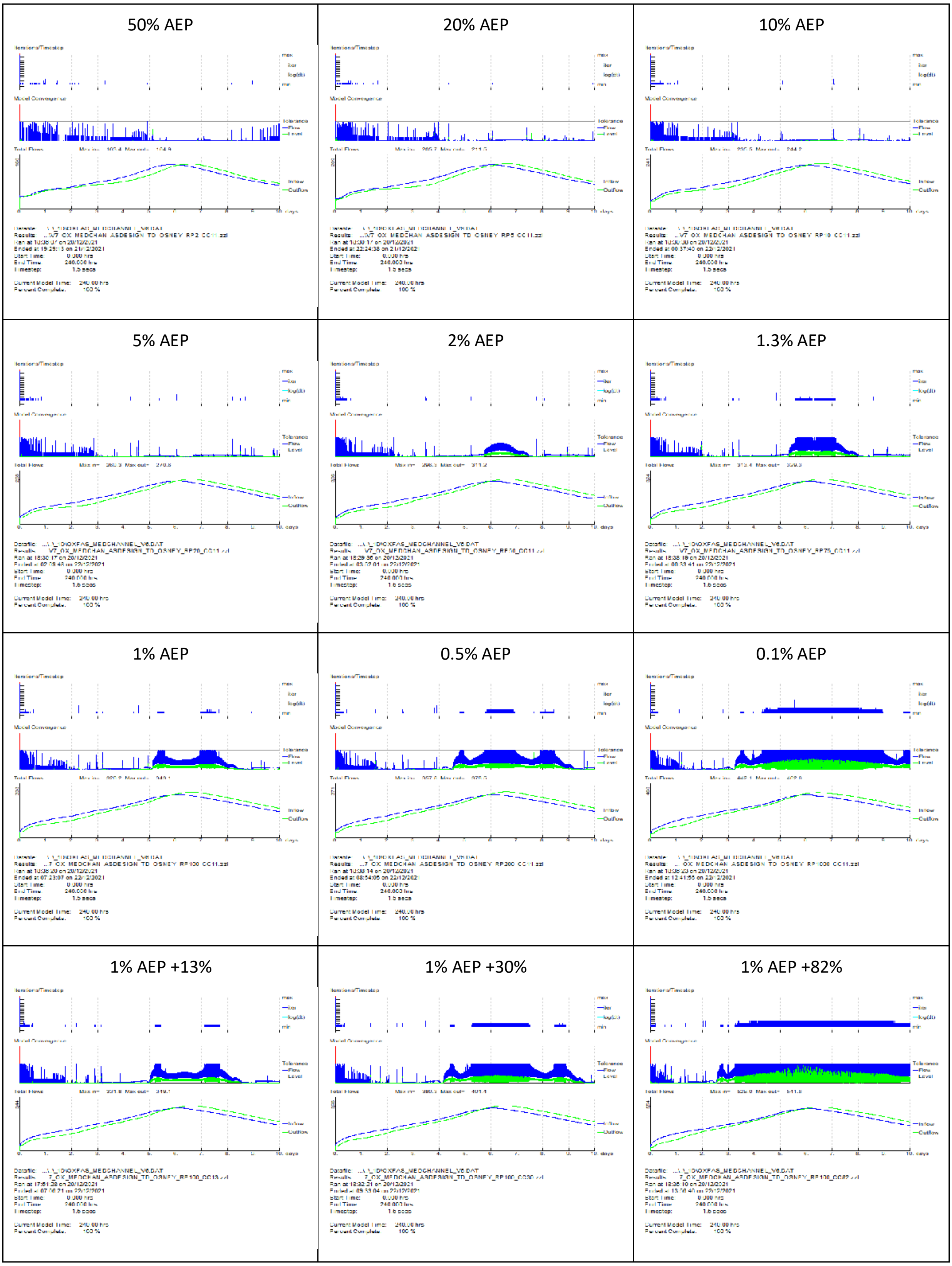


Figure 8.11: 1D convergence plots – detailed design FAS (2021 version)

The 2D output of cumulative mass errors and dVol (smooth plots) are detailed in Figure 8.12. The cumulative mass errors are within +/- 1%.

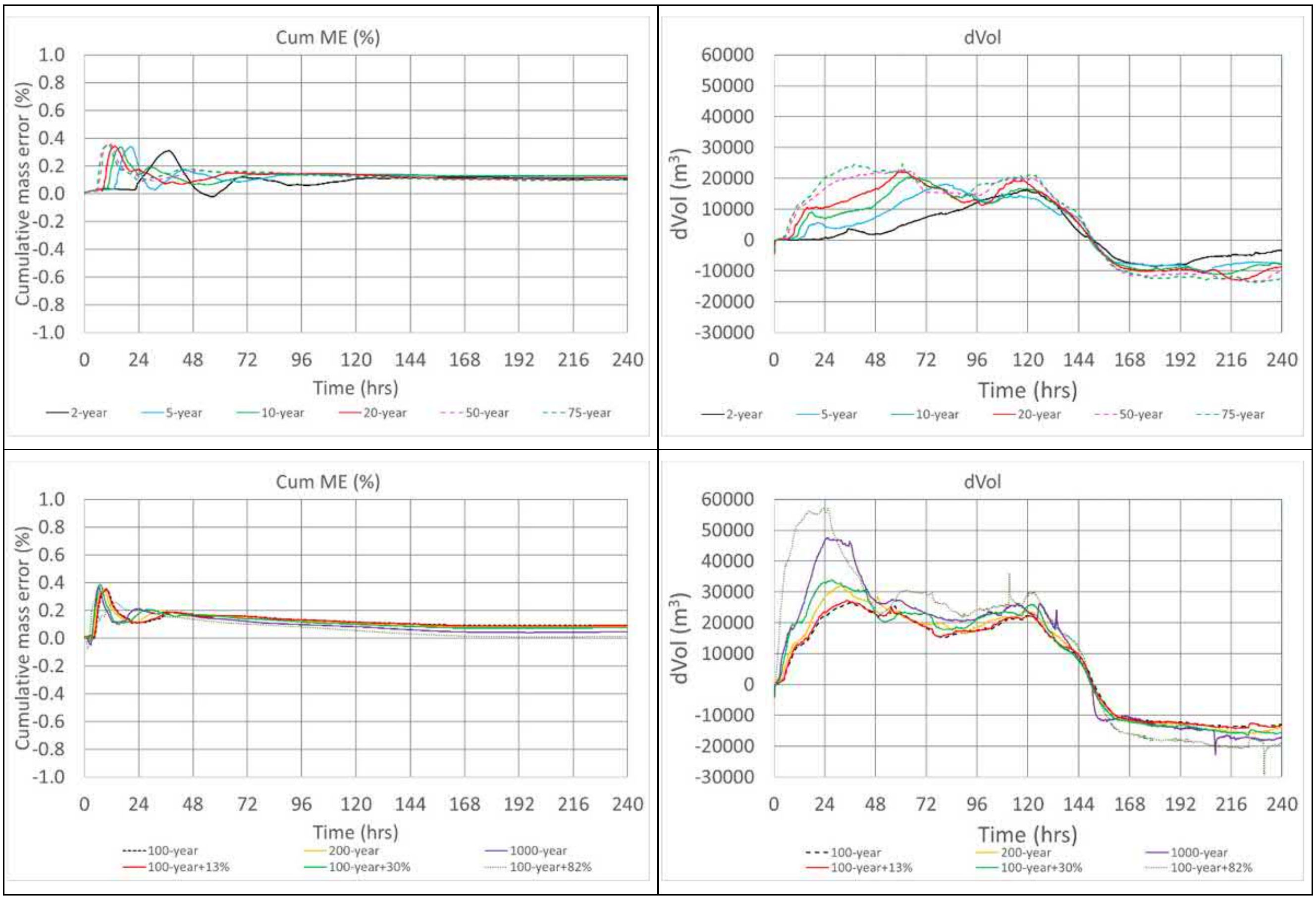


Figure 8.12: Cumulative Mass Error and dVol - detailed design FAS (2021 version)

9. Final modelling stage: modelling uncertainty / limitations (2021)

Modelling uncertainty

A structured approach is needed for assessing, recording and addressing residual uncertainty associated with flood risk management decisions, which is well considered in the guidance published by the Environment Agency: Accounting for residual uncertainty: updating the freeboard guide, Report SC120014[3]

Extract: Report SC120014

> Evidence supporting flood risk management decisions will always have some degree of uncertainty associated with it because flooding mechanisms might be poorly understood or flood information is incomplete or inaccurate. Some of these uncertainties will have been addressed through standard design and appraisal procedures; others will not. Those uncertainties that remain are called residual uncertainties.

Initial sensitivity tests have been undertaken to understand the uncertainty with the choice of model parameter and impact on water levels (refer to section 6.2). For example, for the 2% AEP event, +/- 20% 1D roughness showed average increase/decrease in peak water levels of +0.13m and -0.15m for 1D river levels, and for the same event, +/- 20% 2D roughness gives an average increase/decrease in 1D peak water levels of +/- 0.02m

More detailed sensitivity tests have been undertaken to support the residual uncertainty analysis that determined the freeboard provision included in the design of the flood alleviation scheme. A summary of the findings of this analysis follows, taken from the Residual Uncertainty Analysis report[4] completed for this project (January 2022).

The analysis assessed the uncertainty following the latest guidance (SC120014) and adopted the Tier 1 approach (first order error analysis). A summary of the analysis findings follows and for the full details reference should be made to the separate report.

The Tier 1 method requires the identification of the secondary variables (for example, peak river flow and channel roughness) which influence the primary variable (predicated river water level through the study area). The influence of change in each secondary variable is assessed in isolation for a given confidence interval. The freeboard associated with uncertainty in the primary variable is quantified by summation of the secondary variable uncertainties. The method assumes a linear response of the primary variable to small changes of the identified secondary variables, this assumption is suitable for linear flood defence schemes.

Sensitivity tests using the Oxford FAS detailed design model simulated changes to the following secondary variables (to determine the partial derivative for the Tier 1 method). Of these variables, there are only two of significance for determining the residual uncertainty - changes in fluvial peak flow estimates and changes in channel and floodplain roughness.

- Fluvial peak flow estimates: + 5% increase in flow
- Channel & Floodplain Mannings' "n": +/- 5% increase in Mannings' "n"
- Bridge afflux co-efficient: +/- 10% in calibration coefficient
- Weir co-efficient: +/- 5% in calibration coefficient

The residual uncertainty has been calculated for specific areas within the limits of the flood alleviation scheme for the 95%, 68%, 55% and 38% confidence intervals. The median average residual uncertainty is given in Table 9.1 (for maximum and minimum values refer to the Residual Uncertainty Analysis report).

[3] Robinson, A, F Ogunyoye, P Sayers, T van den Brink, and O Tarrant. 'Accounting for Residual Uncertainty: Updating the Freeboard Guide'. Environment Agency, February 2017. https://www.gov.uk/government/publications/accounting-for-residual-uncertainty-an-update-to-the-fluvial-freeboard-guide

[4] Oxford FAS - Residual Uncertainty Analysis - IMSE500177-CH2-00-00-RP-HY-0115| P01

Taken as an average across the whole area the residual uncertainty is estimated to be 0.60m for 95% confidence interval and 0.15m for 38% confidence interval. This is reasonably consistent except for Area 4 (E & H) where the residual uncertainty is estimated to be 0.95m for 95% confidence interval and 0.25m for 38% confidence interval.

Table 9.1: Residual uncertainty - median average

Confidence interval	**95%**	**68%**	**55%**	**38%**
All	0.60	0.30	0.25	0.15
Area 1	0.65	0.35	0.25	0.15
Area 2	0.55	0.30	0.20	0.15
Area 3 – A, B & D	0.65	0.30	0.25	0.15
Area 3 – C	0.60	0.30	0.20	0.15
Area 4 – A, B, C, D & G	0.60	0.30	0.20	0.15
Area 4 – E & H	0.95	0.50	0.35	0.25

Modelling limitations

The floodplain 2D cell size has been set at 10m to avoid overly long model run times and even at that resolution each model run takes approximately 2 days (48 hours) to complete. Reducing the cell size to say 5m would increase model runs time by a factor of 4-8 times, which would not be appropriate for this type of study, where numerous simulations are required to produce results for the assessment. Attempts were made to reduce the grid size using TUFLOW HPC and Quadtree solvers, however the trial runs proved unsuccessful (see section 7).

The floodplain 2D cell size could be considered a modelling limitation. However, TUFLOW classic with the 10m grid is considered to be acceptable, which has been confirmed by the model calibration that shows good agreement to water levels and between modelled/observed flood extents. The model area is also relatively flat with extensive floodplains which is suitable for the 10m grid size.

Some of the Thames rivers reaches of the model have large spacings (greater than 200m) between the surveyed sections. There is high cross section spacing (400m+) in the upstream extents, particularly on the River Thames and Witham Stream. There is also high spacing at the downstream extent of the model (900m+). For the area of interest the spacing is typically not more than 200m spacing.

The spacing could be considered a modelling limitation. However, the modelling outputs are considered to be acceptable because the Thames cross sectional profiles are fairly uniform and water levels recorded at the start/end of each reach (lock/weir complexes) have shown good agreement with the modelled water levels during calibration.

There are no detailed bank top surveys for existing channels to apply elevations along the 1D-2D boundary. When connecting the 1D model to 2D, a z-line attributed with bank levels from the 1D channel cross section is used. The approach uses the 'max' command which selects the higher levels from either the underlying DTM or the linear interpolation between the cross section elevations. This is a standard approach used for modelling studies. As the natural bank levels are generally at floodplain level (i.e. no raised banks) and the Thames floodplain is active at low order event (<50% AEP), this is approach is acceptable.

10. Final modelling stage: peer review (2021)

The updated Do Minimum and FAS model and results were reviewed by AECOM (September 2021 and November 2021). A series of sensitivity tests have been undertaken to support the responses to comments on the representation of Hogacre Ditch, choice of LiDAR and bank representation also the length of the new channel. These test runs are explained below.

10.1 Hogacre Ditch

The review identified that the reach of Hogacre Ditch between the railway and White House Road was represented in 1D but not linked to 2D. The sensitivity test linked the 1D reach to 2D and compared results for the Do Minimum 1% AEP and 1% AEP +30% events.

Figure 10.1 details comparison maps which show the changes in floodplain water levels. The sensitivity test showed that at 1% AEP, there would be some additional flooding of ditches/grassland areas and the 1% AEP +30% showed less impacts as the area was flooded using the model without the 1D2D linking. The test showed that the impacts are localised at Hogacre ditch and do not impact water levels over the model domain (as shown by the light green shading in the flood map).

As no properties are impacted, it was not necessary to re-run the Do Minimum model. The Hogacre ditch 1D2D links are included in the FAS model (as the final model was not complete as this stage of the study)

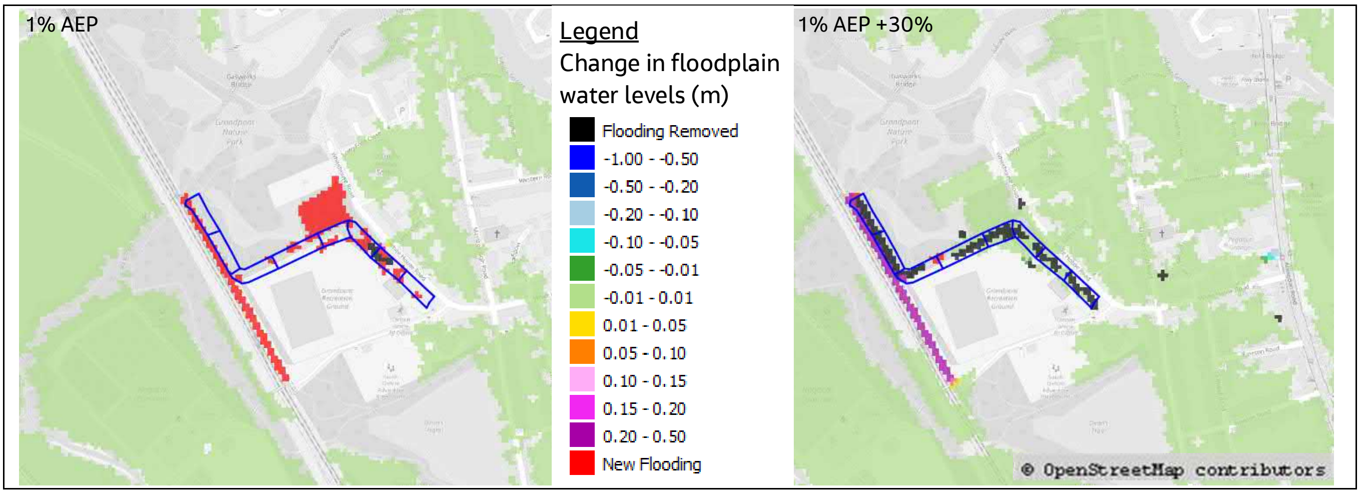


Figure 10.1: Hogacre Ditch sensitivity test (1% AEP and 1% AEP +30%)

10.2 Choice of LiDAR

A newer LIDAR dataset (2020, 1m resolution) which partially covered the eastern half of the model area was compared to the topographic ground surveys collected as part of the Oxford FAS (refer to Section 3) and tested during 2021 Do Minimum model updates using the 2007 flood event.

Figure 10.2 shows the comparison with the topographical survey for the original LiDAR and the area of new LiDAR. Overall, the comparison shows that the original LiDAR provides closer elevations to the topographic survey, as shown by the larger areas shaded green (+/- 5cm).

Figure 10.3 shows the modelled flood extents for the 2007 event using the original LiDAR and the new area of LiDAR. The flood extents using the original LiDAR results in a better match to the recorded flood outlines and post flood event surveys in the Abingdon Road area.

Based on the outcome of the topographical survey comparison and 2007 event calibration, it was decided to retain the original LiDAR survey data.

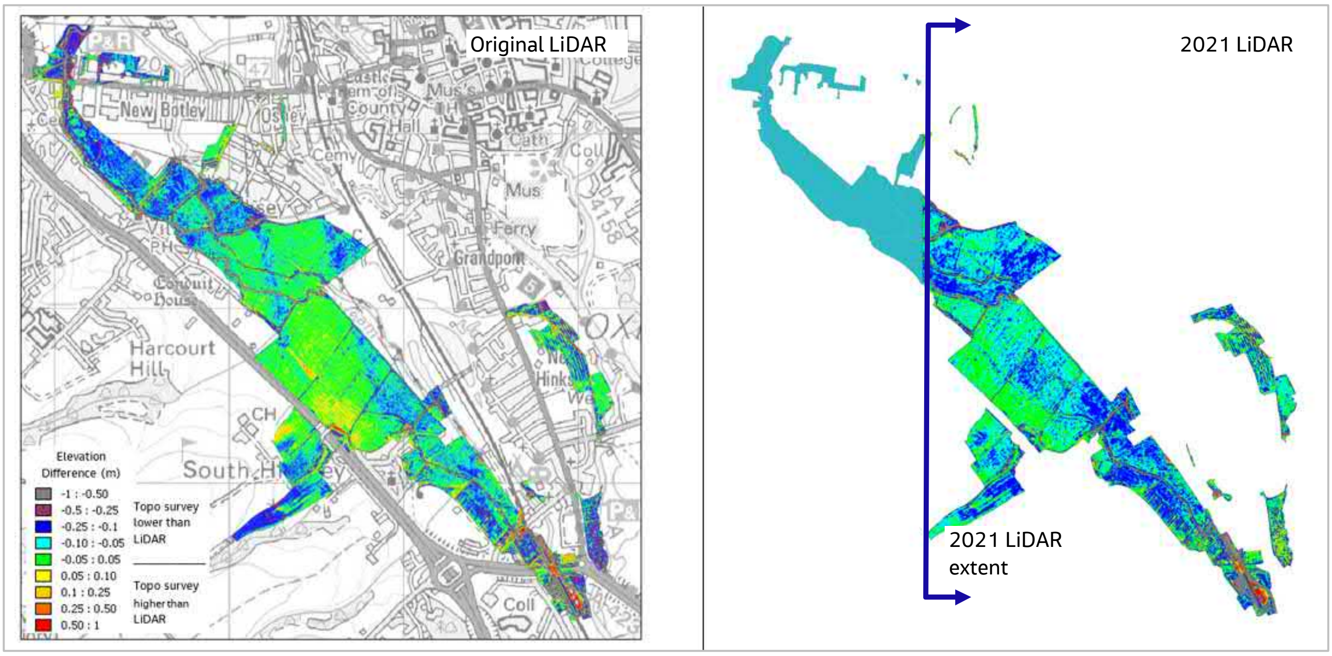


Figure 10.2: Comparison of LiDAR surveys to topographic survey

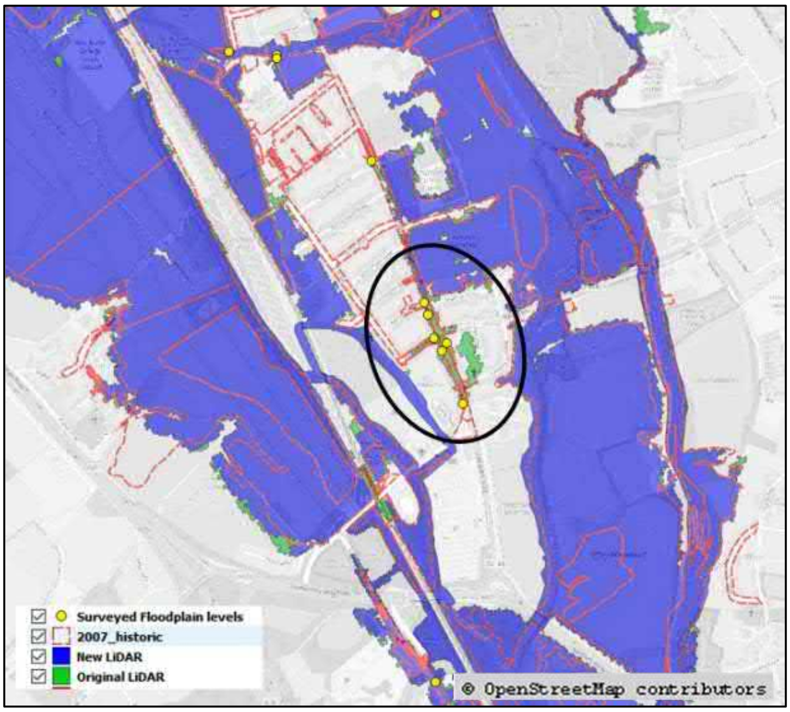


Figure 10.3: Comparison of 2007 event flood extents using the original and new LiDAR surveys

10.3 Bank representation along the reach of the new channel

The new channel is represented in the model as 1D cross sections and linked to 2D at the top of the second stage of the channel, where it meets the natural ground level. It is common practice to apply a z-line attributed with elevations at the 1D2D boundary, however as the scheme proposes to use the natural ground levels, the FAS model assumed elevations along the 1D2D boundary based on the underlying DTM (topographical survey, i.e. natural ground level).

To test the potential impact of this approach, the elevations (as used in the FAS model) along 1D2D boundary of the new channel were raised/lowered by 0.2 and run for the 20%, 2% and 1% AEP events. Figure 10.4 shows the comparison of maximum floodplain water levels for the FAS model and the sensitivity test with bank levels +/- 0.2m. The test shows that the model is not sensitive to the selected bank levels along the new channel and the original approach using the underlying DTM is suitable.

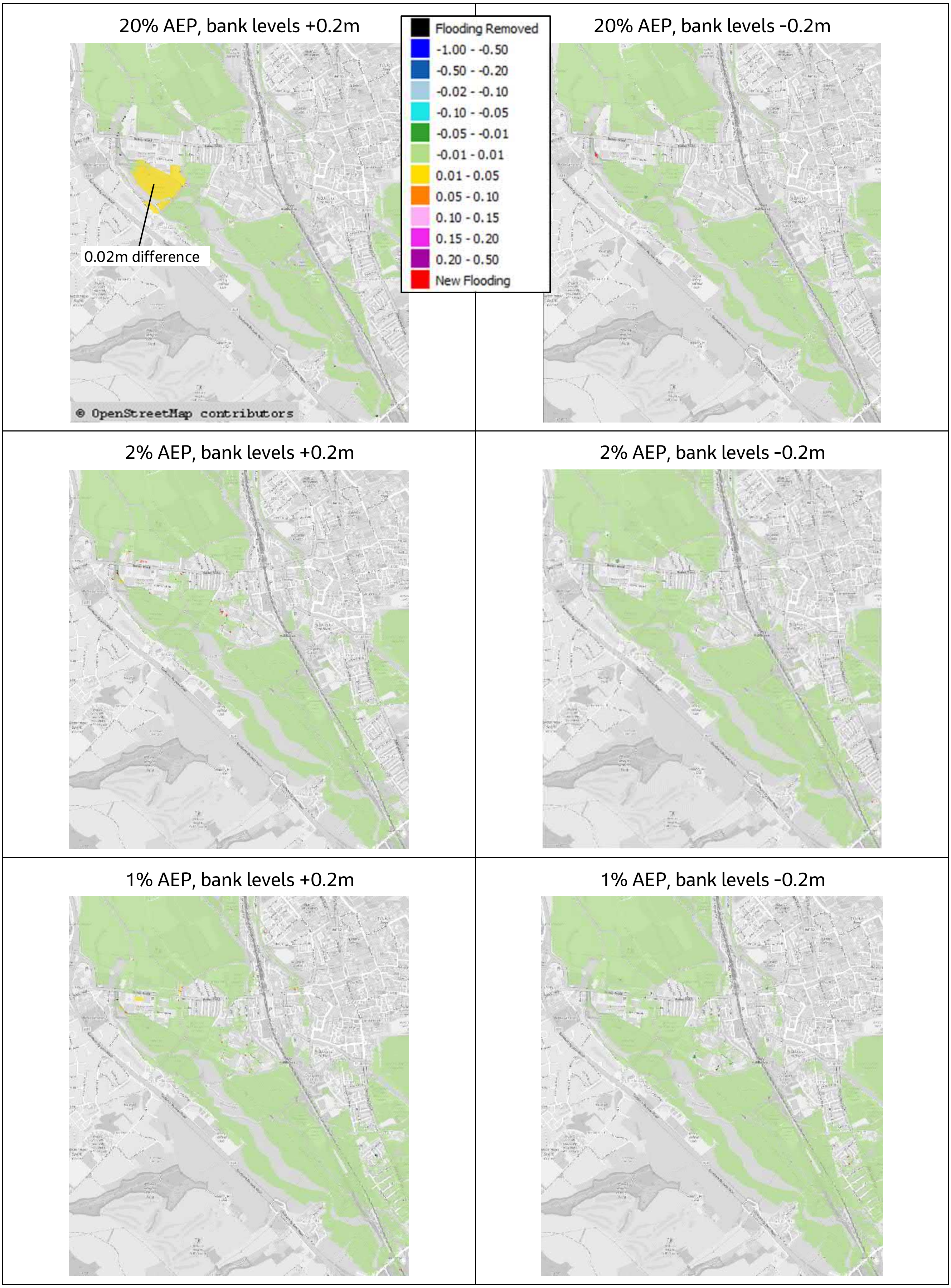


Figure 10.4: Sensitivity to FAS channel bank level approach

11. Conclusions

11.1 Model history/updates

The hydraulic model used for the assessment is an updated version of the original 2014 Environment Agency flood mapping model. During the model updates, care was taken to ensure the model remained stable and ran successfully. The model was updated using the latest survey datasets, with channel roughness and structure coefficients set within acceptable limits and model run parameters kept at default values. The model has been run using double precision with increased minimum iterations to ensure a stable solution.

11.2 Calibration

The calibration and validation work has greatly improved the performance of the model when compared with observed events, particularly for the 2007 flood. The successful validation of the re-calibration of the model against the 2003 event and the most recent 2013/14 provides further confidence in the model's schematisation and baseline parameter set. The model's improved performance is a result of the following changes:

- Improved model inflows, with special care taken to review and reconstruct appropriate inflows for each calibration and validation event.
- Improved model parameters (for example, channel roughness).
- Improved model schematisation (for example, by incorporating more recent survey).

The model shows good agreement with observed peak water levels for the 3 calibration events with modelled peak levels within the accuracy target of +/- 0.15m for 37 out of 41 records.

11.3 Design flood events

The project provides full model results based on design flood events for the 50%, 20%, 5%, 2%, 1.33%, 1%, 0.5% and 0.1% AEP (1 in 2, 5, 20, 50, 75, 100, 200 and 1000-year events) which includes an 11% uplift to the flows derived in 2016 which complies with the latest climate change guidance[5]. The modelling used the Central estimates (50th percentile) for the Cotswolds Management Catchment with climate change flow allowances of +11% (2020s), +13% (2050s) and +30% (2080s); and also tested the Upper End allowance of +82% (2080s).

11.4 FAS detailed design

Flood flows

The modelling of the Oxford Flood Alleviation Scheme has shown it to reduce the fluvial flood risk in Oxford. The proposed combination of the new channel and raised defences upstream of Botley Road and in New Hinksey will protect a large number of properties.

For the 1% AEP event (100-year), peak water levels are predicted to be reduced by approximately 0.09m upstream of Botley Road and 0.08m at Abingdon Road (Mayweed Bridge). The new channel increases the flow capacity west of the railway, reducing the peak flow in the Thames.

For the 1% AEP event (100-year), peak flows are predicted to be reduced by 10m^3/s downstream of the Bulstake Stream and Castle millstream confluence. Further downstream, at the A423 crossing the Thames/Weir Mill Stream, flows are further reduced by 46m^3/s due to new flood channel works, culverts under Abingdon/Kennington Road, A423 Road crossing improvements and the flow control on Eastwyke ditch which stops the cross flows at the railway and from Redbridge stream (Cold Harbour).

[5] Flood and coastal risk projects, schemes and strategies: climate change allowances, Environment Agency, July 2021. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances

The model predicts the flows downstream of Sandford to be slightly reduced at peak flows (0.16m^3/s for 1% AEP) with a slight increase in flow on the rising limb, due to the improved conveyance of the flood alleviation scheme.

Low flows

The new low flow channel has been designed with the Environment Agency and tested for Q_{95} and mean monthly flows. The design shows that flows will favour the new channel with minimal impacts on Navigation. The modelling predicts that the second stage of the new channel would be used for the winter months (December to March inclusive based on the mean monthly flow rates). Outputs from the low flow model simulations have been used for the Geomorphological Impacts Assessment and as inputs to the groundwater modelling.

11.5 Recommendations

During the construction stage any proposed significant changes to the detailed design of the scheme that could lead to a change in flood water levels and scheme performance should be tested using the model in advance to inform decisions. On completion of the scheme, the model will need reconfiguring with the as-built scheme details. For future flood events it will be important to take detailed records to allow for further calibration and validation of the model, including flow/stage gauging, structure operation, capture flood extents and out-of-bank flow routes.

Appendix A. River cross section comparison

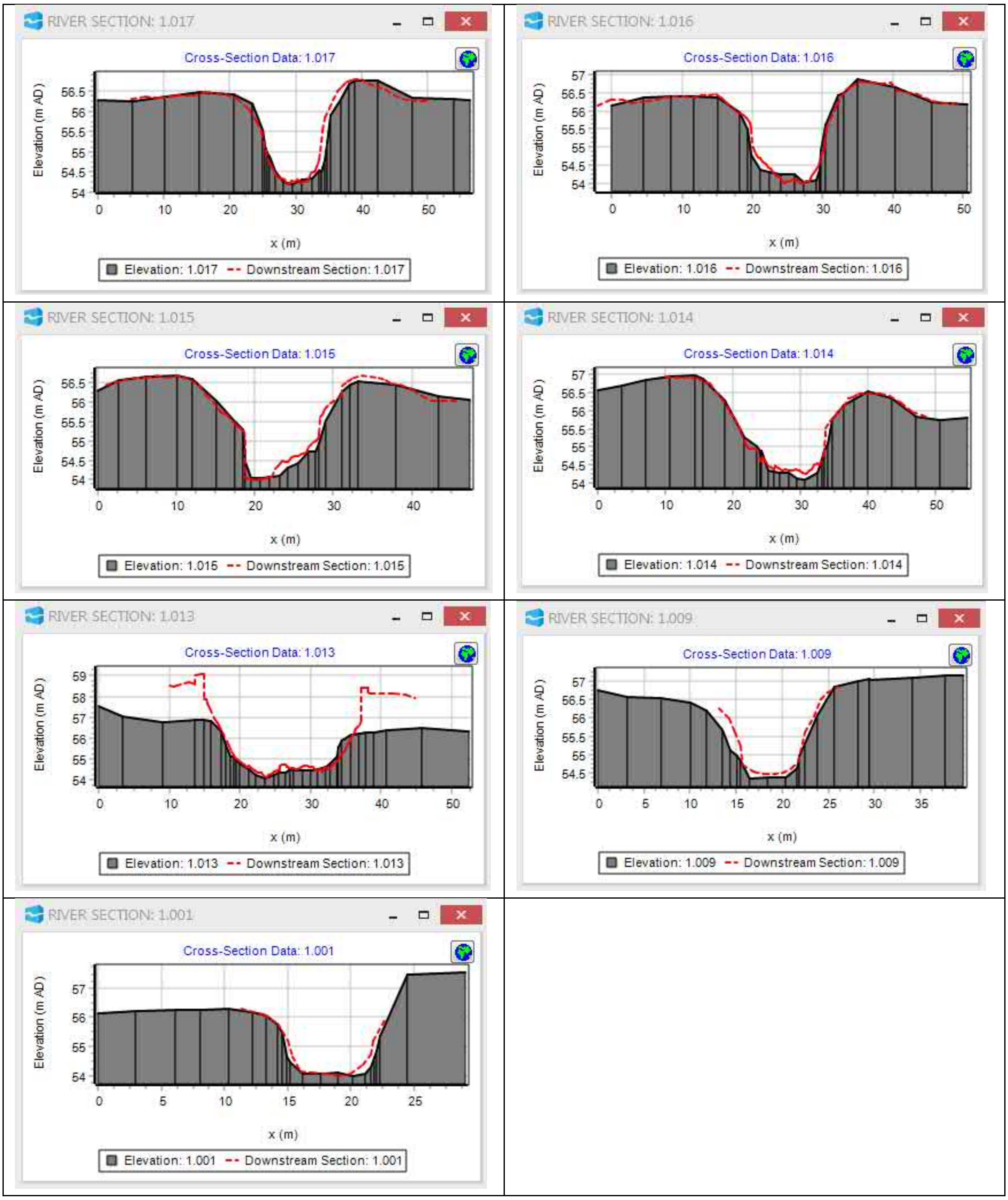


Figure A.1: Seacourt Stream Cross Section Comparison

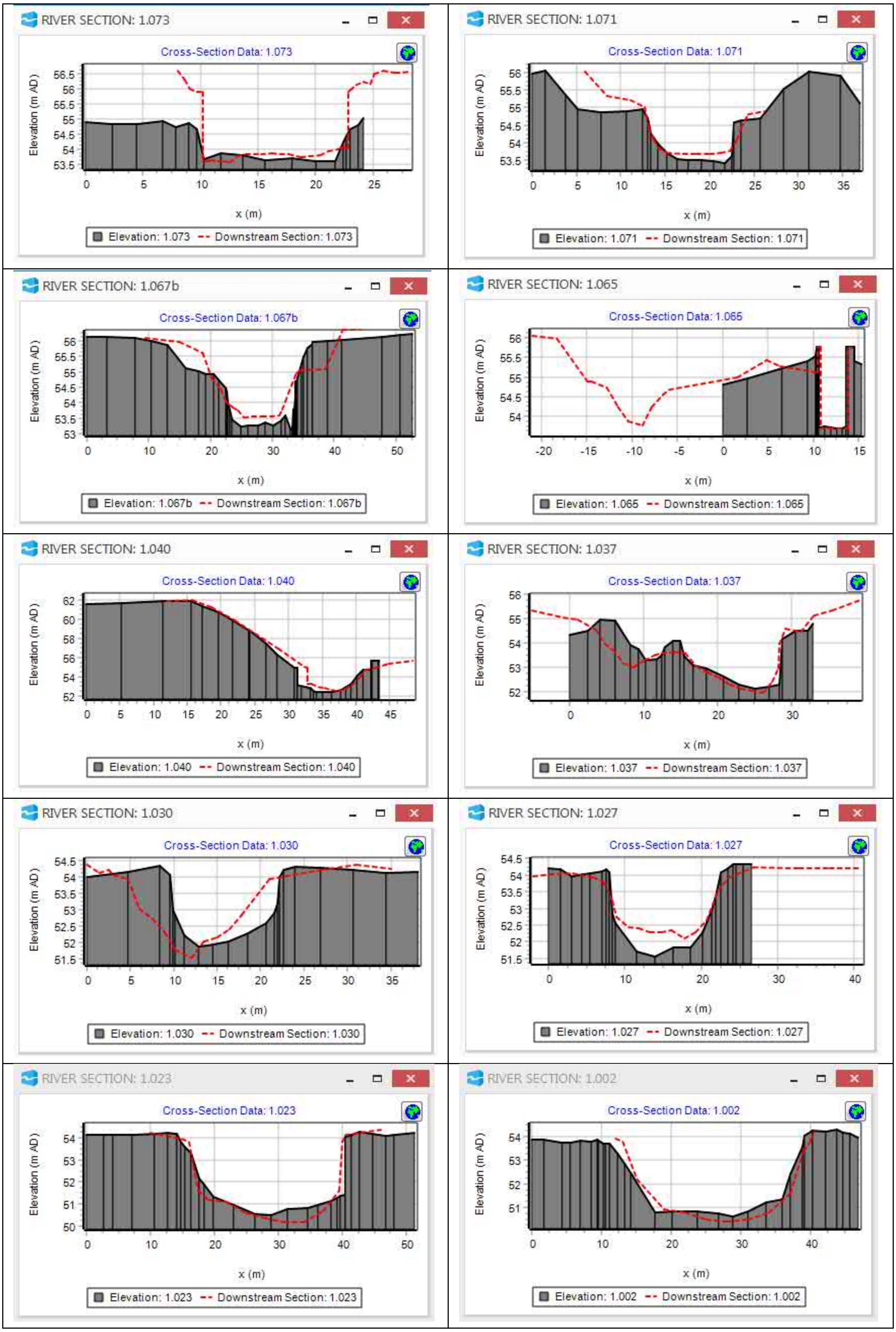


Figure A.2: Hinksey Stream Cross Section Comparison

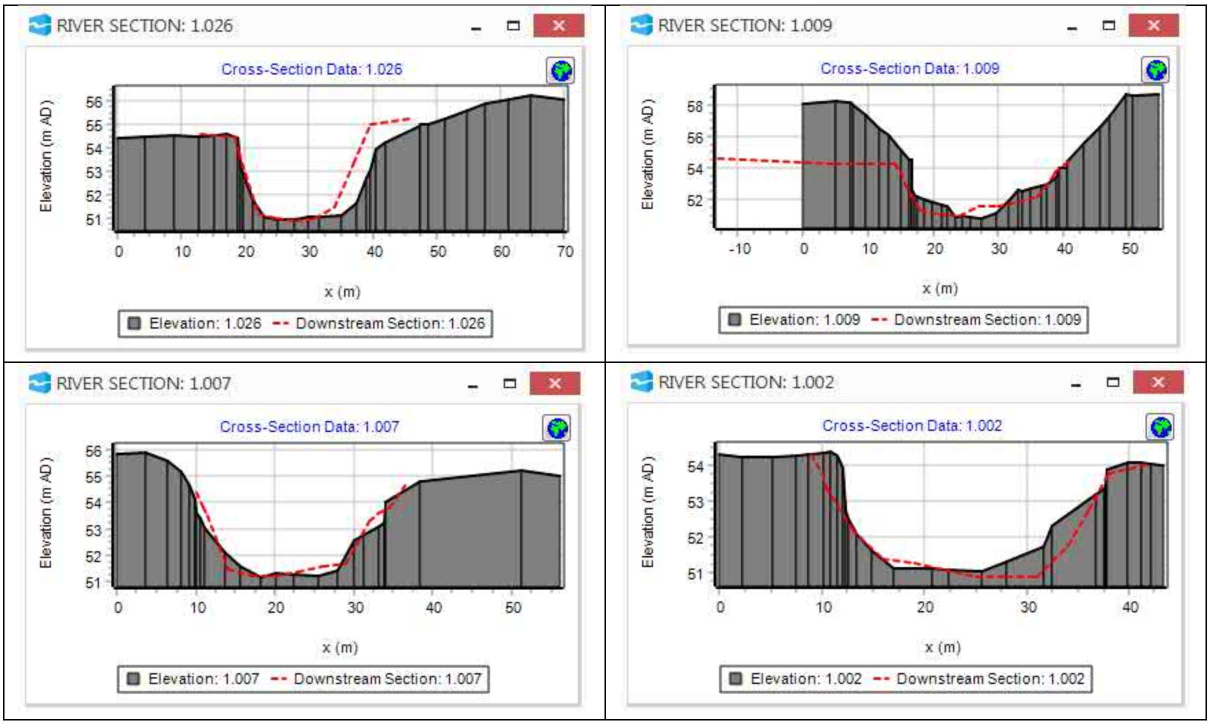


Figure A.3: Weirs Mill Stream Cross Section Comparison

Appendix B. Do Minimum model files (2018 and 2021 version)

Table B.1: Model run files for do minimum

File	2018 Do Minimum Model	2021 Do Minimum Model
1D run file	v2_DM2017_rp100.ief	v1_Ox_DM2021_TD_rp100_cc11.ief (with temporary defences) v1_Ox_DM2021_rp100_cc11.ief (without temporary defences)
1D model file	Ox_DM2017_v3.DAT	Ox_DM2017_v5.DAT
1D boundary files	y0_100yr.IED	<event>_2020_11pc_uplift.IED
2D run file	v2_DM2017_rp100.tcf	v1_Ox_DM2021_TD_rp100_cc11.tcf (with temporary defences) v1_Ox_DM2021_rp100_cc11.tcf (without temporary defences)
2D geometry file	Oxford_DM2017_topo_v2.tgc	Ox_DM_H50_TD.tgc (with temporary defences) Ox_DM_H50.tgc (without temporary defences)
2D boundary file	Oxford_DM2017_v2.tbc	Oxford_DM2017_v2.tbc
2D materials file	Oxford_2D_materials.tmf	Oxford_2D_materials.tmf

Table B.2: Description of layers used in the 2D (TUFLOW) model component

Layer	Format	Description
1d_nwk_estry_TJ00553_devils	Shapefile	ESTRY culvert network for Devils Backbone
1d_nwk_estry_CH2M_willow	Shapefile	ESTRY culvert network for Willow Walk
1d_FM_node_Oxford_v2	Shapefile	Flood Modeller node locations
2d_iwl_Oxford_polygon	Shapefile	Initial water level in certain areas
2d_iwl_lake_Oxford_polygon_v1	Shapefile	Initial water level set in lakes and Hinksey Stream
2d_po_Oxford	Shapefile	Read PO lines
2d_bc_hx_Ox_HXFLC_v4	Shapefile	Sets HX links between 1D channel & 2D domain
2d_bc_sx_estry_TJ00553_devils	Shapefile	Sets SX links for Devils Backbone
2d_bc_sx_estry_CH2M_willow	Shapefile	Sets SX links for Willow Walk
2d_bc_sx_Oxford_20121025_GM01	MapInfo	Sets general SX links
2d_zsh_lakebed_Oxford_polygon_v2	Shapefile	Assumed bed levels in lakes
2d_zsh_banks_Ox_L_v2 | 2d_zsh_banks_Ox_P_v2	Shapefile	Sets elevations along riverbanks at 1D-2D link
2d_zsh_defences_2011_L | 2d_zsh_defences_2011_P	Shapefile	Sets elevations along riverbanks at 1D-2D link with surveys 11227, 11228, 11230 (dated 2011)
2d_zsh_Hinksey_Ditch_L | 2d_zsh_Hinksey_Ditch_P	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_Hinksey_Ditch_polygon	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_embankments_Oxford_L |	Shapefile	Sets elevations along embankments
2d_zsh_temp_defences	Shapefile	Temporary defences
2d_zsh_flowpaths_Oxford_CH2M_G_polyline | 2d_zsh_flowpaths_Oxford_CH2M_G_point	Shapefile	Sets elevations along flow paths
2d_mat_stability_v1	Shapefile	Improve stability at Devil's Backbone and Hinksey
2d_code_Ox_river_v3	Shapefile	Sets null cells within river channel

Layer	Format	Description
2d_loc_Oxford_20120726_GM01	MapInfo	Defines the SW corner/orientation of the 2D grid
2d_code_Oxford_20120928_GM01	MapInfo	Defines the active 2D cells
2d_zsh_DTMfill_Oxford_20120806_GM01	MapInfo	Areas with no LiDAR data get filled in
2d_zsh_rivers_Oxford_CH2M_E	MapInfo	Sets elevations along river channels
2d_lfcsh_culverts_Oxford_F_polyline	Shapefile	Sets 2D flow constrictions for bridges/culverts
2d_mat_manmade_Oxford_20120824_GM0	MapInfo	Define man-made areas
2d_mat_multi_Oxford_20120824_GM01	MapInfo	Define multi-use areas
2d_mat_rail_Oxford_20120824_GM01	MapInfo	Define rail areas
2d_mat_road_Oxford_20120824_GM01	MapInfo	Define roads
2d_mat_rail	Shapefile	Sets roughness on railway
2d_mat_path_Oxford_20120824_GM01	MapInfo	Define paths
2d_mat_rough_ground_Oxford_20120824_GM01	MapInfo	Define rough ground areas
2d_mat_scrub_Oxford_20120824_GM01	MapInfo	Define scrub areas
2d_mat_trees_Oxford_20120824_GM01	MapInfo	Define forested areas
2d_mat_water_Oxford_20120824_GM01	MapInfo	Define water bodies
2d_mat_buildings_Oxford_20120824_GM01	MapInfo	Define building areas
Oxford_DTM_clipped	ASCII	Reads in the DTM grid
Topo1m_RP	ASCII	Reads in Topo survey DTM grid
2d_zsh_rail_proposed_01_polyline | 2d_zsh_rail_proposed_01_point	Shapefile	Network Rail track raising
2d_zsh_J00553_10_L | 2d_zsh_J00553_10_P	Shapefile	Topo survey TJ00553-10
2d_zsh_J00553_19_L | 2d_zsh_J00553_19_P	Shapefile	Topo survey TJ00553-19
2d_zsh_J00553_18_L | 2d_zsh_J00553_18_P	Shapefile	Topo survey TJ00553-18
2d_zsh_J00553_17_L | 2d_zsh_J00553_17_P	Shapefile	Topo survey TJ00553-17
2d_zsh_J00553_05_L | 2d_zsh_J00553_05_P	Shapefile	Topo survey TJ00553-15
2d_zsh_J00553_03_L | 2d_zsh_J00553_03_P	Shapefile	Topo survey TJ00553-13
2d_zsh_J00553_02_L | 2d_zsh_J00553_02_P	Shapefile	Topo survey TJ00553-12
2d_zsh_J00553_15_L | 2d_zsh_J00553_15_P	Shapefile	Topo survey TJ00553-15
2d_zsh_J00553_20_L | 2d_zsh_J00553_20_P	Shapefile	Topo survey TJ00553-20
2d_zsh_temp_defences_v1.shp	Shapefile	Temporary defences (2021 model)
2d_lfcsh_hedges50pc_R.shp | shp\2d_lfcsh_hedges_P.shp	Shapefile	Hedges across western floodplain with 50% flow constriction

Table B.3: Do Minimum Run Log (2021 Version)

Run Name (IEF and TCF)	Datafile	IED	TGC	TBC	TMF
v1_Ox_DM2021_rp2_cc11	Ox_DM2017_v5.DAT	2yr_2020_11pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp5_cc11	Ox_DM2017_v5.DAT	5yr_2020_11pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp10_cc11	Ox_DM2017_v5.DAT	10yr_2020_11pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp20_cc11	Ox_DM2017_v5.DAT	20yr_2020_11pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp50_cc11	Ox_DM2017_v5.DAT	50yr_2020_11pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp75_cc11	Ox_DM2017_v5.DAT	75yr_2020_11pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp100_cc11	Ox_DM2017_v5.DAT	100yr_2020_11pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp200_cc11	Ox_DM2017_v5.DAT	200yr_2020_11pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp1000_cc11	Ox_DM2017_v5.DAT	1000yr_2020_11pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp100_cc13	Ox_DM2017_v5.DAT	100yr_2050_13pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp100_cc30	Ox_DM2017_v5.DAT	100yr_2080_30pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf
v1_Ox_DM2021_rp100_cc82	Ox_DM2017_v5.DAT	100yr_2080_82pc_uplift.IED	Ox_DM_H50.tgc	Oxford_DM2017_v2.tbc	Oxford_2D_materials.tmf

Appendix C. Detailed design model files (2018 version)

Table C.1: Model run files for FAS (2018)

File	2018 Detailed Design Model (up to and including 100-year)	2018 Detailed Design Model (events greater than 100-year)
1D run file	v8_Ox_DD_rp100.ief	v8_Ox_DDken_rp100_35pc.ief
1D model file	Ox_DD_v7.dat	Ox_DD_v7.dat
1D boundary files	y0_100yr.IED	y0_100yr_35pc.IED
2D run file	v8_Ox_DD_rp100.tcf	v8_Ox_DDken_rp100_35pc.tcf
2D geometry file	v7_OX_DD.tgc	v7_OX_DDken.tgc
2D boundary file	v5_OX_DD.tbc	v5_OX_DD.tbc
2D materials file	Oxford_2D_materials.tmf	Oxford_2D_materials.tmf

Table C.2: Description of layers used in the 2D (TUFLOW) model component

Layer	Format	Description
1d_nwk_estry_TJ00553_devils_FAS	Shapefile	ESTRY culvert network for Devils Backbone
1d_FM_node_DD_v1	Shapefile	Flood Modeller node locations
2d_iwl_Oxford_polygon	Shapefile	Initial water level in certain areas
2d_iwl_lake_Oxford_polygon_v1	Shapefile	Initial water level set in lakes and Hinksey Stream
2d_po_Oxford_v1	Shapefile	Read PO lines
2d_bc_Ox_DD_v5	Shapefile	Sets HX links between 1D channel & 2D domain
2d_bc_sx_Ox_DD_v0	Shapefile	Sets SX links for Devils Backbone
2d_bc_sx_Oxford_20121025_GM01	MapInfo	Sets general SX links
2d_zsh_lakebed_Oxford_polygon_v1	Shapefile	Assumed bed levels in lakes
2d_zsh_banks_DD_V1_L | 2d_zsh_banks_DD_V1_P	Shapefile	Sets elevations along river banks at 1D-2D link
2d_zsh_defences_2011_L | 2d_zsh_defences_2011_P	Shapefile	Sets elevations along river banks at 1D-2D link with surveys 11227, 11228, 11230 (dated 2011)
2d_zsh_Hinksey_Ditch_L | 2d_zsh_Hinksey_Ditch_P	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_Hinksey_Ditch_polygon	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_embankments_Oxford_L | 2d_zsh_embankments_Oxford_P	Shapefile	Sets elevations along embankments
2d_zsh_flowpaths_Oxford_L | 2d_zsh_flowpaths_Oxford_P	Shapefile	Sets elevations along flow paths
2d_mat_stability_v3	Shapefile	Improve stability at Devil's Backbone and Hinksey
2d_code_Ox_DD_v4	Shapefile	Sets null cells within river channel
2d_loc_Oxford_20120726_GM01	MapInfo	Defines the SW corner/orientation of the 2D grid
2d_code_Oxford_20120928_GM01	MapInfo	Defines the active 2D cells
2d_zsh_DTMfill_Oxford_20120806_GM01	MapInfo	Areas with no LiDAR data get filled in

Layer	Format	Description
2d_zsh_rivers_Oxford_CH2M_E	MapInfo	Sets elevations along river channels
2d_lfcsh_culverts_Oxford_F_polyline	Shapefile	Sets 2D flow constrictions for bridges/culverts
2d_mat_manmade_Oxford_20120824_GM0	MapInfo	Define man-made areas
2d_mat_multi_Oxford_20120824_GM01	MapInfo	Define multi-use areas
2d_mat_rail_Oxford_20120824_GM01	MapInfo	Define rail areas
2d_mat_road_Oxford_20120824_GM01	MapInfo	Define roads
2d_mat_rail	Shapefile	Sets roughness on railway
2d_mat_path_Oxford_20120824_GM01	MapInfo	Define paths
2d_mat_rough_ground_Oxford_20120824_GM01	MapInfo	Define rough ground areas
2d_mat_scrub_Oxford_20120824_GM01	MapInfo	Define scrub areas
2d_mat_trees_Oxford_20120824_GM01	MapInfo	Define forested areas
2d_mat_water_Oxford_20120824_GM01	MapInfo	Define water bodies
2d_mat_buildings_Oxford_20120824_GM01	MapInfo	Define building areas
Oxford_DTM_clipped	ASCII	Reads in the DTM grid
Topo1m_RP	ASCII	Reads in Topo survey DTM grid
2d_zsh_rail_proposed_01_polyline | 2d_zsh_rail_proposed_01_point	Shapefile	Network Rail track raising
2d_zsh_J00553_10_L | 2d_zsh_J00553_10_P	Shapefile	Topo survey TJ00553-10
2d_zsh_J00553_19_L | 2d_zsh_J00553_19_P	Shapefile	Topo survey TJ00553-19
2d_zsh_J00553_18_L | 2d_zsh_J00553_18_P	Shapefile	Topo survey TJ00553-18
2d_zsh_J00553_17_L | 2d_zsh_J00553_17_P	Shapefile	Topo survey TJ00553-17
2d_zsh_J00553_05_L | 2d_zsh_J00553_05_P	Shapefile	Topo survey TJ00553-15
2d_zsh_J00553_03_L | 2d_zsh_J00553_03_P	Shapefile	Topo survey TJ00553-13
2d_zsh_J00553_02_L | 2d_zsh_J00553_02_P	Shapefile	Topo survey TJ00553-12
2d_zsh_J00553_15_L | 2d_zsh_J00553_15_P	Shapefile	Topo survey TJ00553-15
2d_zsh_J00553_20_L | 2d_zsh_J00553_20_P	Shapefile	Topo survey TJ00553-20
2d_zsh_Remove_Track_R | 2d_zsh_Remove_Track_P	Shapefile	Removed existing raised track from DTM south of Devil's Backbone
2d_zsh_FAS_Raised_Defences_v1	Shapefile	FAS defences
2d_zsh_FAS_Road_Ramp_L | 2d_zsh_FAS_Road_Ramp_P	Shapefile	Add track/road levels over new bridges
2d_zsh_South_Hinksey_kerb_P	Shapefile	Small kerb (100-year), adjacent the South Hinksey
2d_zsh_FAS_Allotment_v0	Shapefile	Represents small defence (20-year level) in Allotments upstream of Botley Road
2d_zsh_AbingdonRd_v0	Shapefile	Represents small defence (100-year level) at the Network Rail access from Old Abingdon Road
Files used for events > 100-year		
2d_zsh_banks_DDken_V1_L | 2d_zsh_banks_DDken_V1_P	Shapefile	Sets elevations along river banks at 1D-2D link
2d_zsh_AbingdonRd_v1	Shapefile	Represents small defence (100-year level) at the Network Rail access from Old Abingdon Road

Appendix D. Mean monthly and Q_{95} model files

Table D.1: Model run files for mean monthly and Q 95 simulations

File	Baseline	FAS
1D run file	Ox_Base_LowQ_v4.ief	Ox_DD_LowQ_v7.ief
1D model file	Ox_Base_LowQ_v4	Ox_DD_LowQ_v7.DAT
1D inflows	ALL_03_with_Q95.IED	
Structure operation	RULES_Kings.IED	
Structure operation	RULES_Godstow.IED	
Structure operation	RULES_Osney.IED	
Structure operation	RULES_Iffley.IED	
Structure operation	RULES_Sandford_v2.IED	

Appendix E. Detailed design model files (2021 version)

Table E.1: Model run files for FAS (2021 version)

File	2021 Detailed Design
1D run file	v7_Ox_MedChan_AsDesign_TD_Osney_rp100_cc11.ief
1D model file	OxFAS_MedChannel_v6.dat
1D boundary files	<event>_2020_11pc_uplift.IED
2D run file	v7_Ox_MedChan_AsDesign_TD_Osney_rp100_cc11.tcf
2D geometry file	v3_Ox_MedChannel_Def_AsDesign_TD_Osney_Track.tgc
2D boundary file	v2a_Ox_MedChannel_OsneyCulv.tbc
2D materials file	Oxford_2D_materials.tmf

Table E.2: Description of layers used in the 2D (TUFLOW) model component (2021 version)

Layer	Format	Description
1d_nwk_estry_TJ00553_devils_FAS	Shapefile	ESTRY culvert network for Devils Backbone
1d_nwk_estry_osney4_FAS.shp	Shapefile	ESTRY culverts for Osney Defence flap valves
1d_FM_node_DD20_v2a.shp	Shapefile	Flood Modeller node locations
2d_iwl_Oxford_polygon	Shapefile	Initial water level in certain areas
2d_iwl_lake_Oxford_polygon_v1	Shapefile	Initial water level set in lakes and Hinksey Stream
2d_po_Oxford_v1	Shapefile	Read PO lines
2d_bc_Ox_DD21_v7a.shp	Shapefile	Sets HX links between 1D channel & 2D domain
2d_bc_hx_Hogacre_v1.shp	Shapefile	Sets HX links between 1D channel & 2D domain
2d_bc_sx_Ox_DD_v0	Shapefile	Sets SX links for Devils Backbone
2d_bc_sx_Oxford_20121025_GM01	MapInfo	Sets general SX links
2d_bc_sx_OsneyCulv.shp	Shapefile	Sets SX links for Osney Defence flap valves
2d_zsh_lakebed_Oxford_polygon_v1	Shapefile	Assumed bed levels in lakes
2d_zsh_defences_2011_L | 2d_zsh_defences_2011_P	Shapefile	Sets elevations along river banks at 1D-2D link with surveys 11227, 11228, 11230 (dated 2011)
2d_zsh_Hinksey_Ditch_L | 2d_zsh_Hinksey_Ditch_P	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_Hinksey_Ditch_polygon	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_embankments_Oxford_L | 2d_zsh_embankments_Oxford_P	Shapefile	Sets elevations along embankments
2d_zsh_flowpaths_Oxford_L | 2d_zsh_flowpaths_Oxford_P	Shapefile	Sets elevations along flow paths
2d_mat_stability_v3	Shapefile	Improve stability at Devil's Backbone and Hinksey
2d_code_Ox_DD21_v6.shp 2d_code_Hogacre_v1.shp	Shapefile	Sets null cells within 1D river channels
2d_loc_Oxford_20120726_GM01	MapInfo	Defines the SW corner/orientation of the 2D grid
2d_code_Oxford_20120928_GM01	MapInfo	Defines the active 2D cells
2d_zsh_DTMfill_Oxford_20120806_GM01	MapInfo	Areas with no LiDAR data get filled in

Layer	Format	Description
2d_zsh_rivers_Oxford_CH2M_E	MapInfo	Sets elevations along river channels
2d_lfcsh_culverts_Oxford_F_polyline	Shapefile	Sets 2D flow constrictions for bridges/culverts
2d_mat_manmade_Oxford_20120824_GM0	MapInfo	Define man-made areas
2d_mat_multi_Oxford_20120824_GM01	MapInfo	Define multi-use areas
2d_mat_rail_Oxford_20120824_GM01	MapInfo	Define rail areas
2d_mat_road_Oxford_20120824_GM01	MapInfo	Define roads
2d_mat_rail	Shapefile	Sets roughness on railway
2d_mat_path_Oxford_20120824_GM01	MapInfo	Define paths
2d_mat_rough_ground_Oxford_20120824_GM01	MapInfo	Define rough ground areas
2d_mat_scrub_Oxford_20120824_GM01	MapInfo	Define scrub areas
2d_mat_trees_Oxford_20120824_GM01	MapInfo	Define forested areas
2d_mat_water_Oxford_20120824_GM01	MapInfo	Define water bodies
2d_mat_buildings_Oxford_20120824_GM01	MapInfo	Define building areas
Oxford_DTM_clipped	ASCII	Reads in the DTM grid
Topo1m_RP	ASCII	Reads in Topo survey DTM grid
2d_zsh_rail_proposed_01_polyline | 2d_zsh_rail_proposed_01_point	Shapefile	Network Rail track raising
2d_zsh_J00553_10_L | 2d_zsh_J00553_10_P	Shapefile	Topo survey TJ00553-10
2d_zsh_J00553_19_L | 2d_zsh_J00553_19_P	Shapefile	Topo survey TJ00553-19
2d_zsh_J00553_18_L | 2d_zsh_J00553_18_P	Shapefile	Topo survey TJ00553-18
2d_zsh_J00553_17_L | 2d_zsh_J00553_17_P	Shapefile	Topo survey TJ00553-17
2d_zsh_J00553_05_L | 2d_zsh_J00553_05_P	Shapefile	Topo survey TJ00553-15
2d_zsh_J00553_03_L | 2d_zsh_J00553_03_P	Shapefile	Topo survey TJ00553-13
2d_zsh_J00553_02_L | 2d_zsh_J00553_02_P	Shapefile	Topo survey TJ00553-12
2d_zsh_J00553_15_L | 2d_zsh_J00553_15_P	Shapefile	Topo survey TJ00553-15
2d_zsh_J00553_20_L | 2d_zsh_J00553_20_P	Shapefile	Topo survey TJ00553-20
2d_zsh_Remove_Track_R | 2d_zsh_Remove_Track_P	Shapefile	Remove existing track from DTM south of Devil's Backbone
2d_zsh_FAS_Road_Ramp_L | 2d_zsh_FAS_Road_Ramp_P	Shapefile	Add track/road levels over new bridges
2d_zsh_banks_DD20_V8_L | 2d_zsh_banks_DD20_V8_P	Shapefile	Sets elevations along river banks at 1D-2D link
2d_zsh_temp_defences_v1.shp	Shapefile	Temporary defences (2021 model)
2d_lfcsh_hedges50pc_R.shp | shp\2d_lfcsh_hedges_P.shp	Shapefile	Hedges across western floodplain with 50% flow constriction
2d_zsh_AccessTrack_L.shp | shp\FAS\2d_zsh_AccessTrack_P.shp	Shapefile	Access track upstream of Botley Road defences
2d_zsh_FAS_Defence_Design_Level.shp	Shapefile	FAS defences with freeboard
2d_zsh_AbingdonRd_v2	Shapefile	Represents small defence at the Network Rail access from Old Abingdon Road
2d_zsh_FAS_Defence_OsneyV23.shp	Shapefile	Osney Mead FAS Defence (2 crest levels)

Table E.3: FAS Model Run Log (2021 version)

Datafile	TGC	TBC	TMF
OxFAS_MedChannel_v6.dat	v3_Ox_MedChannel_Def_AsDesign_TD_Osney_Track	v2a_Ox_MedChannel_OsneyCulv	Oxford_2D_materials

Run Name (IEF and TCF)	IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp2_cc11	2yr_2020_11pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp5_cc11	5yr_2020_11pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp10_cc11	10yr_2020_11pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp20_cc11	20yr_2020_11pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp50_cc11	50yr_2020_11pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp75_cc11	75yr_2020_11pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp100_cc11	100yr_2020_11pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp200_cc11	200yr_2020_11pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp1000_cc11	1000yr_2020_11pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp100_cc13	100yr_2050_13pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp100_cc30	100yr_2080_30pc_uplift.IED
v7_Ox_MedChan_AsDesign_TD_Osney_rp100_cc82	100yr_2080_82pc_uplift.IED

Appendix F. Minns Estate recorded water levels

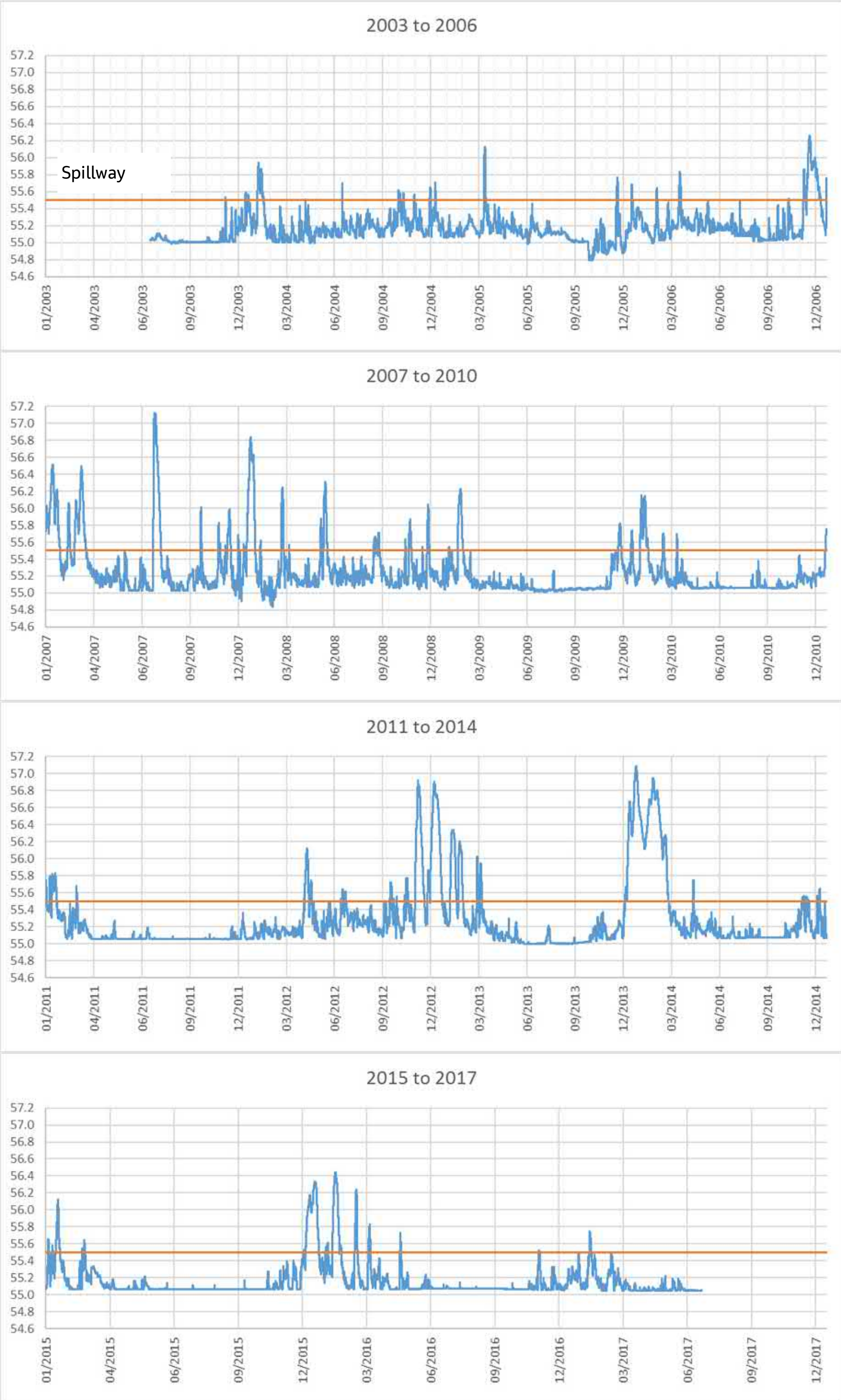
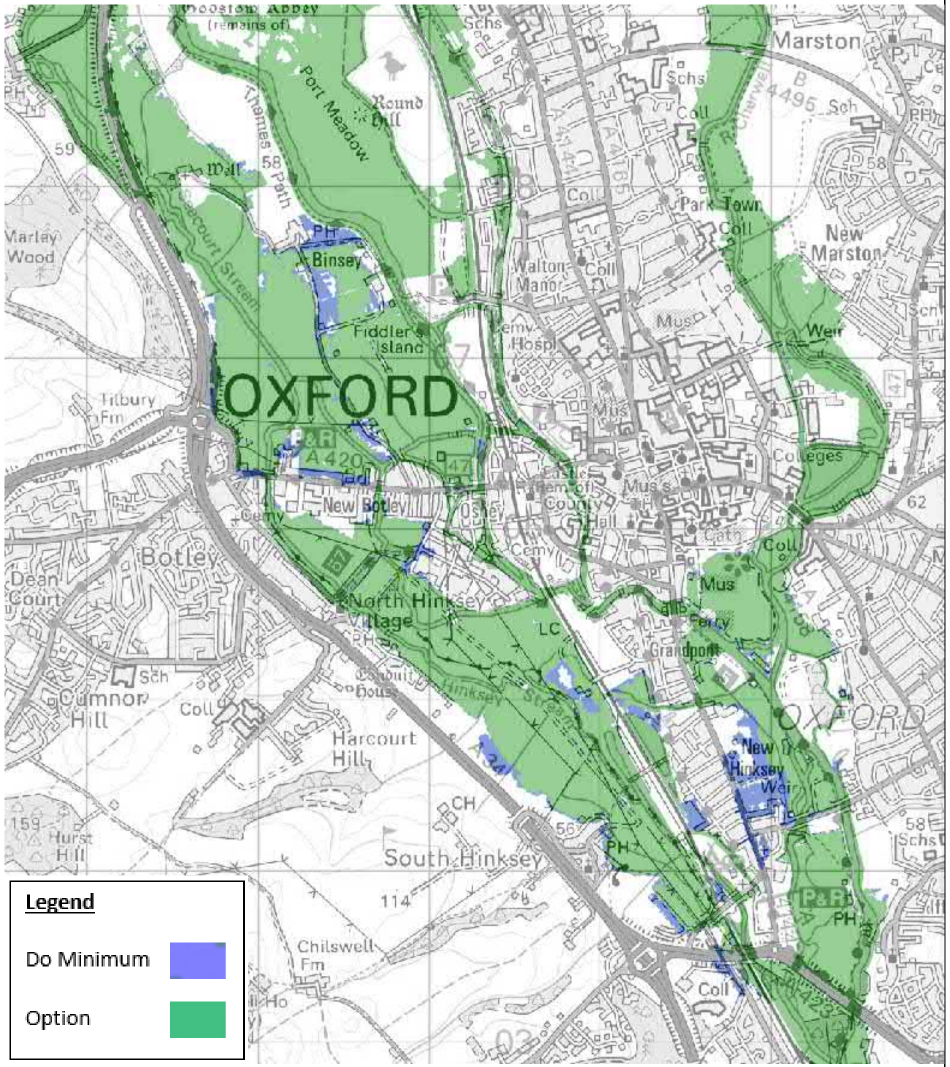


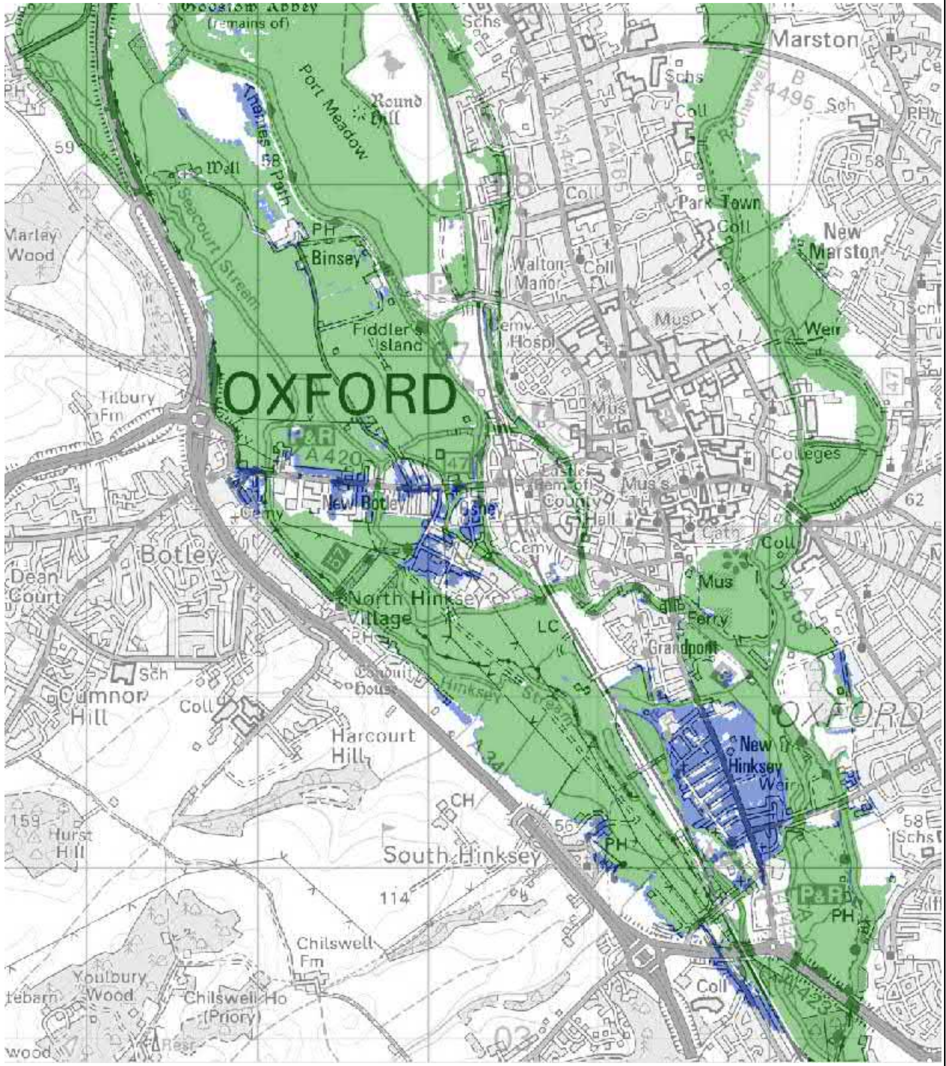
Figure F.1: Minns Estate recorded water level record and spillway level

Appendix G. Flood extent comparison (2018 version)

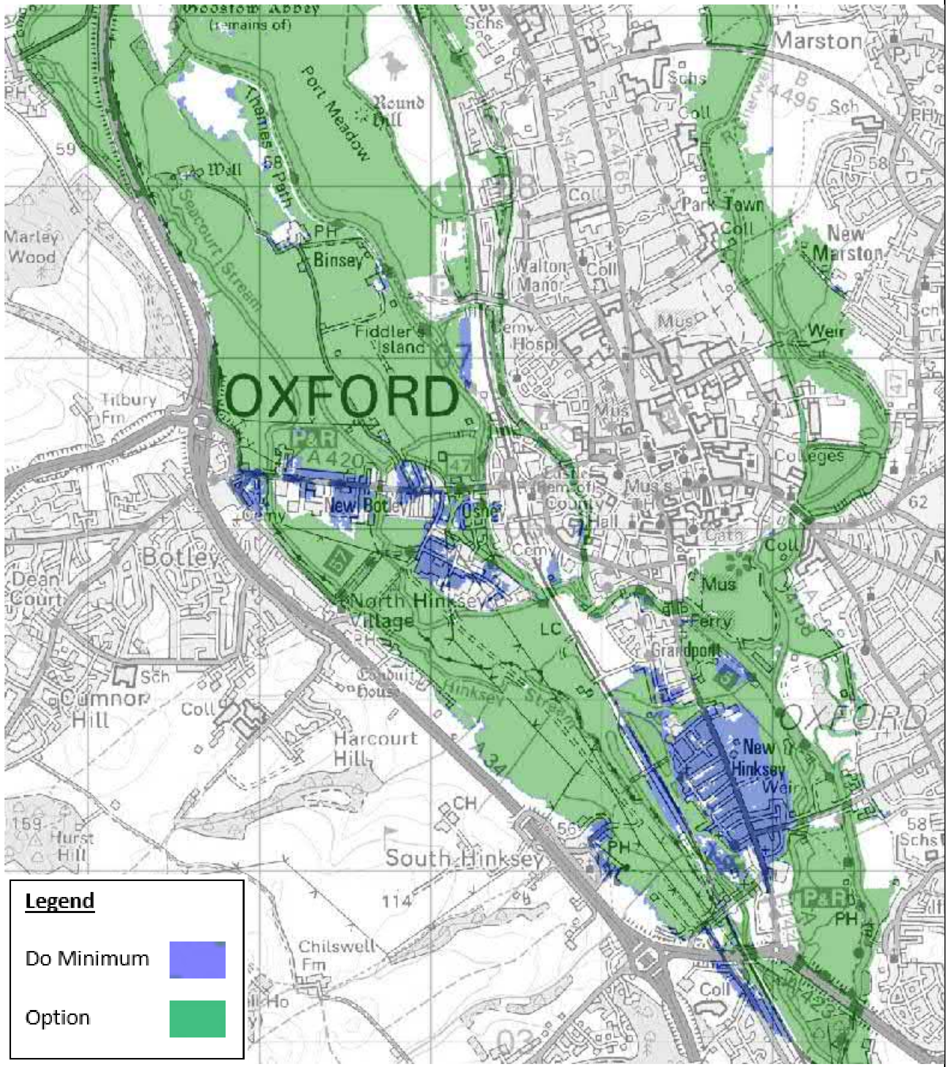
Outline Design – 5-year



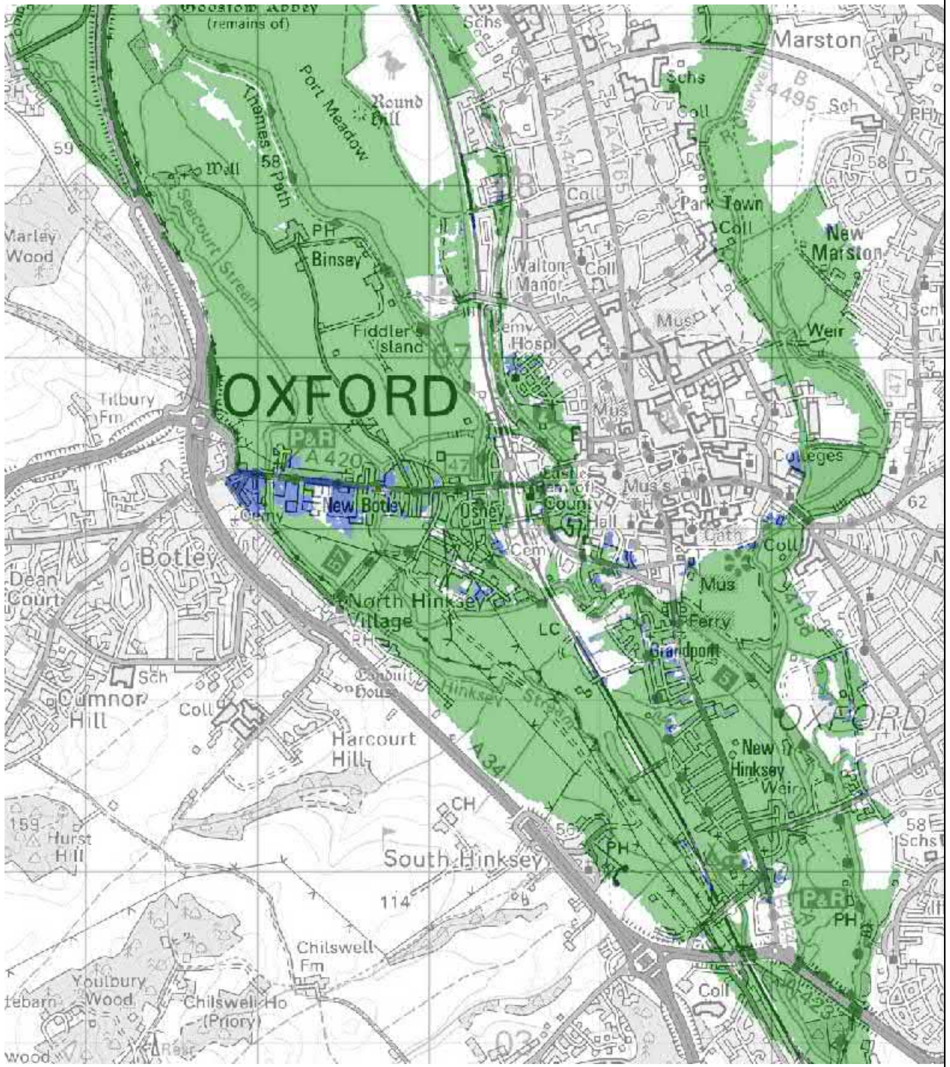
Outline Design – 20-year



Outline Design – 50-year



Outline Design – 100-year +35%



Appendix H. Model review (2018 version)

Model review comments detailed in “Oxford_FAS_Model_Review_RHDHV_20171218.PDF”

Project:	**Oxford Flood Alleviation Scheme - Modelling Review**
EA Project reference	IMSE500177
RHDHV Project No:	PB7234
Review Title:	Oxford FAS Stage 6 Detailed Design Modelling Review
Revision:	0.2
Date:	18-Dec-2017
Author(s):	Andrew Craig, Katarzyna Bozek

Royal HaskoningDHV

Project Background Informaion	As the Outline Business Case for the Oxford Flood Alleviation Scheme has been submitted and awaiting approval, the next phase of the project is underway focusing on refinement and updates to the hydraulic model developed by CH2M, including relevant design details and options. Royal HaskoningDHV were commissioned to carry out an independent review of the model including investigation of the model build and configuration. This is to ensure that the model is robust and suitable for informing the detailed design.
Purpose of the Review	This commission consists of reviewing changes and updates made to the baseline (do minimum / DM) and with scheme detailed design (DD) models since the last outline design reviews carried out by Capita AECOM in 2016. The modelled domain is approximately 15km in length and includes the main river Thames and tributaries, although the focus reach of the Scheme through the western side of Oxford is closer to 7km. The downstream implications of the scheme will be modelled through the use of a further model developed for the Abingdon scheme, also by CH2M, which is not within the scope of this review.
Scope of the Review	This report details the review of the baseline (DM), detailed design (DD) and low flow models that were updated in 2017 following previous 2016 model reviews, including new topographic surveys plus scheme design refinements. Sensitivity testing has also been carried out by CH2M, and comments are included in this review. The primary focus of this review is in assessing suitability of any changes made to the model since the previous review and checking for any outstanding issues to be addressed, with particular emphasis on the scheme and surrounding reaches. This review included two rounds, in order to incorporate changes made by CH2M in response to the first review.
	The inflow hydrology has been reviewed in the previous phase of the study and is not required to be further evaluated at this stage.
Disclaimer	No part of these specifications/printed matter may be reproduced and/or published by print, photocopy, microfilm or by any other means, without the prior written permission of HaskoningDHV UK Ltd.; nor may they be used, without such permission, for any purposes other than that for which they were produced. HaskoningDHV UK Ltd. accepts no responsibility or liability for these specifications/printed matter to any party other than the persons by whom it was commissioned and as concluded under that Appointment. The integrated QHSE management system of HaskoningDHV UK Ltd. has been certified in accordance with ISO 9001:2015, ISO 14001:2015 and OHSAS 18001:2007. Whilst reasonable skill and care have been used in reviewing the models, in line with industry standards, it is not realistic in a short timeframe to check every detail of such a large model, and there are some information sets that we were not provided access to. Furthermore, our review has been focussed on the model representation of the baseline (DM) and with scheme (DD) models, but RoyalHaskoningDHV have not reviewed or commented on the design itself.

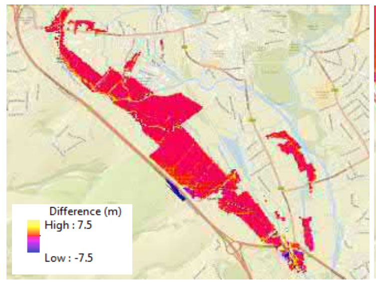
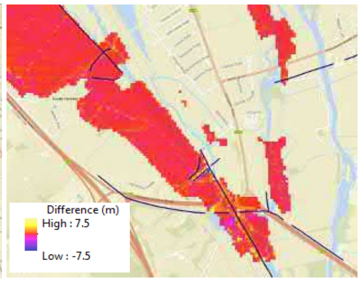
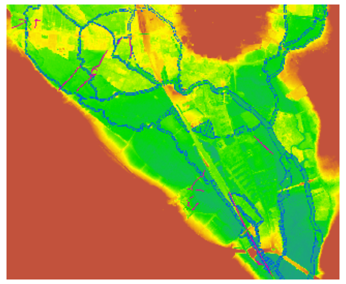
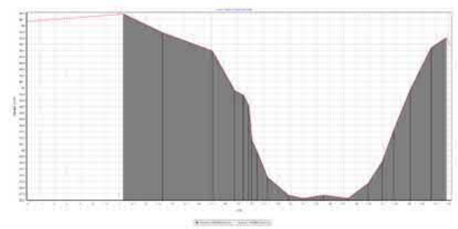
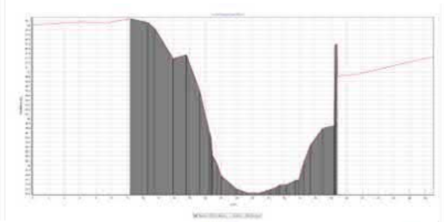
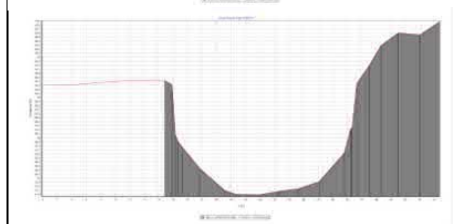
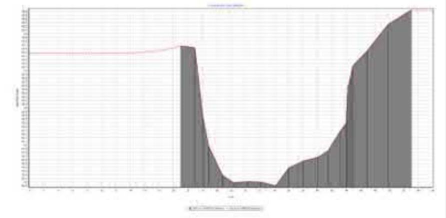
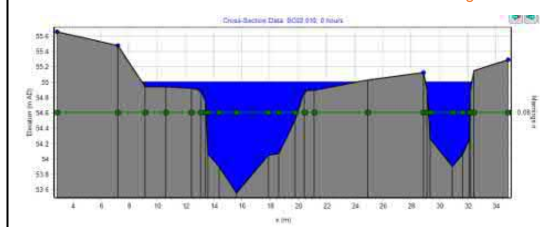
Key to Model Review Colour scheme	**Level of Action Required**
Actions written in RED	Potential for high impact on model results and study outcome. Model amendments essential.
Actions written in AMBER	May affect results and study outcome. Model amendments may be required, or alternatively justification should be provided in the hydraulic modelling report. The decision may be informed by sensitivity testing and/or client priorities.
Comments written in BLACK (Default)	Negligible impact on study outcome. General observations or issues to be taken note of as best modelling practice and where appropriate discussed in the report.

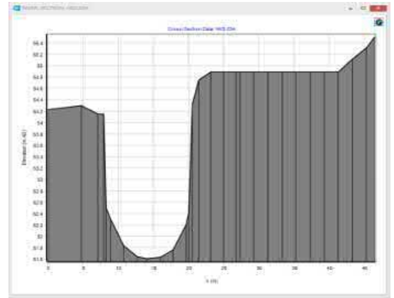
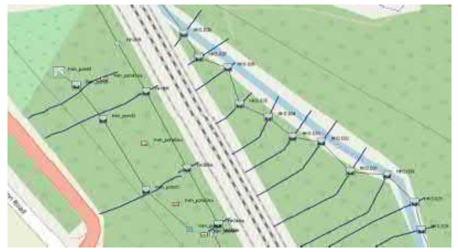
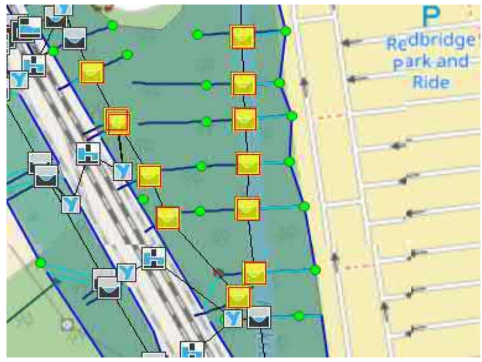
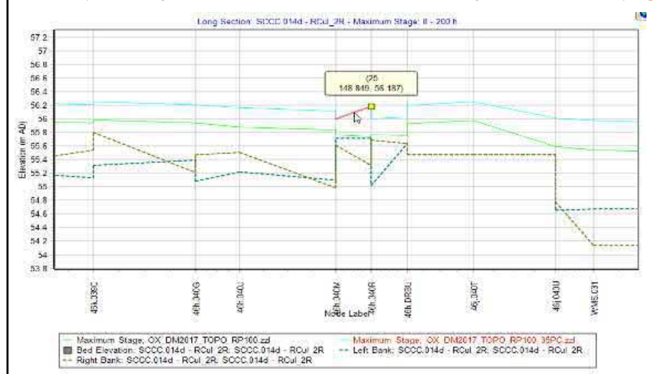
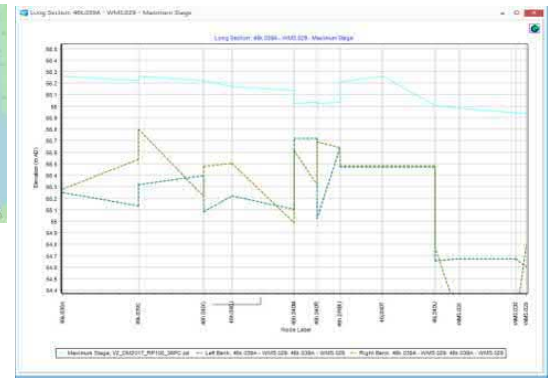
Data Received	Date Received
Reports/Documents	
IMSE500177-CH2-00-00-VS-C-0001.pdf	16/10/2017
OFFICIAL_SENSITIVE_IMSE500177-HGL-00-ZZ-RE-N-000124-Modelling_Report_update_03November	16/10/2017
Oxford_FAS_Review_Modelling_CH2M_Responses_8Jan2016.docx	17/10/2017
Oxford_FAS_Stage4_Review_Options_Modelling_Fluvial_OFFICIAL_SENSITIVE_20160412.pdf	17/10/2017
Oxford_FAS_Stage5_Review_OutlineDesign_Modelling_Fluvial_OFFICIAL_SENSITIVE_201607.doc	17/10/2017
Oxford_FAS_Stage5_Review_OutlineDesign_Modelling_Fluvial_OFFICIAL_SENSITIVE_201607.pdf	17/10/2017
Oxford_Model_Sensitivity_testing_8Jan2016.docx	17/10/2017
IMSE500177-HGL-00-ZZ-RE-N-000104-Model_Stage3_Responses_OFFICIAL_SENSITIVE.docx	17/10/2017
IMSE500177-HGL-00-ZZ-RE-N-000104-Model_Stage3_Responses_OFFICIAL_SENSITIVE_Capita28042016.docx	17/10/2017
IMSE500177-HGL-00-ZZ-RE-N-000105-Model_Stage4_Responses_OFFICIAL_SENSITIVE.docx	17/10/2017
IMSE500177-HGL-00-ZZ-RE-N-000105-Model_Stage4_Responses_OFFICIAL_SENSITIVE_capita28042016.docx	17/10/2017
Oxford_FAS_Review_Hydrology_20151214.pdf	17/10/2017
Oxford_FAS_Review_Modelling_20151216.pdf	17/10/2017
IMSE500177-CH2-00-00-TN-HY-0131 – DD Peer Review Handover Note.pdf	17/10/2017
IMSE500177-CH2-00-00-TN-HY-0132 – DD Hydraulic Modelling Sensitivity Tests.pdf	30/10/2017
IMSE500177-CH2-XX-00-TN-HY-0141.docx (Peer Review Model Updates)	07/12/2017
Model Files	
Old Baseline Model (2016)	
Ox_DM2015_rp100_results_1March2016.zip	17/10/2017
Oxford_DM_model_190716.zip	17/10/2017
Oxford_DM_Results_29Feb2016.zip	17/10/2017
Outline Design Model	
Oxford_FAS_Model_140616.zip	17/10/2017
Oxford_FAS_Results_140616.zip	17/10/2017
Latest Do Minimum and Detailed Design Models (2017)	
latest_Model.zip Including following Folders:	16/10/2017
_1D	
_TUFLOW	
Ox_DM2017_topo_rp5	
Ox_DM2017_topo_rp20	
Ox_DM2017_topo_rp50	
Ox_DM2017_topo_rp100	
Ox_DM2017_topo_rp100_35pc	
v3_Ox_DD_rp5	
v3_Ox_DD_rp20	

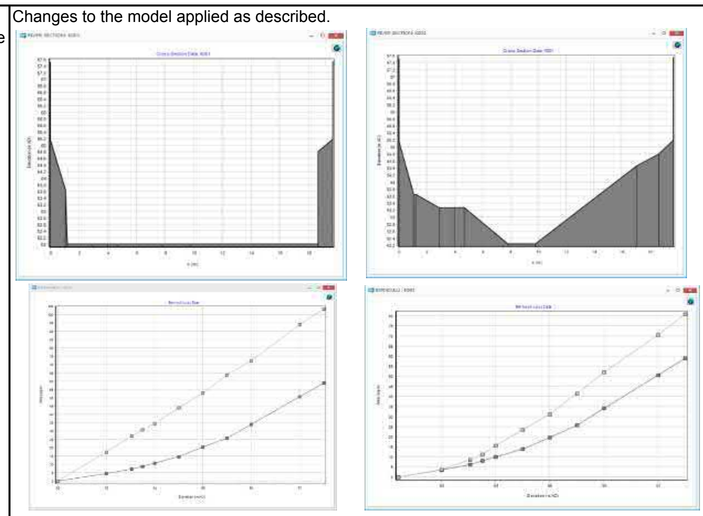
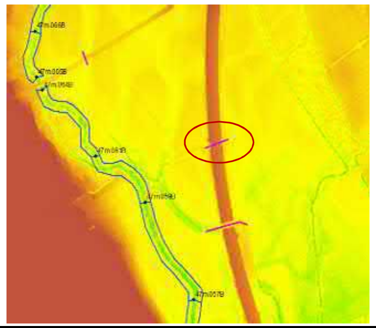
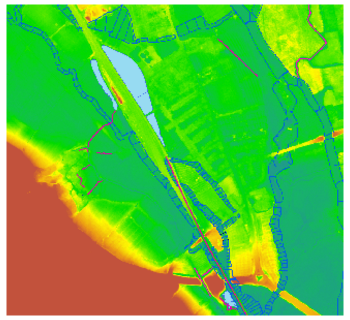
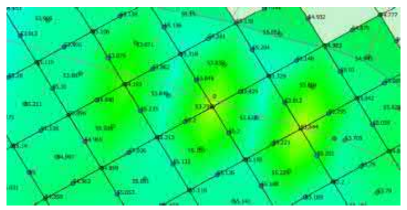
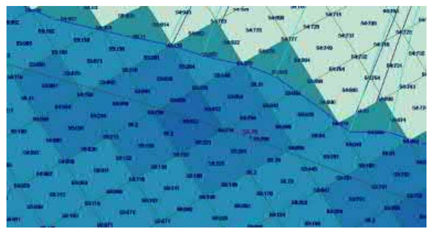
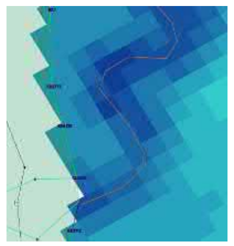
v3_Ox_DD_rp50	
v3_Ox_DD_rp100	
v3_Ox_DD_rp100_35pc	
Low Flow Model	
MM_Q95_Model.zip	17/10/2017
Updated Model for second round of review	
Updated_Model.zip Including following Folders:	07/12/2017
Oxford_models_7Dec17 (with _1D and _TUFLOW	
v2_DM2017_topo_rp5	
v2_DM2017_topo_rp20	
v2_DM2017_topo_rp50	
v2_DM2017_topo_rp100	
v2_DM2017_topo_rp100_35pc	
v8_Ox_DD_rp5	
v8_Ox_DD_rp20	
v8_Ox_DD_rp50	
v8_Ox_DD_rp100	
v8_Ox_DD_rp100_35pc	
Survey Data	
New_Survey.zip Including following Folders:	16/10/2017
1. J00553 - East Of Abingdon Road-finals	
2. J00553 - Manor Farm-finals	
3. J00553 - Devils Backbone	
4. J00553 -South Hinksey-finals	
5. J00553 - North Hinksey	
6. J00553 - Weirs Lane -final	
7. J00553 - Henry & Helen Road	
8. J00553 - Botley- final	
9. J00553 - Grand Pont - provisional	
10. J00553 - Redbridge Park & Ride	
11. J00553 - South Hinksey Level-final	
14. J00553 - Campsite - provisional	
15. J00553 - Seacourt P&R-revA	
16..J00553-BotleyFields	
17. J00553 - Willow Walk	
18. J00553 - New Hotel Hinksey	
19. J00553 - Botley Levels	
20-J00553 - Osney Island	

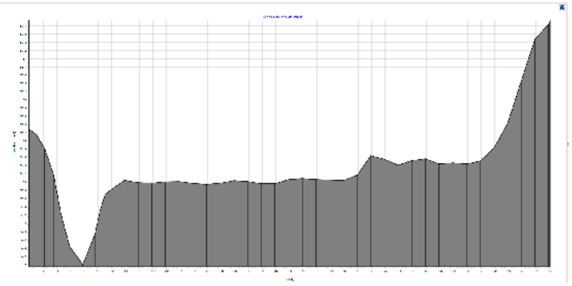
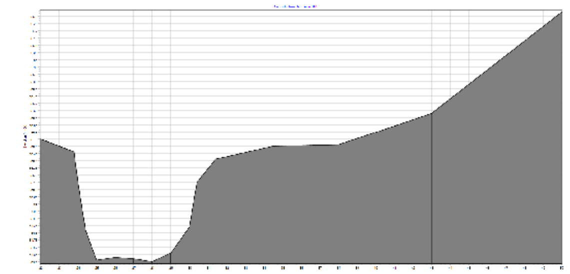
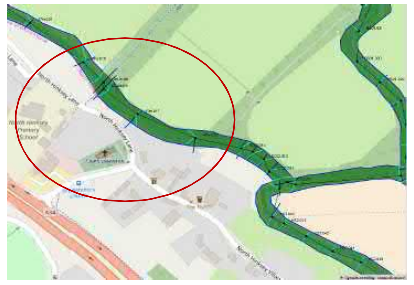
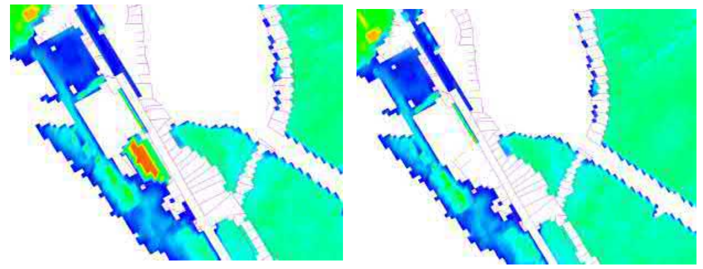
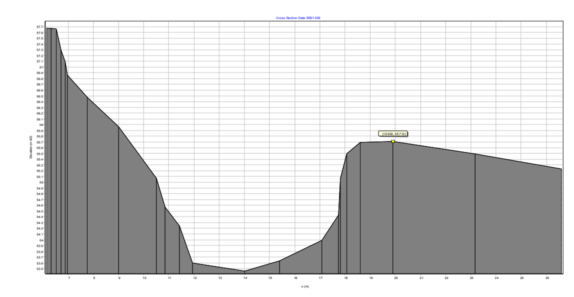
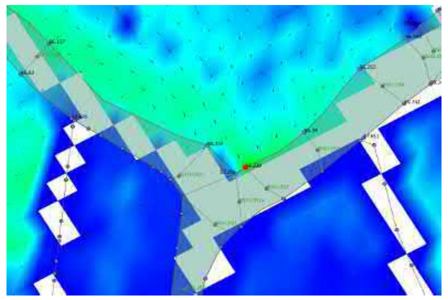
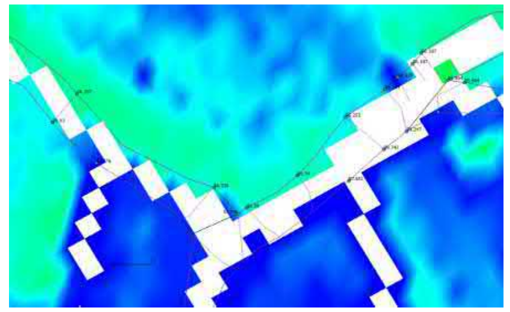
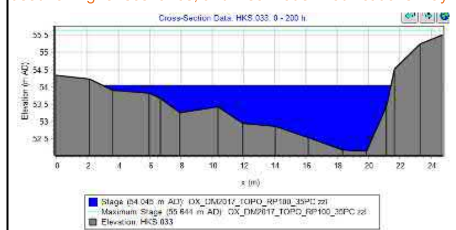
J00550 - Seacourt Stream-provisional	
J00551 Hinksey Stream - Rev A - channel Survey	
J00552 - Weirs Mill Stream-finals	
Draft_Bridges_20170817.zip Including following Folders:	16/10/2017
1110 - Botley Bridge Modifications	
2110 - Westway Cycle Path	
2210 - Willow Walk	
3110 - North Hinksey Causeway	
3230 - Bulstake Footbridge	
3330 - Devils Backbone	
4210 - Electric Compound	
4450 - Old Abingdon and Kennington	
4500 - A423 West Culvert	
4800 - A423 East Culvert	
4840 - A423 East Footbridge	

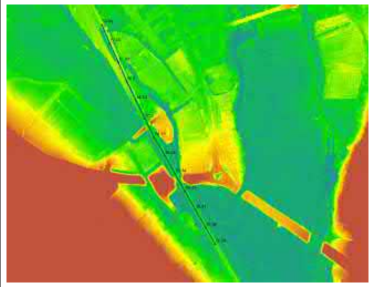
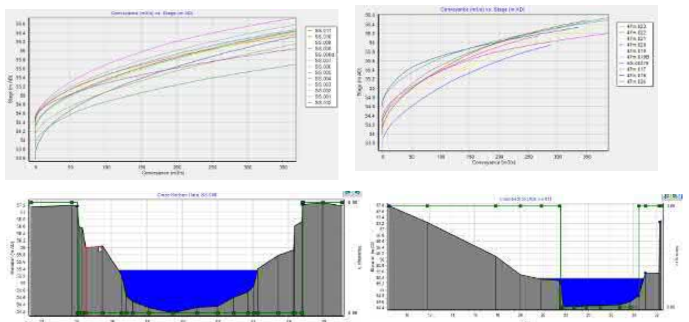
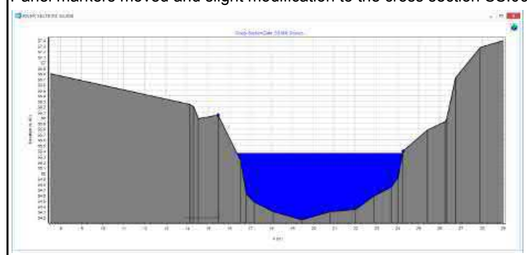
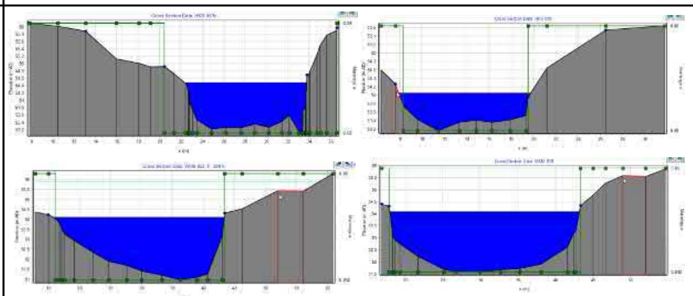
DO MINIMUM MODEL

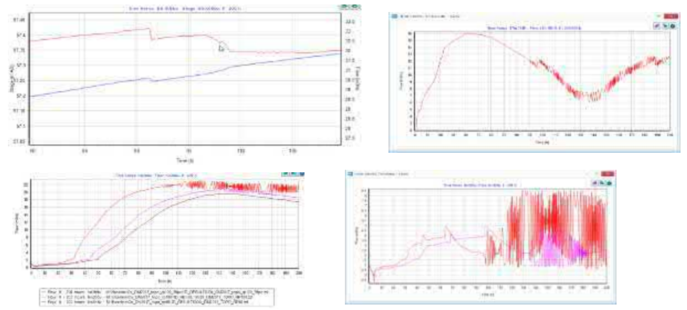
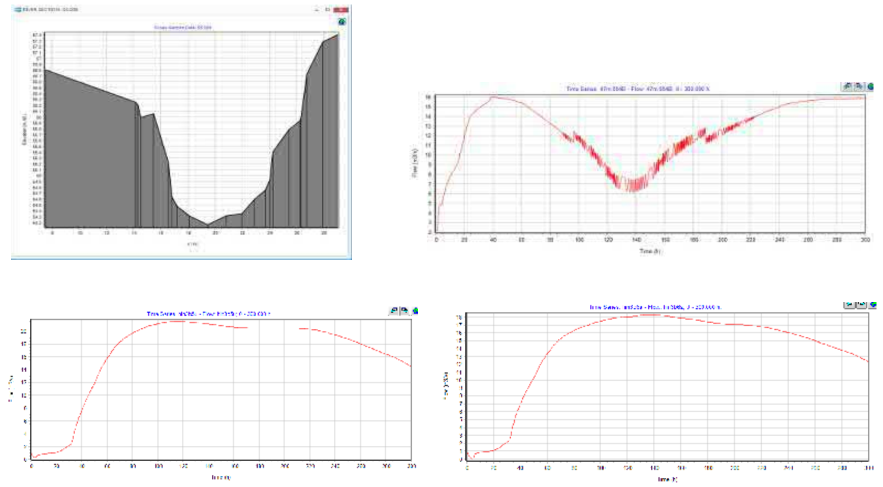
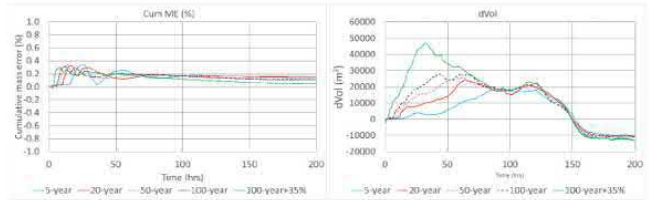
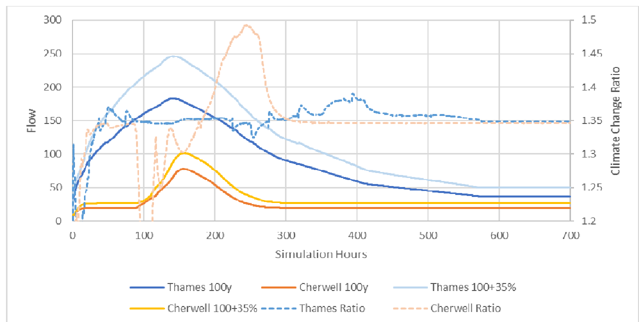
Item No.	Item to Review	Comments	CH2M Model Updates	RHDHV Comments (second review Dec 2017, after CH2M changes)
MODEL BUILDING				
1.1	Suitability of fit between the model and latest available LiDAR and crest survey.	The main LiDAR data grid used for the majority of the model domain has not been updated since the previous model review, therefore this review was focused on the latest topographic survey which was used instead of Lidar where available (coverage shown in CH2M report). Survey TJ00553-12 - Chiswell Path was not provided therefore could not be checked. A comparison between elevations read in the 2D grid (zpts) and the new topo layer is shown in first figure below. Overall there is a good match (red indicates no discrepancies), most significant differences are along features where zshp lines have been used to define elevations based on survey data (see second figure). More Z-lines were added to enforce the features of the floodplain along the new channel survey, as shown in third figure. 		No updates needed
1.2	Suitability of fit between the model and new channel cross-section data.	Following survey data was not provided and therefore checks could not be carried out: *Surveys 00007 – 1982 and 08169 – 2004 for cross-sections 47m.024 to 47m.016 and SC02.014 to SC02.010; *B174 As Built - 2013 for cross-sections K007 to K001 Also, full details of the Network Rail double culvert were not provided against which to check the model's representation. Changes in cross-sections in accordance with Table 6: Update to Do Minimum model – 1D Model Handover Note. Softbed survey used for all cross-sections. All cross-sections match provided survey data. Below are some comparison figures. Cross-sections WMS.0.31 and WMS.030 in the model are identical, based on survey J00552 section 1.030. 		No updates needed
		Note section SC02.010 contains a double section which is thought to cross multiple channels and ought to be clipped to the correct channel. 		No change made in the model - this should ideally be noted and explained in the main report.
1.3	Suitability of fit between the model and the beach profile /coastal defence data	NOT REQUIRED		
1.4	Representation of structures including any bypassing. Comment on how any operational structures are represented in design mode.	From a sample number of checks, focussing mainly on the new survey reaches, we did not find any issues with incorrect structure bypassing, although it is not feasible to check every structure in detail for a model of this size.		No updates needed.

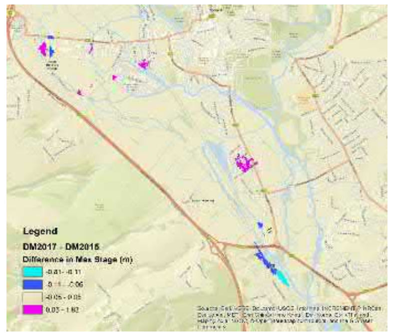
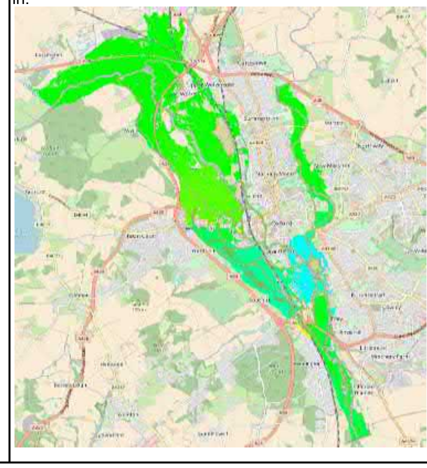
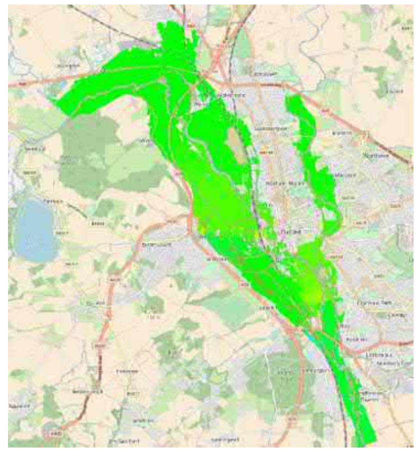
1.5	Schematisation of the 1D floodplain, suitability of extended cross-section, reservoir units. Suitability of cross-section spacing (use of interpolates), orientation of cross-sections, any intersecting cross-sections.	No reservoirs in model. This review focused mainly on cross-sections added or amended based on the latest channel surveys. No issues raised on schematisation in the previous model review. No changes to extended cross-sections in the lower 2km of the model or along parts of Eastwyke Ditch have been made from in the previous model. However, we notice that Hagacre Ditch is present in both 1D and 2D domains which is not appropriate (despite the flow being relatively small), and the reason for the missing reach from Hag11 to the Thames should be justified in the CH2M report. Along the Hinksey Stream there are a couple of cross-sections that have been deactivated in the 2D domain but the cross-sections have not been extended, see second figure below.  	Cross sections at HKS.034, HKS.033 and HKS.032 modified to represent the floodplain on the right bank up to the railway	Changes to the model applied on Hinksey Stream. However, the main report should clarify the situation (data, decisions, influence) regarding Hagacre Ditch.  
		A couple of parallel 1D reaches are missing spills between the channels despite their banks being exceeded (there is no flow in the 2D domain here). Both parallel reaches are short and impacts likely to be small, but this ought to be checked and confirmed by CH2M.  		No changes to the model. Both parallel reaches are short and impacts likely to be small, but this ought to be stated by CH2M in the main report.
		Long section profile of 100y+35% generally follows a sensible increase above the 100y peak levels. However, new adverse gradient detected at Iffley due to lateral spill for 100y+35% event - CH2M should check that they are satisfied with spill geometry, coefficient and results. 	Schematisation at structures at Weirs Millstream (Donnington Road) adjusted to replace side spill with an in-line spill which was causing circulation of flows and adverse rise in water level. (Spill 46h.040QrSpU)	Changes to the model applied at Weirs Millstream. No adverse gradient in the updated model results at this location. Impact on upstream water levels was relatively small (0.016m increase).  

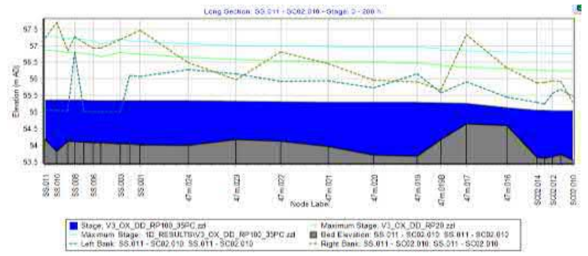
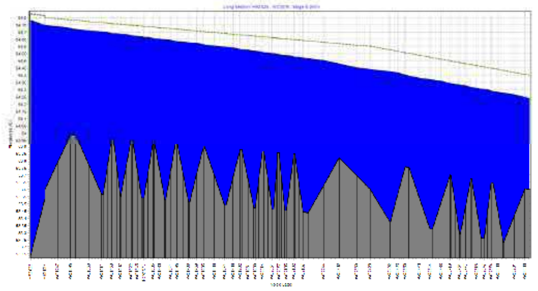
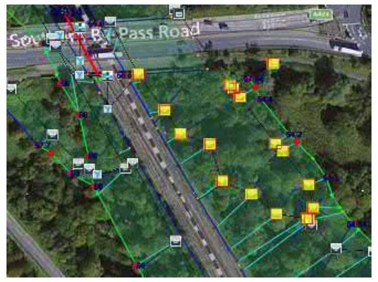
			CH2M identified: Correction to cross section K001 and update of areas used in Bernoulli unit which represents the bend before the bridge.	Changes to the model applied as described. 
1.6	Suitability of the 2D schematisation, including grid resolution, grid orientation, inclusion of features affecting flow routes.	Grid resolution and orientation have not changed since the last model review. The grid resolution follows general practise for a model of this size. The orientation axis aid representation of many of the rivers flowing in a SSE direction. In the previous review it was suggested to consider refining or carry out a sensitivity test with finer grid, to which the response was: 'Smaller grid size was considered but considered prohibitive given the model size. Sensitivity test set up for 5m grid, however model crashes during the simulation.' Perhaps CH2M could test the latest model at a finer grid as it is slightly more stable than earlier versions? With regard to representation of flowpaths, two comments from previous review were addressed, HX line along Thames was loweredand a z-line was added to allow flow under A34 at the highlighted location (figure below). Other comments suggesting adding zshp at three ditches were not considered as it was suggested in the response that model representation is adequate given depth of flooding at these locations. Additional lake\pond was added to the shapefile defining the assumed bed levels in lakes (figure on the right). No other changes to flowpaths in comparison to the previously reviewed version of the model. No survey or 'design model' data was provided to check the new Network Rail raised embankment.  		No updates needed
				No updates needed
		Behaviour of 2d_zsh_Hinksey_Ditch requires checking as it appears to produce irregular geometry (figures below, east of South Hinksey). Similar irregularities are noted for 2d_zsh_rivers_Oxford_CH2M_E where non-uniform depth patterns are shown in the results. CH2M should check that the results are robust in these locations where zsh have been used, or test alternative options (e.g. wider zline). On the latter example, Ch2M should also check/justify their approach to allowing water to re-enter the main river at the end of the 2D ditch (near Sandford).   		No changes made to model. Whilst impacts likely to be small, the main report should provide further explanation on approach/assumptions and/or tests to confirm that the model is working as intended.
1.7	Suitability of linkage between 1D and 2D domains	Focus was put mainly on reaches with the new channel survey data. HX link type used to link river channel (1D) and floodplain 2D domain with loss coefficient 0.5 applied to all HX links (update based on comments from previous review), including new cross-sections. A smaller number of SX connections were also used, where 1D spills or structures are used to define the flow provided to the 2D domain.		No updates needed.

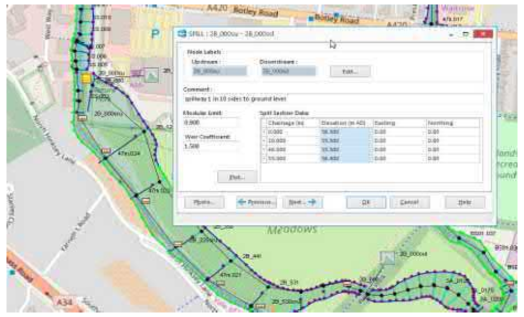
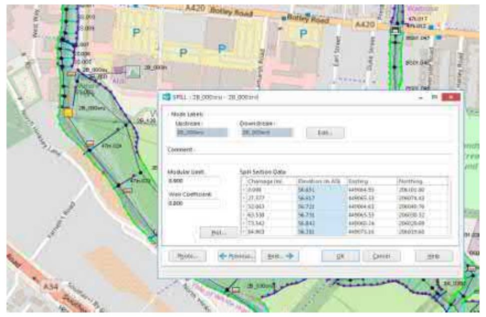
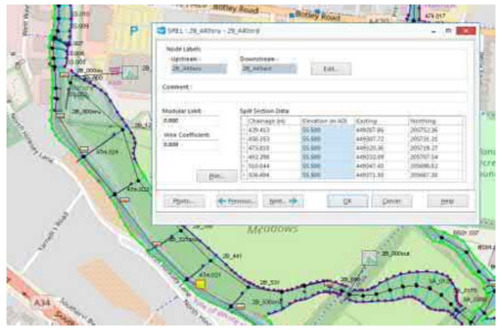
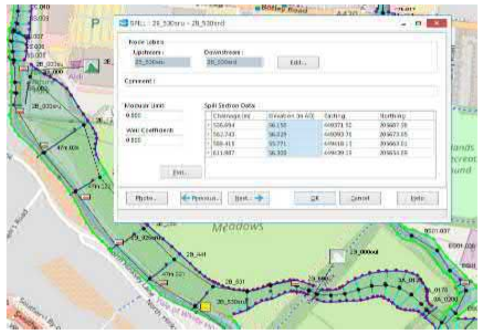
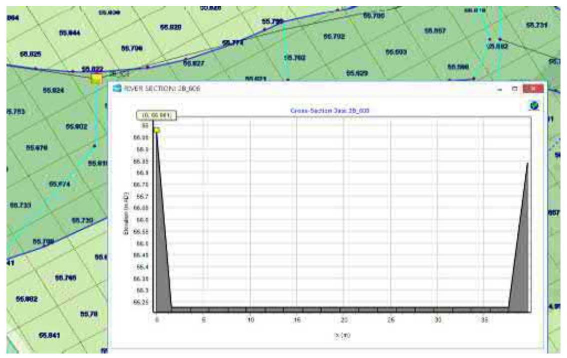
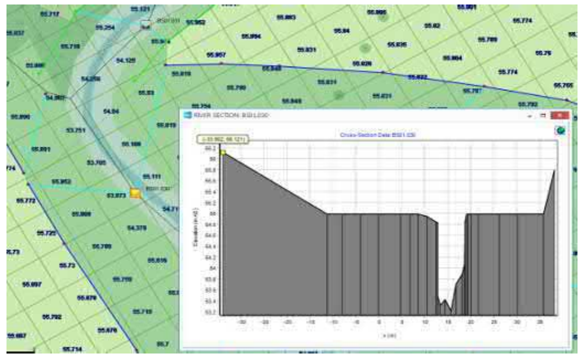
		Overall the null cells within river channels match well the width of the 1D cross-sections. There are a few cross-sections that seem not to be deactivated in the 1D model. See below.    	Cross sections trimmed to 2D boundary at nodes hin3b6 and hin3b6a. Clipping of sections introduced oscillations in flow/level when the small pond on the right bank (modelled in 2D) reached the same water level as the 1D section. To removed oscillations, pond removed from 2D and modelled as 1D cross sections (Ken_pond1/2/3/4). Banks connection between pond and channels represented as spills with low coefficient for stability (0.3).	Changes to the model applied as described. No significant change in surrounding model results shown below (original results on the left, updated results on the right).  
		A low point on HX just upstream of Botley Road was found, which should ideally be set back onto slightly higher ground as it is forming a flow concentration.  	Low point along HX line removed. Change to 2D bank z line	Change to the model as described. 
		There is a single SX point close to the HD07.005 HTBDY with no SX line. It is not clear what connection it represents, therefore CH2M should check this location and/or more details should be provided. 		No changes to the model. The approach/assumptions should be clarified in main report.
1.8	Suitability of linkage between 2D domains/nested grid	No nested grids, there is only one 2D domain.		No updates needed.
1.9	Suitability of the model to represent floods (All AEPs). Any glass-walling must be identified together with areas where a 20% increase in flows would generate glass walling / instability.	Note the largest event with results that we were provided is the 100+35% (which is fractionally larger than the 1000y event), and although a 100y+70% IED has been created we have not been provided with these results. The 100y+35% does not glass wall at 2D model boundaries. However, as noted in 1.5, some sections of Hinksey Stream have not been extended to the railway line and therefore glass wall in 1D. CH2M to confirm whether the model may be used for higher scenarios, and if so model modifications may be required. 		No model results provided for events higher than the 100y+35%. No further checks by RHDHV.
1.10	Suitability of the downstream boundary condition(s).	As discussed in 2015 review, the downstream boundary is a NCBDY. A QHBDY from downstream model results may have been a preferable alternative, although calibration results appeared reasonable at Sandford tail. Sensitivity testing in 2016 showed that water levels upstream of Sandford are not very sensitive to changes at the downstream boundary.		No updates needed.
1.11	Suitability of the tidal/coastal boundary condition(s).	NOT REQUIRED		

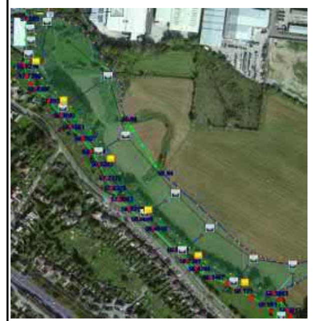
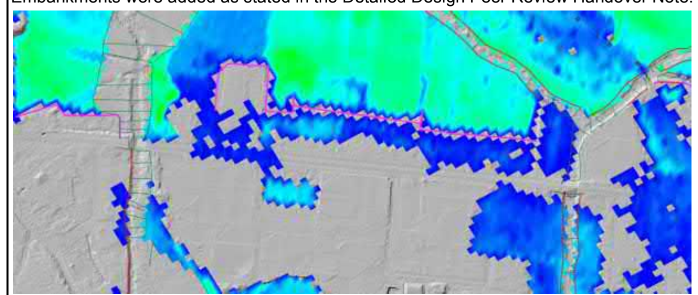
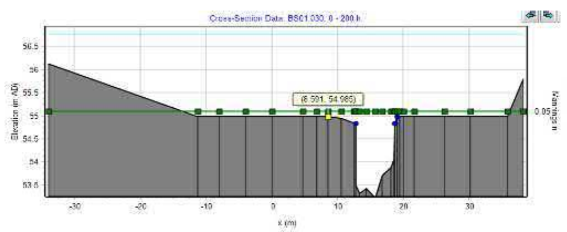
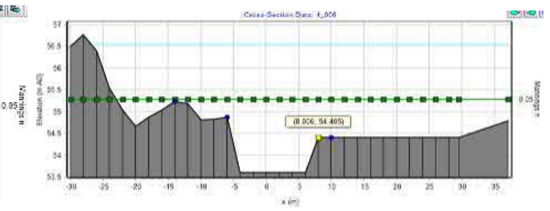
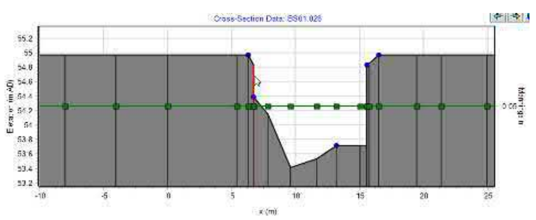
1.12	Suitability of roughness parameters, spill and structure coefficients.	1D roughness: As discussed in previous review, there is a wide range of roughness values distributed across the 1D model, with the Thames generally 0.036-0.042, and the side streams 0.035-0.08. Some of these values may be a product of earlier history of the model, whilst others were set by CH2M during calibration, possibly influenced by limitations in geometrical information. The model calibration was previously demonstrated as a good overall calibration. Whilst some of these roughness values appear toward the upper end of their expected range, the same roughness values have been applied to both baseline and scheme design. 2D roughness: The roughness layers and values applied to the model have remained the same as the 2015 model (0.035 for roads, varying up to 0.085 fo trees and 1.0 for buildings), plus the addition of two small areas of new rail roughness patches (0.055) under Abingdon Road and the A423. There are also some small areas with stability patches (0.10) 1D structure coefficients: Are generally within anticipated range, with values for in-line spills as low as 0.5 (presumably spills partially obscured by buildings or heavy vegetation), up to 1.7. A few spills on the Cherwell have a coefficient of 0.25 which is acceptable as these spills are lateral spills between two 1D channels. Velocity coefficients on the main Thames sluice gates (for weir and gate flow) have been set at between 0.6 and 1 which has presumably been informed by calibration against observed head losses, and the range appears reasonable. 2D structures: There are a small number of ESTRY flood relief culverts in the floodplain, namely layers 1d_nwk_estry_CH2M_willow.shp (circular, roughness 0.03) and 1d_nwk_estry_TJ00553_devils.shp (rectangular, roughness 0.08, which seems high for a culvert).		No updates needed.
1.15	Changes on the ground are not represented in the model (e.g. defence raising).	Z-line was added to represent Network Rail track raising however no as-built survey (or other) data was provided to check the elevations of the raised track. 		No updates needed.
1.16	Defences for removal in the without defences model.	No undefended version of the model provided for review.		
1.18	Locations at greatest risk of siltation/erosion (through consultation with AP team) and current model representation.	NOT REQUIRED		
1.19	Locations sensitive to culvert/bridge blockage.	NOT REQUIRED		
1.20	Review and comment on the suitability of the location of the 1D bank markers on all 1D cross sections within the model.	Panel markers for the newly added cross sections are generally adequate to provide smooth conveyance tables. Some locations could benefit from additional panel markers such as SS.008, WMS.019/023), and a fix of panel marker/roughness change position for HKS.059, although these are unlikely to have a significant impact on study outcomes. Similarly, it is also preferable to avoid panel markers at the base of a steep channel side as in SS.011, SS.007, HKS.067b (it may seem that vegetation on the banks should receive higher roughness, but a panel marker at the base of a bank introduces a frictionless panel divide which removes the effect of bank friction from the main channel's friction equation, which effectively reduces overall friction losses and defeating the object).		
				Panel markers moved and slight modification to the cross section SS.008 (see item 1.14). No other changes made. 
				
MODEL CALIBRATION, VERIFICATION AND SENSITIVITY TESTING				
1.13	Calibration and fit with flood history, including commenton tolerance thresholds (150mm at most).	A calibration update has not been run or provided for the 2017 review. Calibration was reviewed in 2015 and the reader is therefore referred to the CH2M calibration report and 2015 review. The 2017 CH2M model handover note makes reference to likely minor improvements in calibration at Minns Estate (Seacourt Stream) and Cold Harbour (Hinksey Stream) due to telemetry datum surveys carried out since the 2015 calibration exercise.		No update needed.
MODEL ACCURACY AND STABILITY				

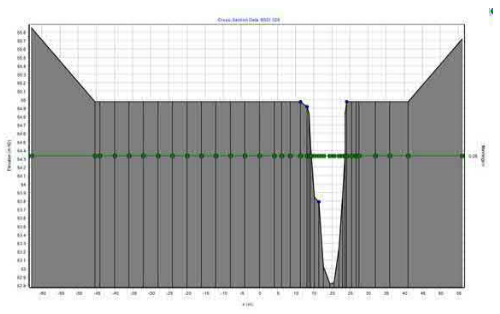
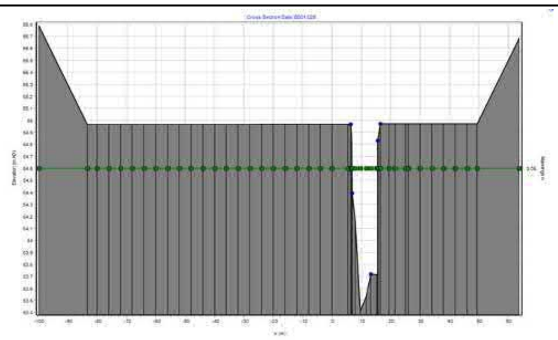
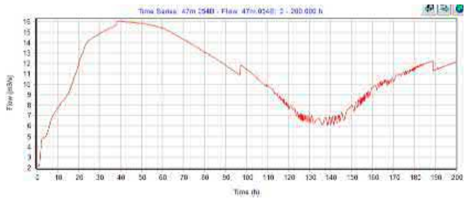
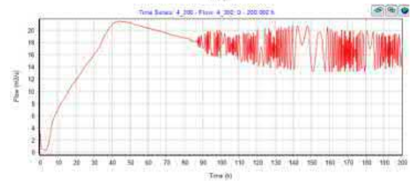
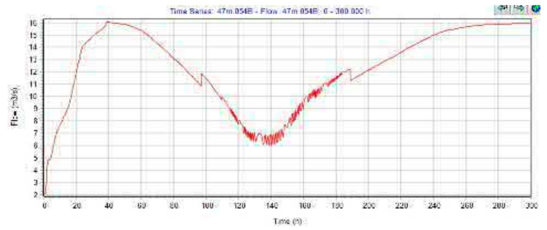
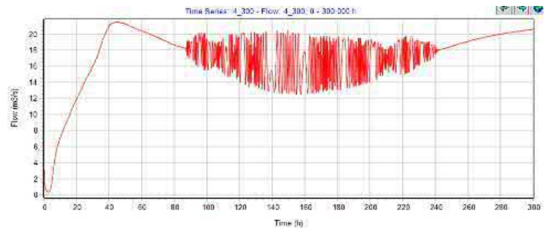
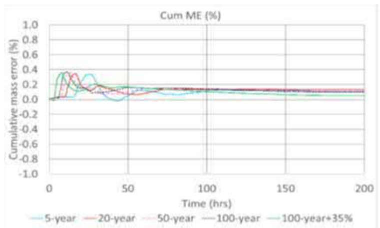
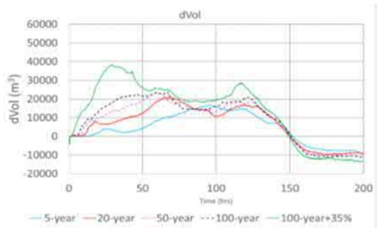
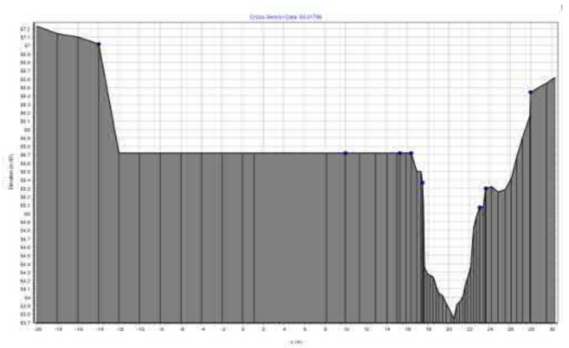
1.14	Numerical convergence, including mass balance and suitability of run parameters and acceptability of current run-times.	1D run parameters: Timestep 1.5s is half that of the 2D domain, which is correct. DFlood=10m (acceptable for linked model), minitr=3, maxitr=19, matrixdummy=0.00001 all acceptable. Both 1D and 2D models use double precision. Htol is on default, although setting Htol tighter than Qtol can aid model stability and reduce oscillations (because the stage is calculated more precisely before flow becomes unstable). 1D stability: The 1D stability summary bitmaps are shown in the CH2M report, and appear at face value to show good convergence. The non-convergence in the 100y+35% at 98 hours at 197 hours are both associated with water levels at the top of abutments at bridge SS.008bu and is relatively minor (the abutments probably don't reflect typical reach geometry so this issue could possibly be fixed with very minor modifications to abutment geometry). However, there are also some oscillations in the results, for example at the A34 underpass (47m.053B) and on Hinksey Stream downstream of Abingdon Road (e.g. node hin3B6a, notably for the 100y+35% but also some on the 100y event as shown below). Whilst the amplitude of the oscillations is relatively minor on the scale of the scheme, it may be possible to reduce these fluctuations by tightening HTol (due to short timestep and high volumes exchange between 1D and 2D domains), and introducing an interpolate downstream of this node. 	Cross Sections and Bridge/spill at SS.008 modified to remove localised change in section for abutment	Changes to model as described. Instability at SS.008 has been resolved. A34 underpass (47m.053B) unchanged, hence still minor oscillations as previous version. The oscillations on Hinksey Stream (hin3B5u/hin3B6a) have been resolved. 
		2D run parameters: As reported in the CH2M handover note and model files, the 2D grid size is 10m, with a 3 second 2D timestep (one third of cell size which is within suitable range). 2D stability: The CH2M model handover note includes Cum Mass Error (%) and dVol charts (reproduced here), which have been checked against model outputs and these confirm that the 2D model stability is well within target range of 1% Cum ME and smooth dVol.  Figure 10: 2D Cumulative Mass Error and dVol (Do Minimum)		No update needed.
		HX loss coefficient was added to all HX links (including new reaches) and boundary viscosity coefficient was set to 3 in the TUFLOW control files, based on discussions and testing as part of the previous reviews.		No update needed.
Project Specific Requirements				
1.23	Check that the Topography has been incorporated into the modelling correctly	New topographic survey data was interpolated and converted to grid format with grid resolution of 1m, matching resolution of LiDAR DTM. The 2D model geometry file (tgc) was updated to read both geometry files, however the latest topography takes preference over LiDAR DTM where they overlap. Details on the difference between the LiDAR DTM and Topo survey was provided in the Oxford Flood Alleviation Scheme Peer Review Handover Note (October 2017). Suitability of fit between the model and updated topography is provided in Item 1.1 and 1.2.		No update needed.
1.24	Check that any outstanding issues from the review by Capita in June 2016 have been resolved.	Majority of the comments from previous review have been addressed. Couple of comments with regard to flowpath representation were considered but no action taken as CH2M suggested not to have significant impact on model results. CH2M responses provided for all other comments stating that no action is required.		No update needed.
1.25	Check that correct inflows have been used in the models.	Note that hydrology and model inflows were reviewed previously (2015). We have checked that same boundaries (IED's) have been applied in 2017 model. IED's have also been provided for 2017 representing climate change scenarios. The climate change scenarios were not reviewed in 2015/2016. It is interesting to note that the increases to the two main inflows (Thames and Cherwell) have not been simply scaled up using a scaling factor as shown below. The basis for the development of these bespoke inflows should be clarified in the CH2M reporting. Note the largest event with results that we were provided is the 100+35% (which is fractionally larger than the 1000y event), and although a 100y+70% IED has been created we have not been provided with these results. 		Updated report has not been provided therefore this has not been checked. As stated previously, the basis for the development of these bespoke inflows should be clarified in the CH2M reporting.
1.26	Design events to be provided are likely to be 20%, 5%, 1% and 1% plus climate change AEPs	Note that the 100y+35% is the largest event reviewed, which was not reviewed in 2015. In addition, 2% AEP event was provided. Many of the tests and results inspection were based on the 100y+30% as the largest event, with a smaller number of the inspections also covering the lower events.		No update needed.

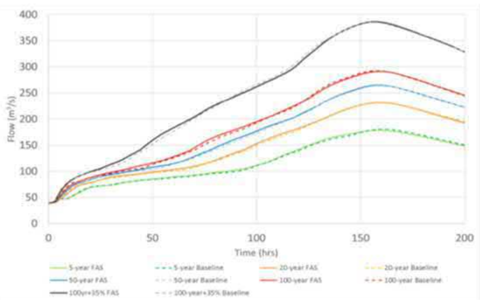
1.27	Comparison of the 2015 Baseline results and 2017 Results	A comparison was carried out for 5%AEP event. Below a difference plot is shown. The increase in max stage corresponds mainly to areas where Network Rail culverts were updated and the railway embankment was raised.  		No update needed in respect of this comparison. However, as a separate sense check, we compared the locations and magnitude of changes between the results issued for the first and second review. The changes were generally small, and correlated with the changes made to the model between the reviews as anticipated. Screenshots of 2D results comparisons below (Blue - decrease, green 0, yellow - increase). 20y differences on left, 100y+35pc on right (as anticipated the changes are more apparent for the smaller event than the larger event where the changed tend to drown out under larger floodplain flows). 1D long sections are not shown as the changes are too small to see in overview without zooming in.  

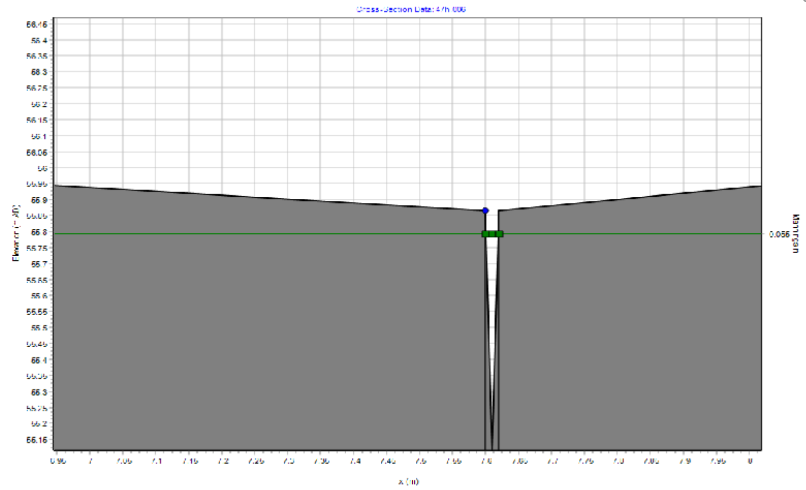
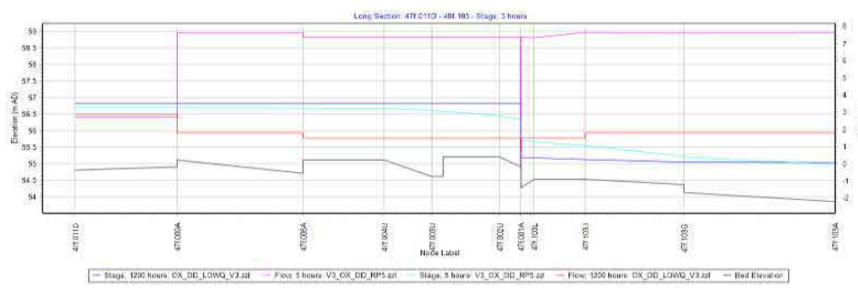
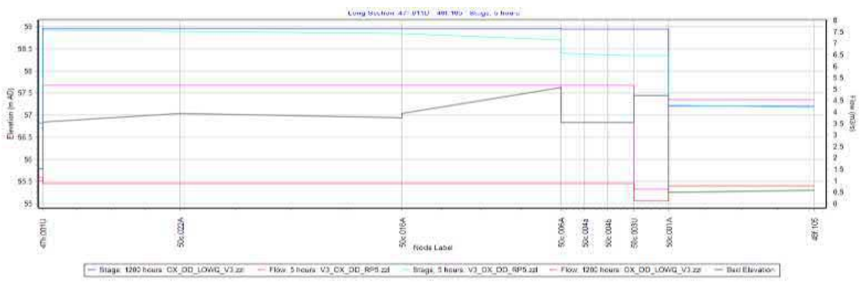
Item No.	Item to Review	Comments	CH2M Model Updates	RHDHV Comments (second review Dec 2017, after CH2M changes)
DETAILED DESIGN MODEL				
MODEL BUILDING				
1.1	Suitability of fit between the model and latest available LiDAR and crest survey.	Reviewed as part of baseline (DM) model review - the same LiDAR DTM and topo survey patch is applied in both the baseline and design models, hence no new comments here. Where necessary for the detailed design model, larger areas of the DTM/s are nulled out and then represented in 1D instead.		No updates needed.
1.2	Suitability of fit between the model and new channel cross-section data.	It is interesting that the bed of 47m.017-016 is significantly higher than surrounding bed levels. This should be checked by CH2M. 		No changes to the model. CH2M have confirmed that this bed elevation pattern is in line with surveys.
		Close spacing has been used between the added cross-sections (WC1199d-WC3018) in the new channel with pools/riffles (with relative path lenghts adjusted for meanders). CH2M should make sure this approach and reasoning is clear in their report. 		No changes to the model. CH2M have indicated that the bed profile is intentional for riffles and pool design, but should nevertheless be stated clearly in report.
1.3	Suitability of fit between the model and the beach profile /coastal defence data.	NOT REQUIRED		
1.4	Representation of structures including any bypassing. Comment on how any operational structures are represented in design mode.	The new channel offtake downstream of Botley Road (node 2B_000su) is represented as a lateral spill unit with coefficient 1.5, which may overestimate the amount of flow entering the channel (depending on angle of approach, shape of profile, material, etc). Sensitivity testing should be used to confirm whether the design is very sensitive to this, and possibly consider localised detailed 2D modelling of the crest (perhaps with TVD if high Froude numbers). As commented under 1.12, the spills between the two channels may also be overestimated spill coefficients. The invert drop at 2B_698 is represented as a spill with coefficient 1.5. Whilst this may be acceptable, the details/description of the structure, and justification for selection of coefficient, should be provided in the CH2M report. The new channel inverts at Willow Walk (nodes 3A_0255d - 0255) are somewhat higher than surrounding. It would be useful if the CH2M report included long sections of the reaches of new channels, with comments on transitions where applicable. Similarly, the invert drop at node WC740 should be described in the CH2M report.	Coefficient for spillway (2B_000su) reduced to 1.0 (was 1.5) and bank spills (2B_000sru and 2B_530sru) chainage checked and coefficient reduced to 0.5 (was 0.8).	Changes made as described on left by CH2M. Further discussion on remaining structures should still be added to the main CH2M report.
1.5	Schematisation of the 1D floodplain, suitability of extended cross-section, reservoir units. Suitability of cross-section spacing (use of interpolates), orientation of cross-sections, any intersecting cross-sections.	Where necessary for the specifying the new channel for the detailed design model, larger areas of the DTM/s are nulled out and then represented in 1D instead, with extended sections. Section spacing is acceptable. For reaches where the low flow channel is designed to meander, relative path lengths have been assigned. Most sense checks on schematisation, intersections and results appeared reasonable. However, some parallel reaches do not have allowance for lateral spills between them such as at Redbridge shown below. 		No changes made. Whilst the influence of the missing spills is likely to be small, this assertion should be made by CH2M in their report to justify not implementing this change.
		Spillway to Willow Walk. Not all cross-sections have lateral spill between the reaches. It should be ensured that total length of the spill matches the length of the channel between reaches SS_005 and SS_001, in addition to justification of spill coefficients. 		Number of lateral spills have not changed, however the spill unit 2B_000sru has been modified to match the reach length between sections SS.003 and SS.001. Discussion on spill coefficients should be provided by CH2M in their report.

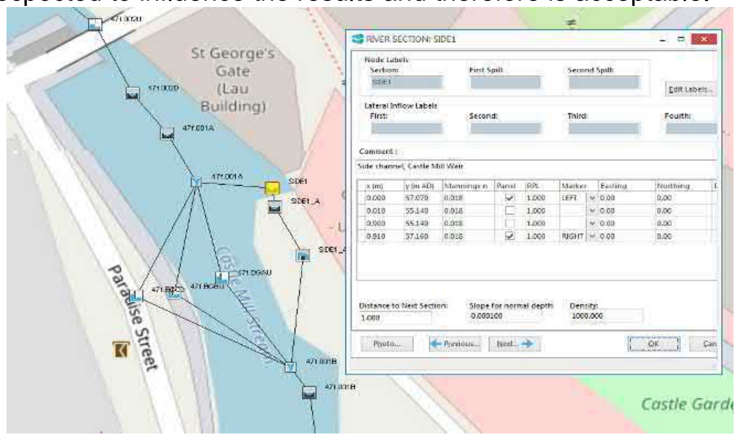
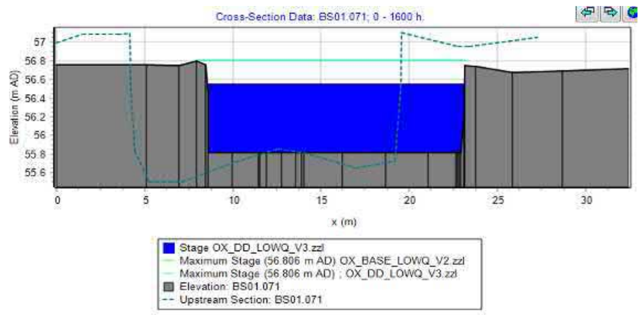
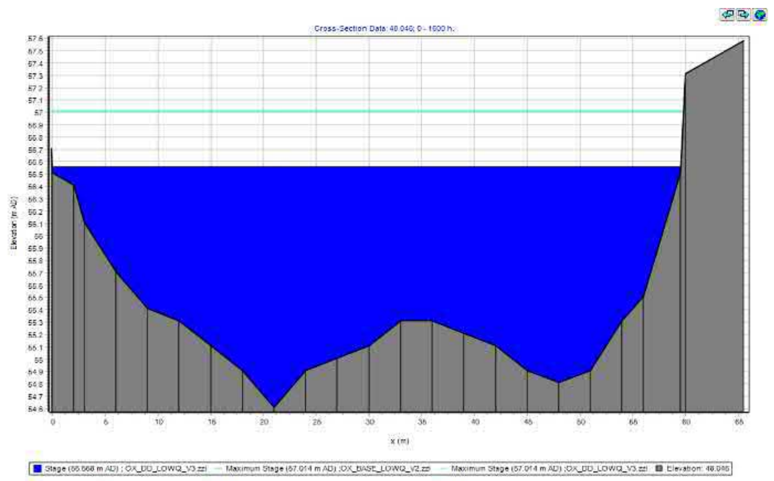
		The elevations of the spills here are not consistent. More details should be provided on areas where existing ground was retained or adjusted.  		Spill units have been updated. No report has been provided therefore no more details available. CH2M should ensure that clear details are provided in the main report and in drawings for construction.
		 		See above.
1.6	Suitability of the 2D schematisation, including grid resolution, grid orientation, inclusion of features affecting flow routes.	Comments on the baseline model also apply here. 2D resolution generally suitable for representing the scale of features in the scheme given current model computation time. Area 4a the track removal ought to be clearly stated in the CH2M report.		No update needed.
1.7	Suitability of linkage between 1D and 2D domains	The linkage between 1D and 2D for the new channel is not forced to manual z elevations, rather the elevations for the interchange are picked up from the computation zpoint grid (which in turn is based on LiDAR). Loss coefficient of 0.5 is still applied on the HX lines, which is considered acceptable.		No update needed.
		Only minor discrepancies found between the width of the cross-sections in 1D model and the width of nulled areas in 2D domain. Here focus was on the new channels introduced in the detailed design. More highlighted in the Baseline model review. 		No update needed.
		There are number of locations where the model grid elevations in 2D domain do not all correspond to the top of banks in the 1D model. See couple examples below where they are lower in the areas where the link between 1D and 2D for the new channel is not forced to manual z elevations. This was raised in the previous outline design model review.  		No update needed. Considered to have insignificant impact on model results.
		As highlighted in the baseline model review, there is a single SX point close to the HD07.005 HTBDY with no SX lines. It is not clear what connection it should represent, more details should be provided. 		No report has been provided therefore no more details available. The approach/assumptions should be clarified in the main CH2M report.
1.8	Suitability of linkage between 2D domains/nested grid	No nested grids, there is only one 2D domain.		No update needed.

1.9	Suitability of the model to represent floods (All AEPs). Any glass-walling must be identified together with areas where a 20% increase in flows would generate glass walling / instability.	Note the largest event with results that we were provided is the 100+35% (which is fractionally larger than the 1000y event), and although a 100y+70% IED has been created we have not been provided with these results. The 100y+35% does not glass wall at 2D model boundaries. However, as noted in 1.5, some sections of Hinksey Stream have not been extended to the railway line and therefore glass wall in 1D. CH2M to confirm whether the model may be used for higher scenarios, and if so model modifications may be required.		No update needed.
1.10	Suitability of the downstream boundary condition(s).	No change from baseline DM model.		No update needed.
1.11	Suitability of the tidal/coastal boundary condition(s).	NOT REQUIRED		
1.12	Suitability of roughness parameters, spill and structure coefficients.	1D roughness: Upstream of Botley Road (node SS-01799 to SS-01517), widened floodplains are assigned Mannings n=0.05, whilst the channel is still 0.08. Downstream of this, the new channel roughness is generally 0.05, apart from a few residual values of 0.06 on the floodplains, and values of 0.04 near the end of the model datafile (Ab_culu to A423_R264, which are near Redbridge. Culverts typically 0.04 or 0.05 on the invert, with 0.015 or 0.020 on the walls and soffits. The justification of the chosen roughness values ought to be provided in the CH2M report. 2D roughness: The roughness layers and values applied to the model remain the same as the baseline model (0.035 for roads, varying up to 0.085 for trees and 1.0 for buildings), plus changes (two minor additions) of stability roughness patches (0.1). 1D structure coefficients: As per baseline for most of model as expected. For new channel, the proposed check weirs have spill coefficients varying between 1.2 and 1.7 - the locations, weir profile descriptions, and justifications for these coefficients should be included in CH2M report. Lateral spills out of Seacourt Stream downstream of Botley Road (shown below) have coefficients of 0.8 which is probably too high for lateral spills over flat ground. 2D structures: As per baseline DM model, except that two of the ESTRY flood relief culverts from 1d_nwk_estry_TJ00553_devils are removed in the FAS version, presumably due to the embankment for the new bridge although this should be clearly stated in the CH2M report. 		Spill coefficients have been updated to 0.5. Comment remains on need for clarity of CH2M report on the removal of the culverts.
1.15	Changes on the ground are not represented in the model (e.g. defence raising).	Note a number of the defences in Botley have been set at 100m to preclude all flooding, whilst the final design height will be deduced from the largest modelled event (with relevant freeboard).		No update needed.
		Embankments were added as stated in the Detailed Design Peer Review Handover Note. Example of embankment u/s Botley Road. 		No update needed.
1.16	Defences for removal in the without defences model.	No undefended version of the model provided for review.		No update needed.
1.18	Locations at greatest risk of siltation/erosion (through consultation with AP team) and current model representation.	NOT REQUIRED		
1.19	Locations sensitive to culvert/bridge blockage.	NOT REQUIRED		
1.20	Review and comment on the suitability of the location of the 1D bank markers on all 1D cross sections within the model.	Panel markers generally acceptable for most sections of the new channel, although some minor improvements could aid stability in locations shown.  		No changes to the model.
		As mentioned in the baseline review, panel markers should ideally be avoided at the base of steep slopes.  		No changes to the model.

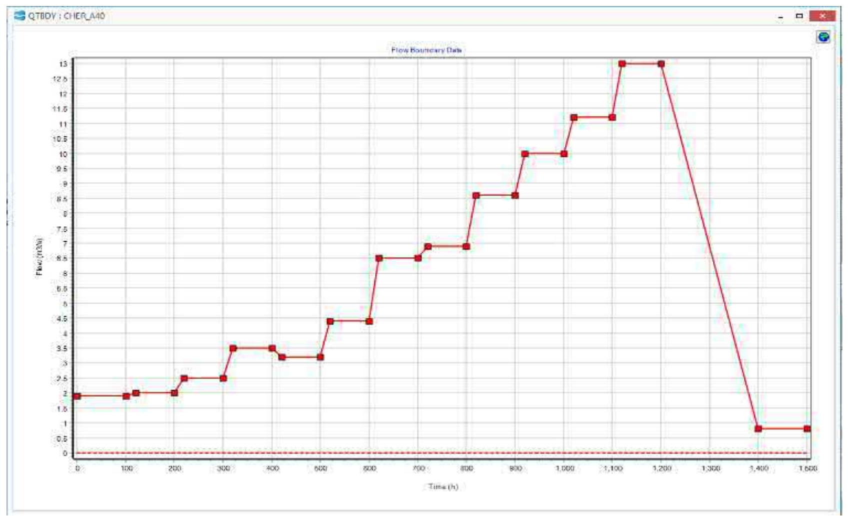
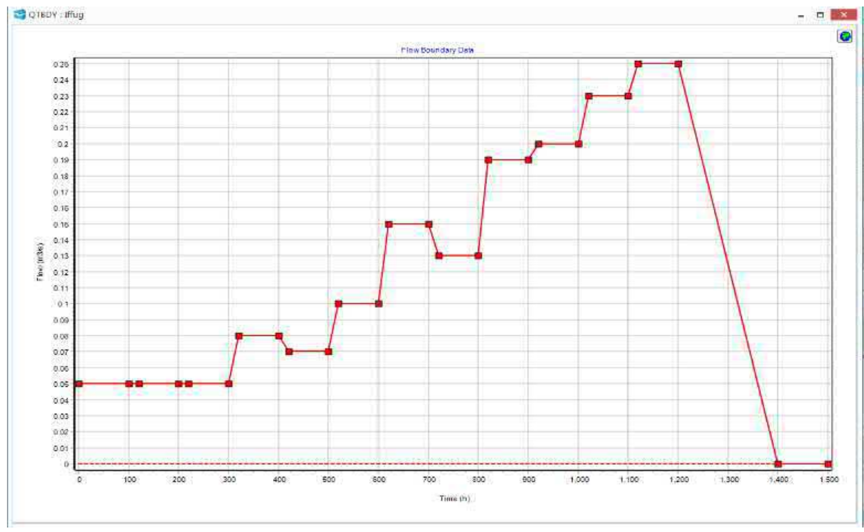
		 		No changes to the model.
MODEL CALIBRATION, VERIFICATION AND SENSITIVITY TESTING				
1.13	Calibration and fit with flood history, including commenton tolerance thresholds (150mm at most).	Calibration assessed as part of baseline model, not applicable for design model.		No update needed.
MODEL ACCURACY AND STABILITY				
1.14	Numerical convergence, including mass balance and suitability of run parameters and acceptability of current run-times.	1D run parameters same as baseline, therefore similar general comments apply here. 1D stability: The 1D stability summary bitmaps are shown in the CH2M report, and appear at face value to show good convergence although slightly poorer convergence than baseline. The non-convergence in the 100y+35% at 111 hours at 173 hours are both associated with bridge SS-01391 making a rapid transition to orifice mode when the water level reaches the soffit. This transition could be softened by giving a small range for the transition. The oscillations in the results at the A34 underpass (47m.053B) for the 100y+35% are smaller than in the baseline. Whilst the amplitude of the oscillations is relatively minor on the scale of the scheme, it may be possible to reduce these fluctuations by tightening HTol (due to short timestep and high volumes exchange between 1D and 2D domains), and by introducing an interpolate downstream of this node. There are significant oscillations in the new channel near Redbridge, in the reach containing node 4_300. It may be possible to reduce these fluctuations by tightening HTol (due to short timestep and high volumes exchange between 1D and 2D domains.   		No specific changes to the model, other than the cumulative effect of all other changes. Stability/oscillations similar to previous.  
		2D run parameters: same as baseline, which is acceptable. 2D stability: The CH2M model handover note includes Cum Mass Error (%) and dVol charts (reproduced here), which have been checked against model outputs and these confirm that the 2D model stability is well within target range of 1% Cum ME and smooth dVol.  		No update needed. Similar to previous results.
Project Specific Requirements				
1.23	Check that the Topography has been incorporated into the modelling correctly	Review focused on the added new cross-sections and structures for the FAS. Overall good match with the description in the model handover note and provided drawings for new bridges.		No update needed.
1.24	Check that any outstanding issues from the review by Capita in June 2016 have been resolved.	Refer to comment 1.20. In some places more panel markers are included than required. 		No update needed.

		Bank lines have been updated at locations identified in previous review.  		No update needed.
		It was pointed out in the previous review that the Hogacre Ditch is partly encompassed within the two-stage channel, but is not explicitly modelled in 1D or 2D. This has not been revised nor more details were provided in the Model Handover note.  		No update needed.
1.25	Check that correct inflows have been used in the models.	Same inflows applied as in the baseline model, so same comments apply.		No update needed.
1.26	Design events to be provided are likely to be 20%, 5%, 1% and 1% plus climate change AEPs	Design events provided as for the Baseline DM Model.		No update needed.
1.27	Downstream impacts	The chart from the CH2M handover note reproduced below shows a slight time advance in the hydrograph, particularly in the 100-200m3/s range of flows. This could slightly exacerbate flooding downstream as the rising limb coincides with tributary inflows from the Ock and Tame. This is due to be tested in more detail by CH2M using the Abingdon model. No further comments at this time.  		No update needed at this time. However, comment still remains that possible effects downstream will require carefull consideration in due course.

LOW FLOW MODEL		
Item No.	**Item to Review**	**Comments (first review only - no second review)**
MODEL BUILDING		
1.1	Suitability of fit between the model and latest available LiDAR and crest survey.	There are only relatively minor changes in geometry from the baseline DM and detailed design DD models to the respective low flow models: removal of 2D domain since flows are in-bank, re-instatement of some deactivated portions of some sections, changes to sluice operating rules, a few bridges removed (low head-loss at low flows), minor changes to section bed geometry and introduction of a few inline spills to maintain water levels during low flows. Therefore the in-bank geometry has already been reviewed under the baseline DM and detailed design DD model reviews.
1.2	Suitability of fit between the model and new channel cross-section data.	As above. Where bed geometry was lowered panel markers were added. There is one cross-section 47h.006 where one panel marker seems to be missing. For best practise and stability of transitions, panel markers should be placed on both sides of the slot. 
1.3	Suitability of fit between the model and the beach profile /coastal defence data.	NOT REQUIRED
1.4	Representation of structures including any bypassing. Comment on how any operational structures are represented in design mode.	Some spill elevations have been increased to maintain water levels. Sluice gates have been shut more tightly than in the flood models (baseline and design), both in datafile and via rule IED units for the main Thames gates. Generally the correlation of flows and water levels is good between low flows in the flood models (for example early the 5-year design run) and the highest (January) low flow run, apart from two locations highlighted in the long section below, namely Oxford Canal / Castle Mill stream and at Wovercote, both of which have significantly reduced sluice gate openings which changes the flow in the reach.  
1.5	Schematisation of the 1D floodplain, suitability of extended cross-section, reservoir units. Suitability of cross-section spacing (use of interpolates), orientation of cross-sections, any intersecting cross-sections.	The 2D domain is de-activated since flows remain in-bank, and a few sections have had their deactivation markers removed to extend the 1D slightly further onto the floodplain.

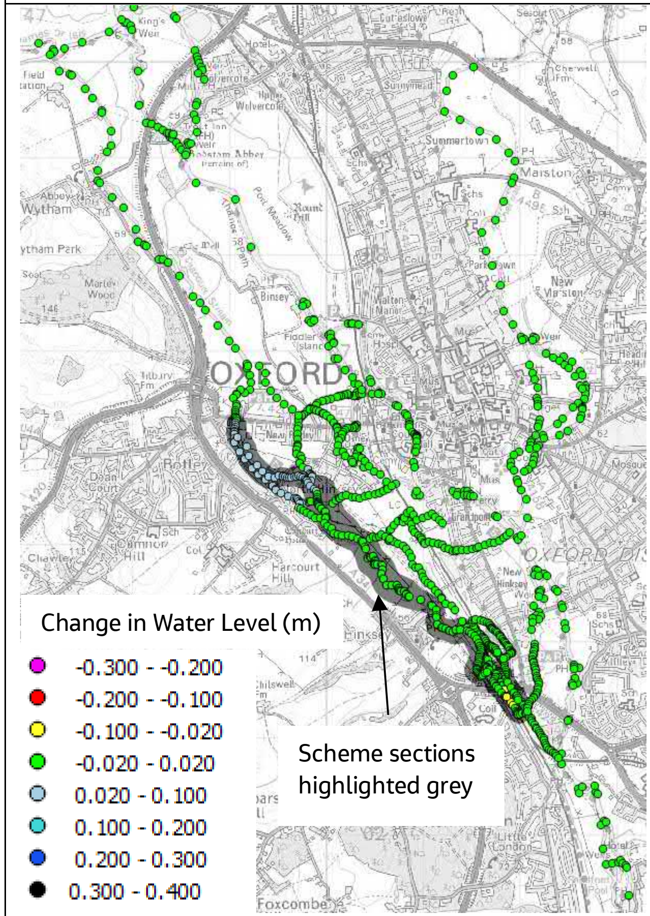
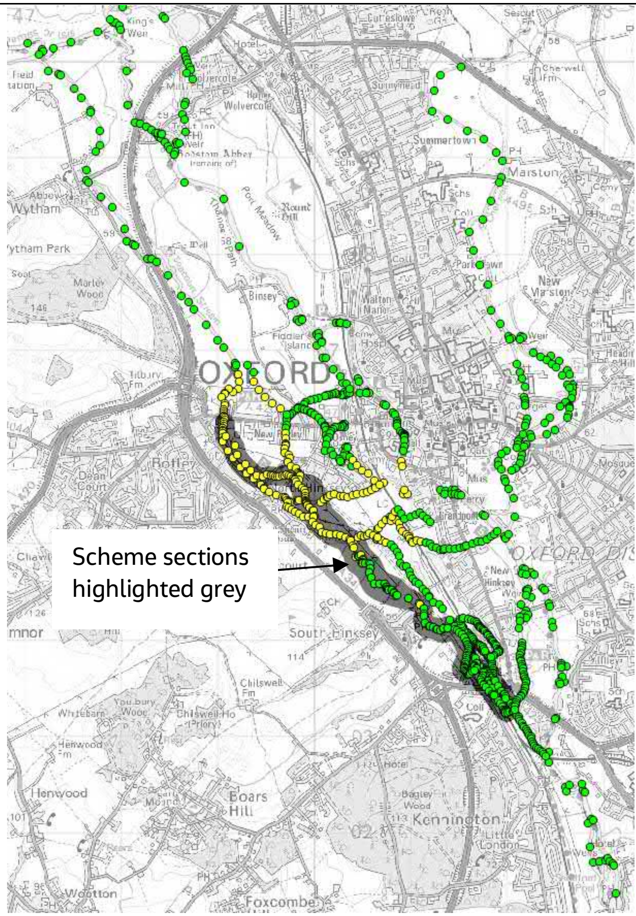
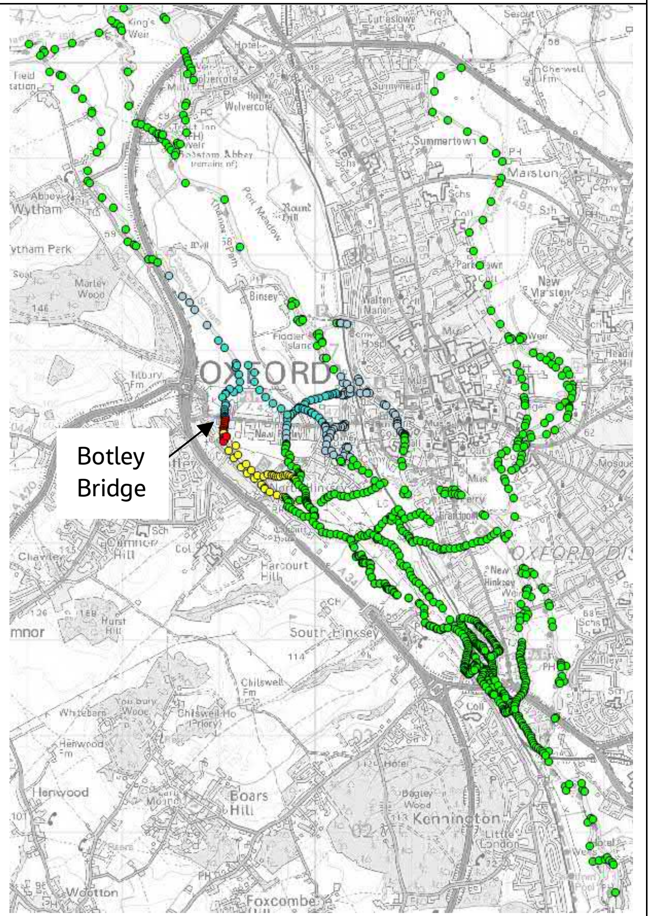
		Side channel at Castle Mill Weir was shortened, with 4 cross-sections downstream of the SIDE1_A weir structure removed (possibly due to stability issues), however the distance to next cross-section was not adjusted in the reach. Although best practise would suggest to udpate distance to next, it is not ecpected to influence the results and therefore is acceptable. 
1.6	Suitability of the 2D schematisation, including grid resolution, grid orientation, inclusion of features affecting flow routes.	No applicable for 1D low flow models.
1.7	Suitability of linkage between 1D and 2D domains	No applicable for 1D low flow models.
1.8	Suitability of linkage between 2D domains/nested grid	No applicable for 1D low flow models.
1.9	Suitability of the model to represent floods (All AEPs). Any glass-walling must be identified together with areas where a 20% increase in flows would generate glass walling / instability.	The only section reported in the diagnostics to exceed its geometry (glass-wall) is BS01.071, which only exceeds very marginally and the banks are significantly lower (even with the de-activation markers removed) compared to the upstream section as shown below. This might be a minor/localised issue. 
		In addition, one other cross section was found to have glass-walling on the left bank, despite not being reported in the zzd. 
1.10	Suitability of the downstream boundary condition(s).	The same normal depth (NCDBDY) is applied as in the flood models, which will not reflect the effect of gates downstream of Sandford (Abingdon). CH2M should make this clear in their report, including affirming that this will not influence any decisions made using the low flow models.
1.11	Suitability of the tidal/coastal boundary condition(s).	NOT REQUIRED
1.12	Suitability of roughness parameters, spill and structure coefficients.	As per baseline DM and detailed design DD models.
1.15	Changes on the ground are not represented in the model (e.g. defence raising).	Not applicable for low flow models.

1.16	Defences for removal in the without defences model.	Not applicable for low flow models.
1.18	Locations at greatest risk of siltation/erosion (through consultation with AP team) and current model representation.	NOT REQUIRED
1.19	Locations sensitive to culvert/bridge blockage.	NOT REQUIRED
1.20	Review and comment on the suitability of the location of the 1D bank markers on all 1D cross sections within the model.	As per baseline DM and detailed design DD models.
MODEL CALIBRATION, VERIFICATION AND SENSITIVITY TESTING		
1.13	Calibration and fit with flood history, including commenton tolerance thresholds (150mm at most).	The low flow splits for the baseline low flow model were validated against spot flow gaugings. This information was not presented or reviewed in this 2017 review.
MODEL ACCURACY AND STABILITY		
1.14	Numerical convergence, including mass balance and suitability of run parameters and acceptability of current run-times.	The low flow models are both stable within the default tolerances (0.01/0.01), apart from minor short duration instability at Sandford hand radials (46.HRU) as they transition through different calculation modes. RHDHV were not supplied with full timeseries to evaluate the magnitude of the mode changes. This behaviour should be stated in CH2M report, including affirmation that the modes (and coefficients) are applicable and will not influence any decisions based on model results.

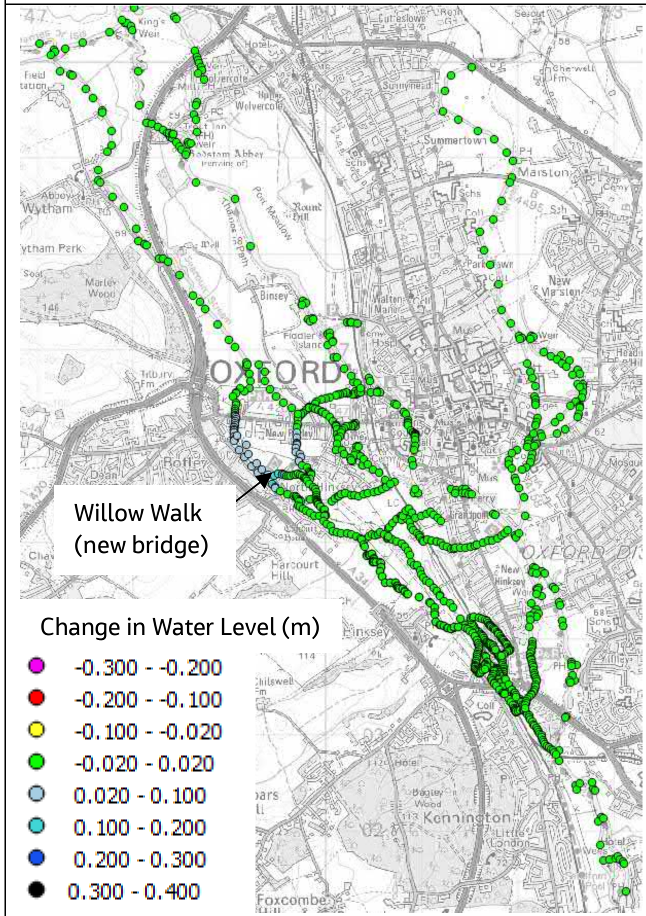
Project Specific Requirements		
1.23	Check that the Topography has been incorporated into the modelling correctly	As per baseline DM and detailed design DD models.
1.24	Check that any outstanding issues from the review by Capita in June 2016 have been resolved.	Only one comment was previously raised with regard to the Q95 model and report. There was no specific comments to model build hence no outstanding actions to address.
1.25	Check that correct inflows have been used in the models.	Q95 and Mean Monthly flows were used as stated in the Model Handover Note. 6 QTBDY boundaries were specified in the IED file, each with monthly flows in order Aug, Sep, Jul, Oct, Jun, May, Apr, Nov, Mar, Dec, Feb, Jan and Q95 flow at the end of simulation. Q95 was only specified for Thames, Evenlode and Cherwell (total flow). Others have zero flow at the end of the simulation. Has the Q95 leaving the model been checked downstream? HD07.023 HTBDY was converted into QTBDY with Q95 flow of 0.05m3/s. It is not mentioned in the note how the Q95 flow was derived for this particular inflow boundary. Same IED file was used for both Base and DD low flow models.  
1.26	Design events to be provided are likely to be 20%, 5%, 1% and 1% plus climate change AEPs	Not applicable. Mean Monthly and Q95 flows used.

SENSITIVITY ANALYSES	
Item to Review	**Comments (first review only - no second review)**
For the sensitivity analyses, CH2M only supplied the Sensitivity Tests report ("Oxford Detailed Design – Model Sensitivity Tests", dated 30 October 2017. Therefore, RHDHV have not reviewed the application of the changes into the models for the sensitivity runs. The following comments are based on the information presented in the above CH2M report. It is worth mention that Appendix B (flood outlines) of the CH2M report appears to have been generated using two opaque colours of red and blue, with semi-transparent mapping. This may mask mixed scenarios where extents increase and decrease within the same map. Therefore, it might be clearer to use semi-transparent red and blue (such that overlapping areas are purple) to allow both increases and decreases to be visible in the same map. The tests performed by CH2M were agreed between CH2M and the Environment Agency.	
Test 1a: 20% increase for 1D channel roughness (scheme sections)	As anticipated, increase in water levels (many points >0.02 in reach below Botley Road, max .05), with a small area near Redbridge decrease in water levels.
Test 1b: 20% decrease for 1D channel roughness (scheme sections)	As anticipated, reduced levels through much of the area of the scheme.
Test 2a: 50% Blockage of Botley Road (Seacourt Stream)	As anticipated, increased levels upstream of Botley Road, decreases downstream (due to water being diverted to other flow routes).
Test 2b: 50% Blockage of the New Willow Walk Bridge	As anticipated, increased levels upstream of Willow Walk.
Test 2c: 50% Blockage of the New Abingdon Road Culverts	As anticipated, increased levels upstream of Abingdon Road, decreases downstream (due to water being diverted to other flow routes).
Test 2d: 50% Blockage of Mundays Bridge	As anticipated, increased levels upstream of Mundays Bridge. No large decreases.
Test 3a: 20% increase for 1D channel roughness (all sections)	As anticipated, predominantly increased water levels, with some reductions near Kings/Wovercote due to water being diverted to other flow routes.
Test 3b: 20% decrease for 1D channel roughness (all sections)	As anticipated, mainly decrease in water levels, with some increases (Kings/Wovercote, and Sandford) due to changes in flow distribution.
Test 4a: 20% increase for 2D roughness	As anticipated, only a few pockets of significant (>0.02m) increases.
Test 4b: 50% increase for 2D roughness	As anticipated, mostly increase in water levels, with some reaches less impacted.
Test 4c: 20% decrease for 2D roughness	As anticipated, mostly decrease in water levels, with some reaches less impacted.
Summary	In general, the global roughness change results in the most change in water levels, followed by the bridge blockage scenarios which have more localised impacts (increases upstream, decreases downstream). The scheme roughness increase by 20% results in an increase of up to 0.05m. In the context of the scheme design this shows the importance of matching Mannings roughness to the anticipated maintained channel states, which should be clearly stated and justified in the CH2M report.
	It was previously demonstrated that changes at the downstream boundary influence levels at Sandford Lock tail, but that upstream of Sandford Lock the water levels are much less sensitive to the downstream boundary.
	Other possible tests to possibly consider: - Changes to weir, sluice or spill coefficients (inline and lateral) as highlighted in the 2017 model review.
	Sensitivity to changes in hydrology are broadly understood (for example increasing inflows would increase water levels), and are reflected to some extent in the climate change runs, which allows the spatial distribution of the increases to be mapped spatially. Also, it is worth noting that the hydrology and model have been well calibrated and reviewed, and the Thames has relatively long records, which all serve to reduce the emphasis on further sensitivity testing the hydrology.

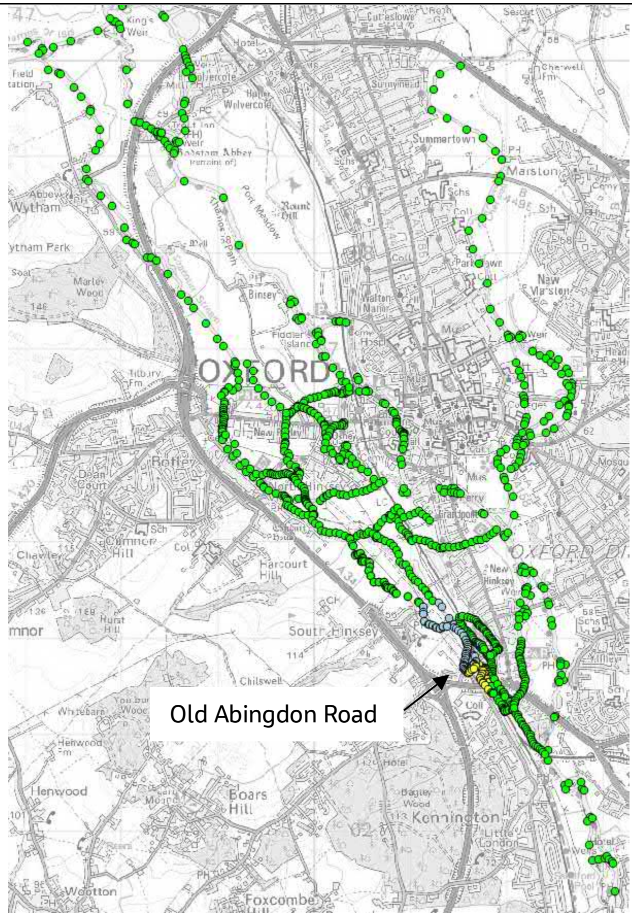
Appendix I. Sensitivity test: changes in water level - 20 year

1a - 20% increase for 1D channel roughness (scheme sections)	1b - 20% decrease for 1D channel roughness (scheme sections)	2a - 50% Blockage of Botley Road (Seacourt Stream)
		

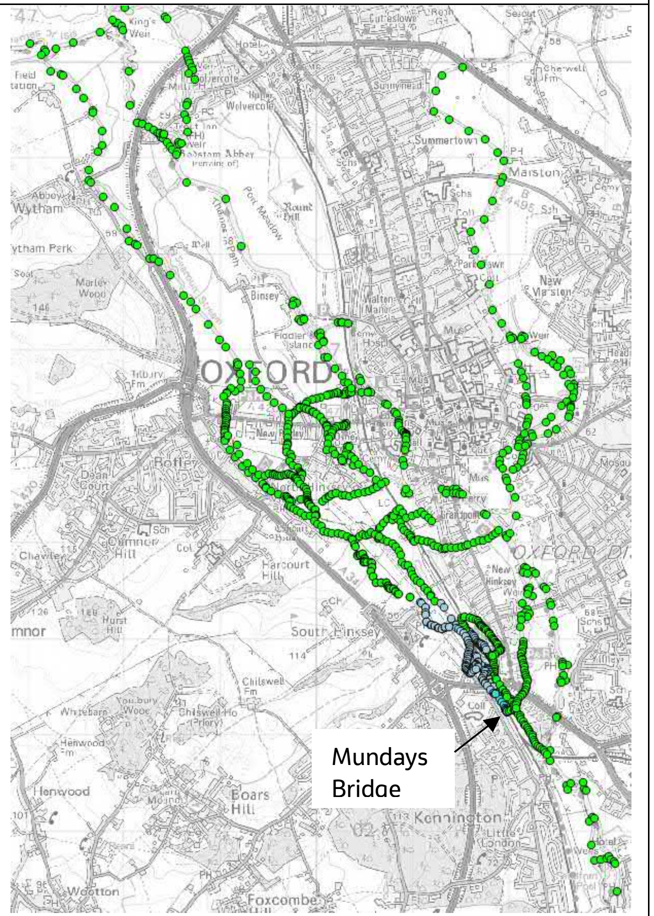
2b - 50% Blockage of the New Willow Walk Bridge



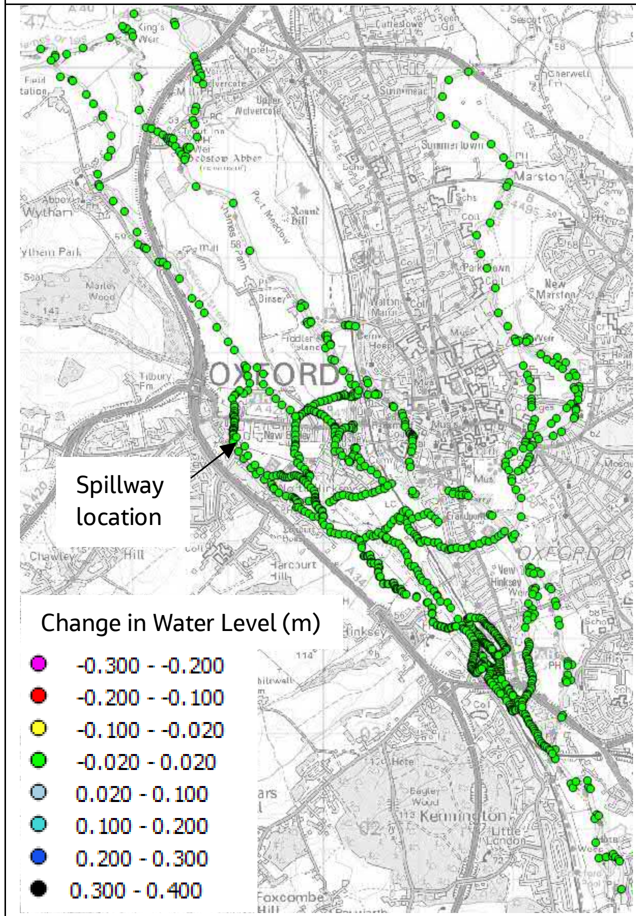
2c - 50% Blockage of the New Abingdon Road Culverts



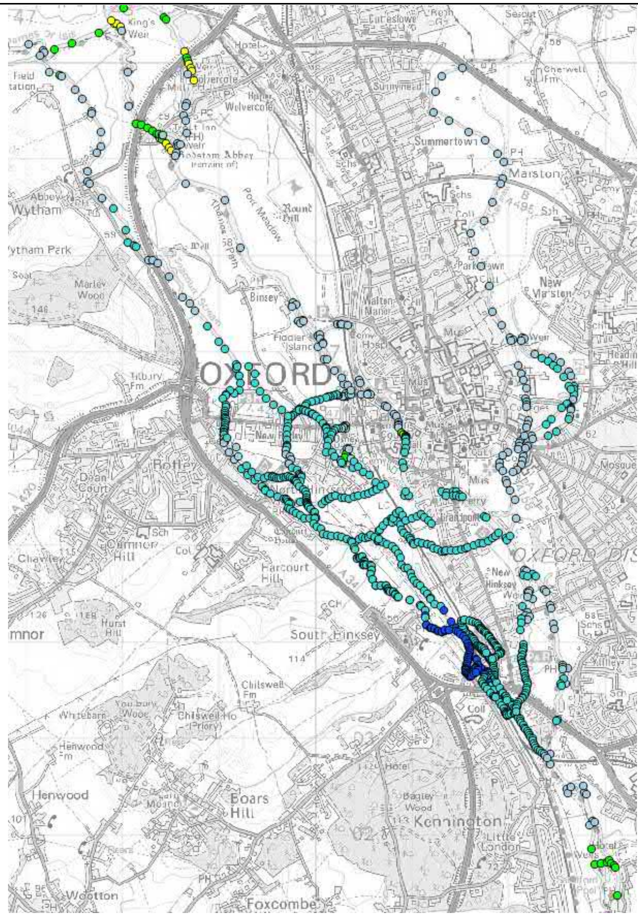
2d - 50% Blockage of Mundays Bridge



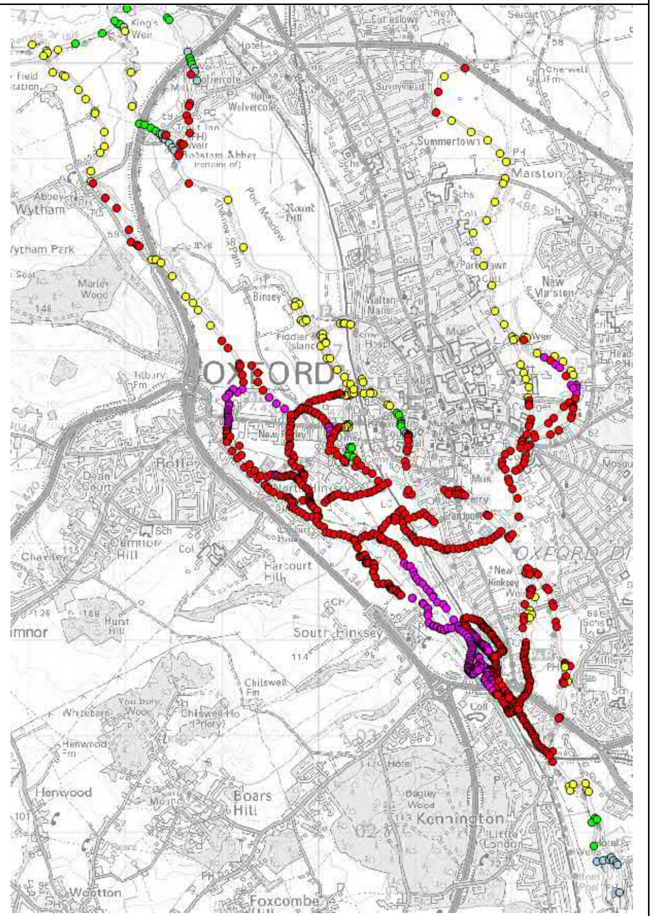
5 – reduced spillway coefficient



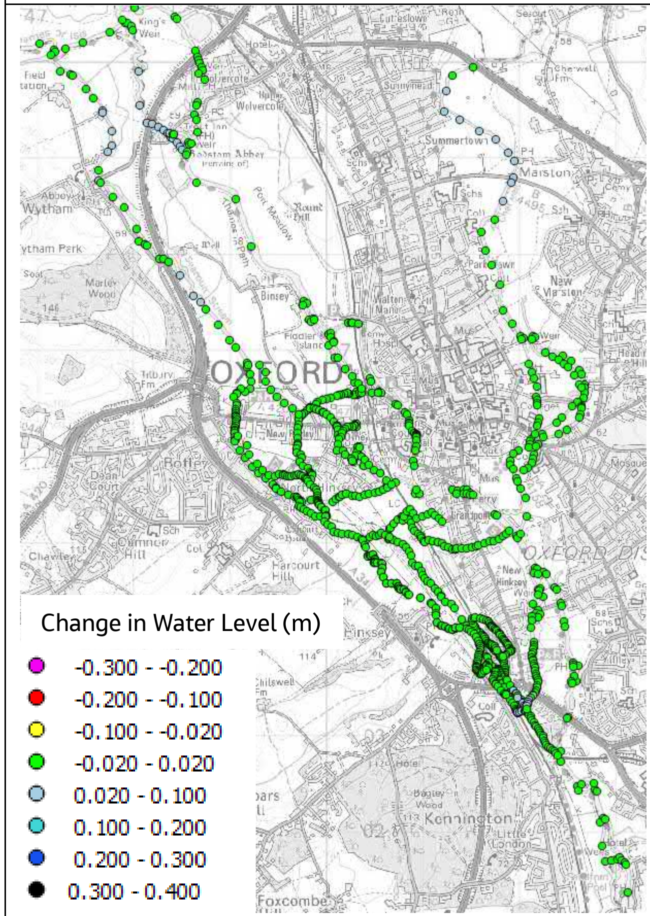
3a - 20% increase for 1D channel roughness (all sections)



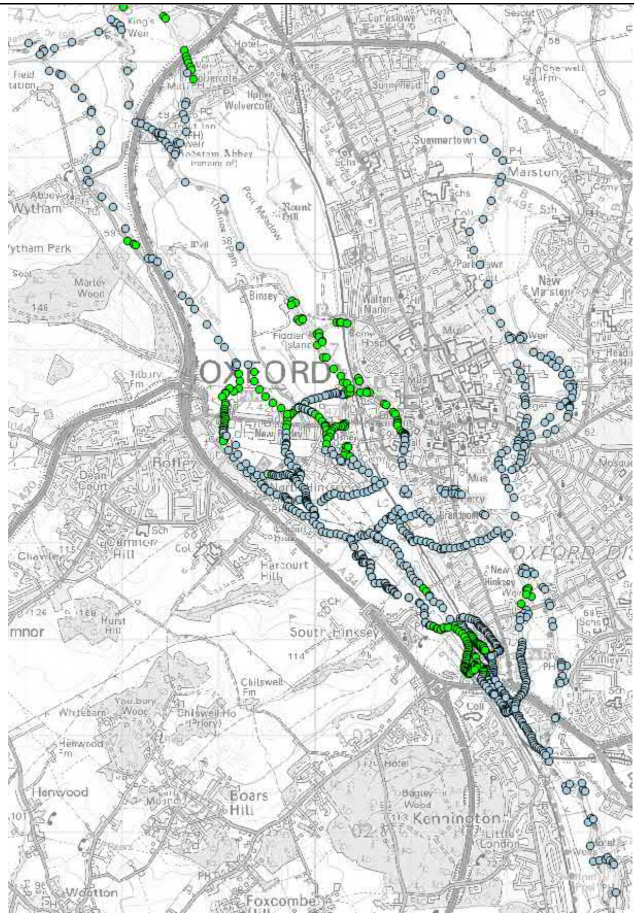
3b - 20% decrease for 1D channel roughness (all sections)



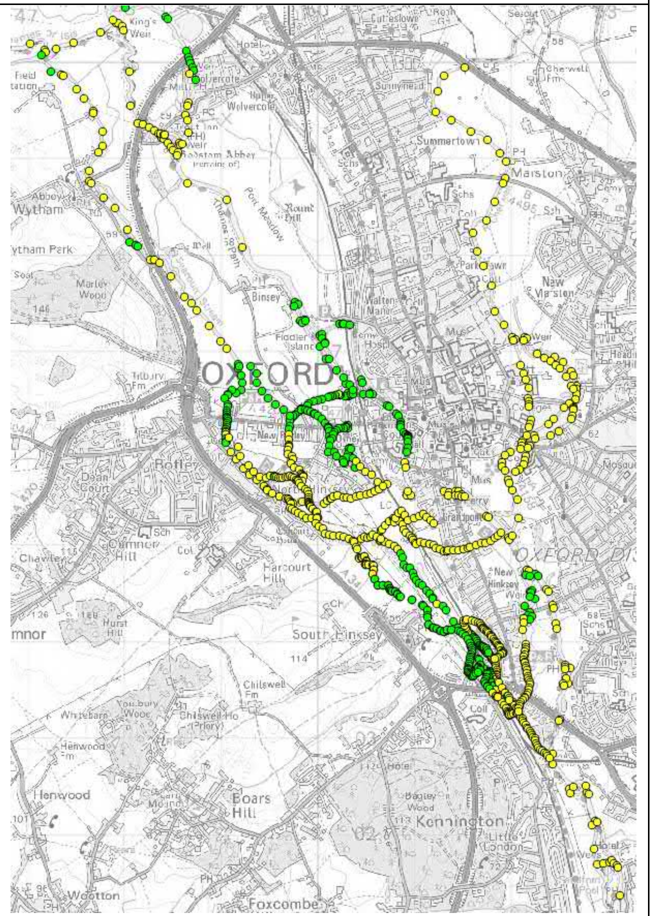
4a - 20% increase for 2D roughness



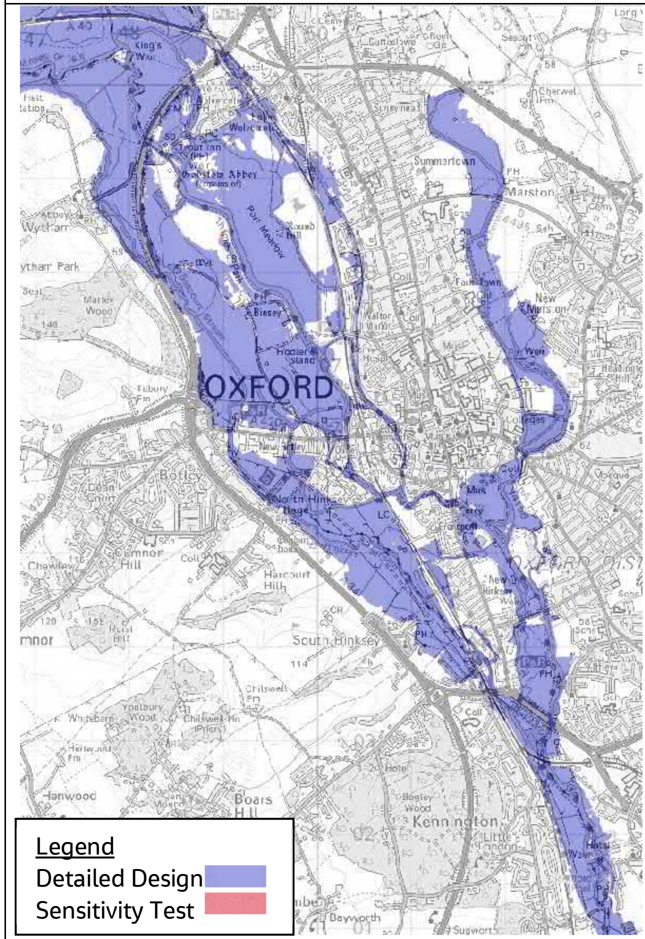
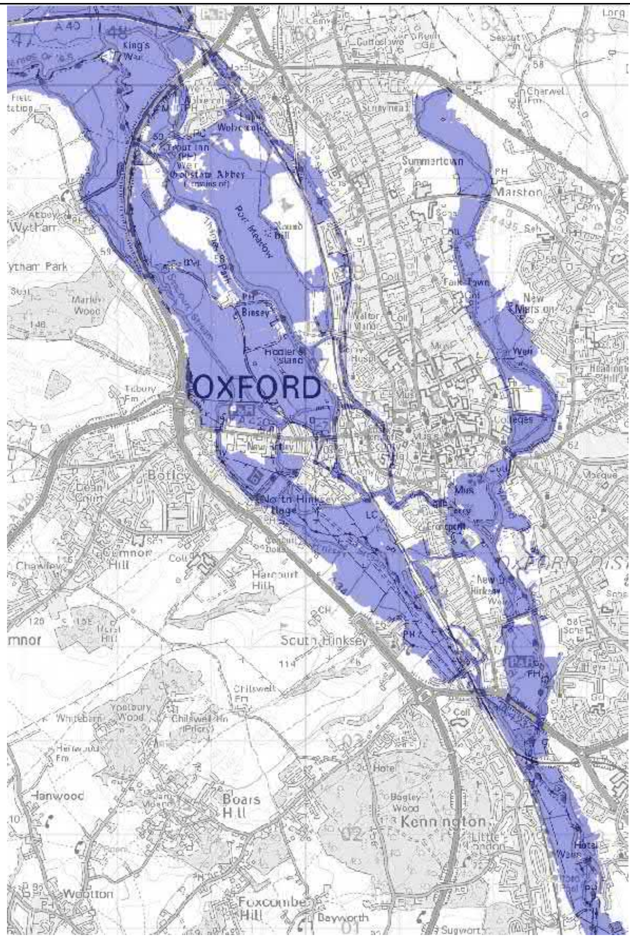
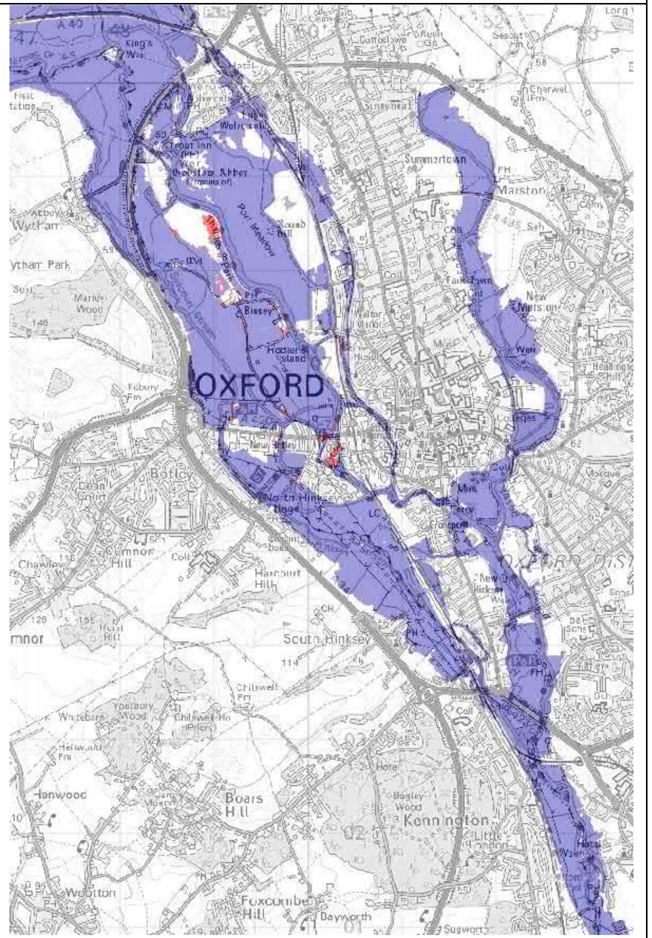
4b - 50% increase for 2D roughness

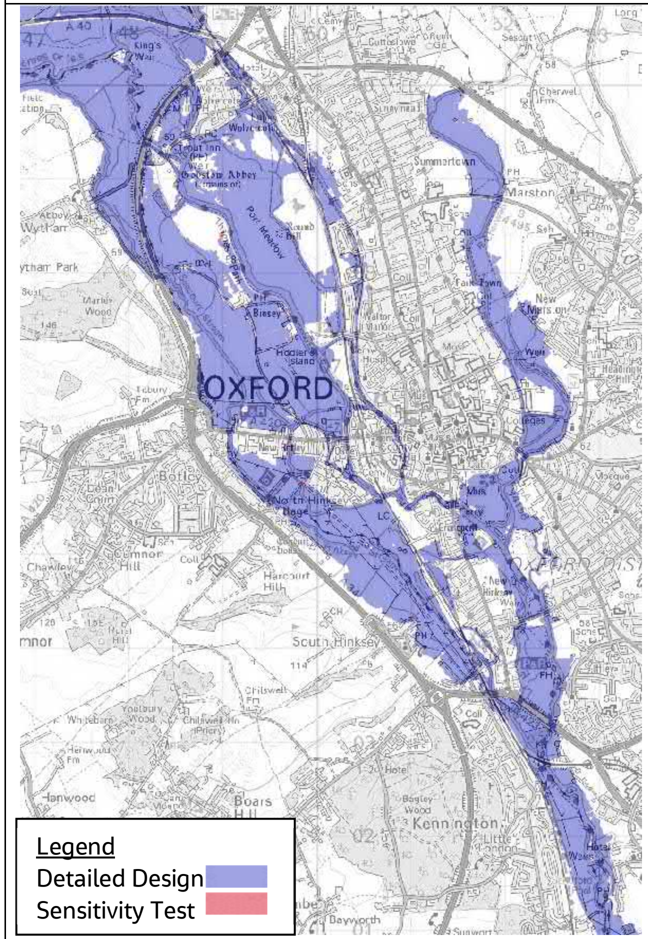
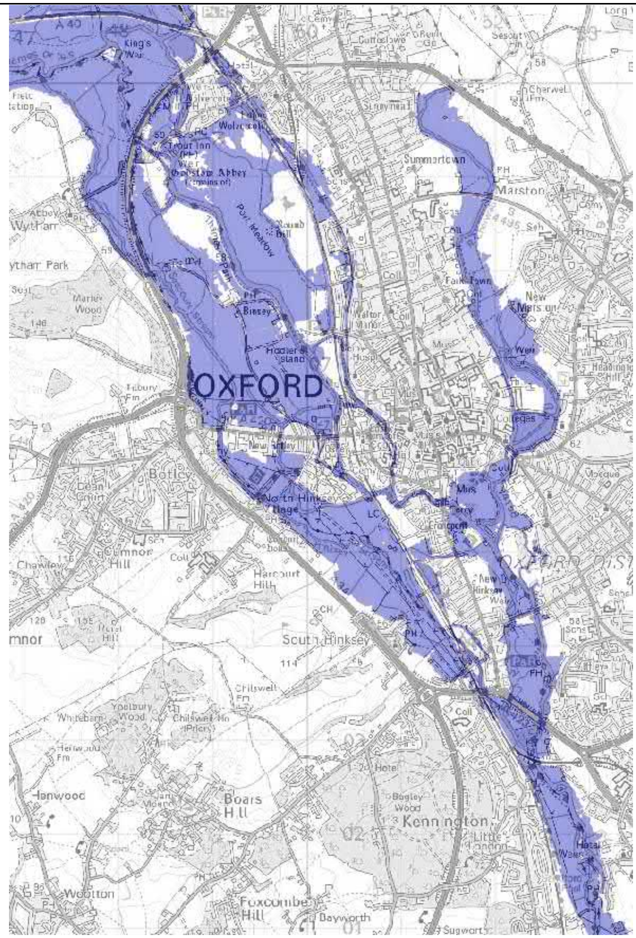
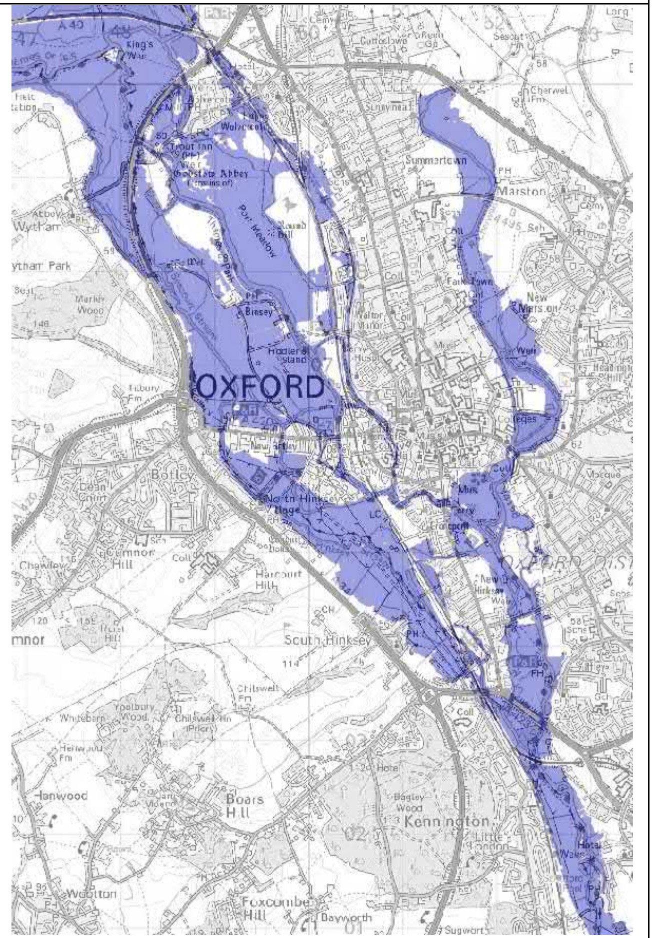


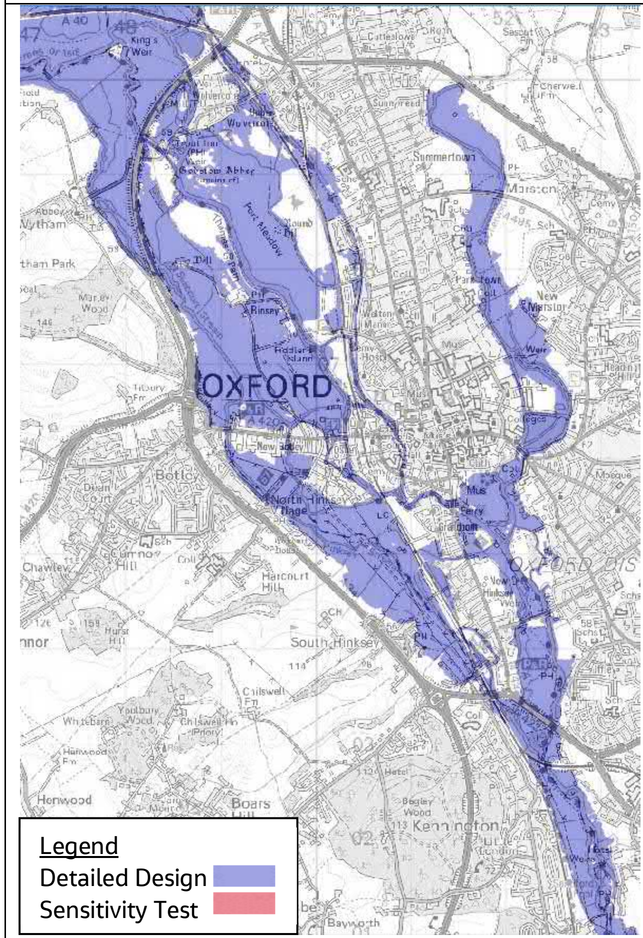
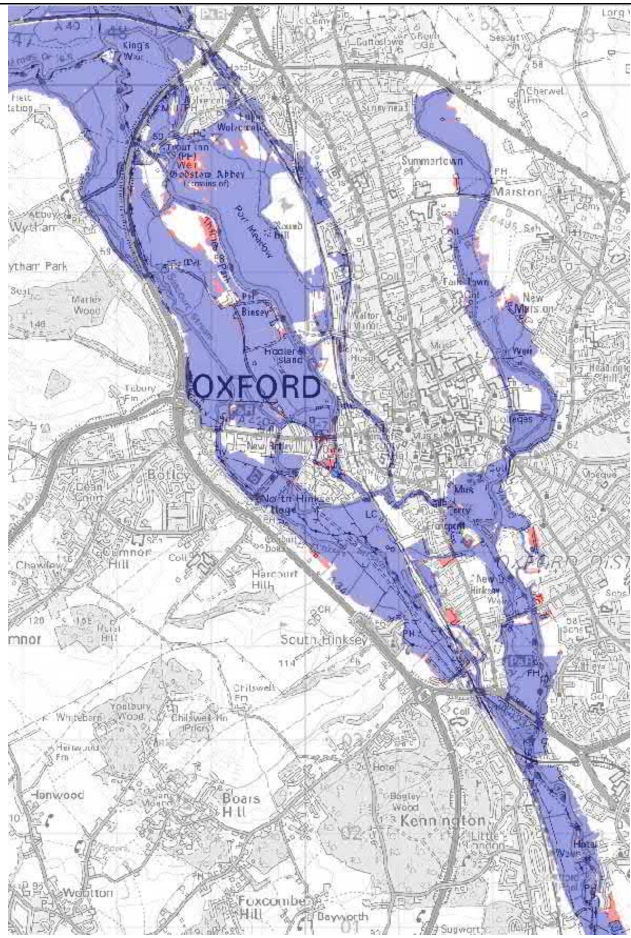
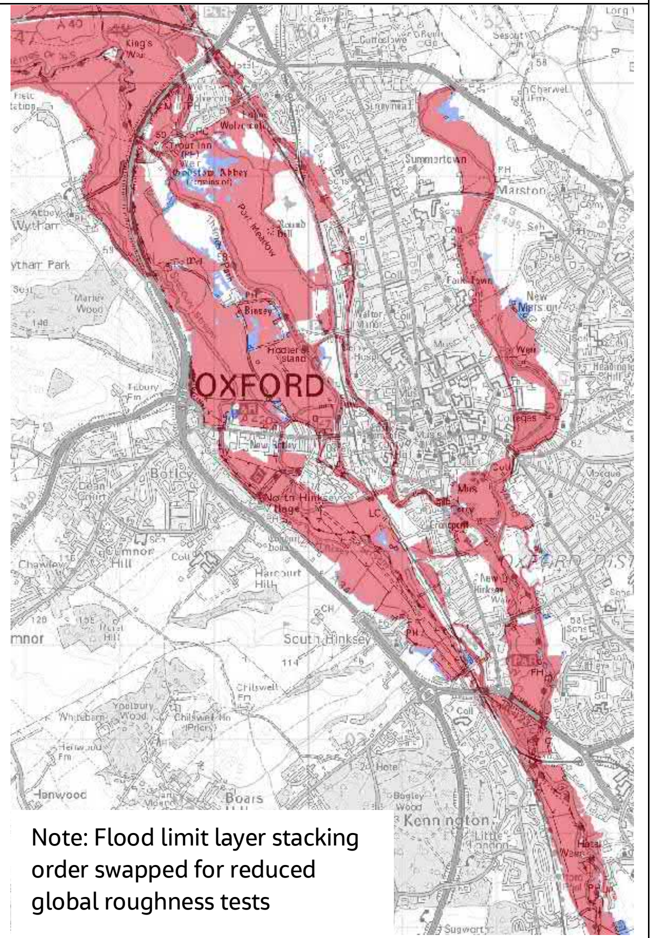
4c - 20% decrease for 2D roughness

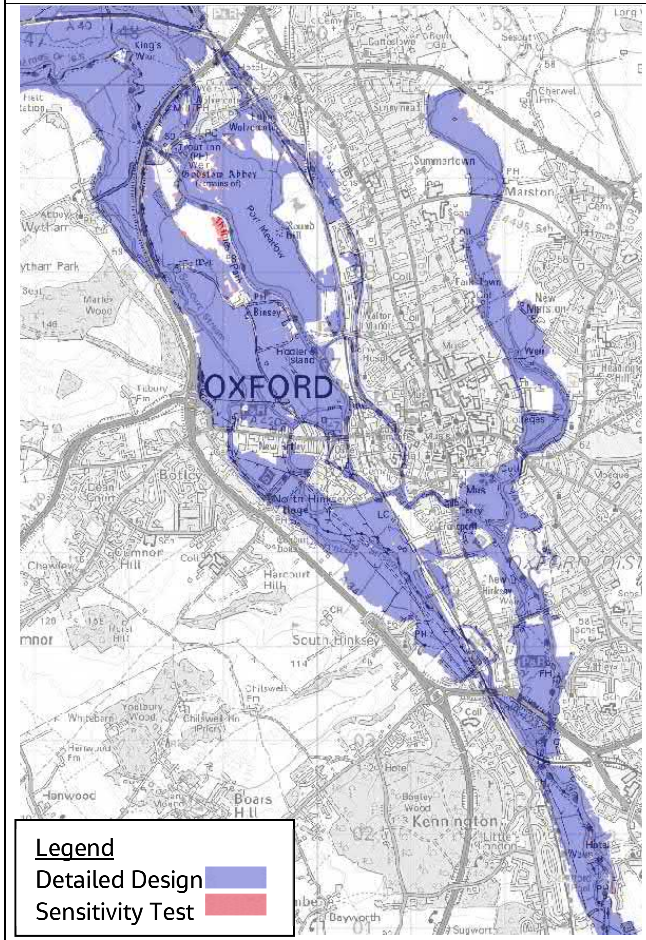
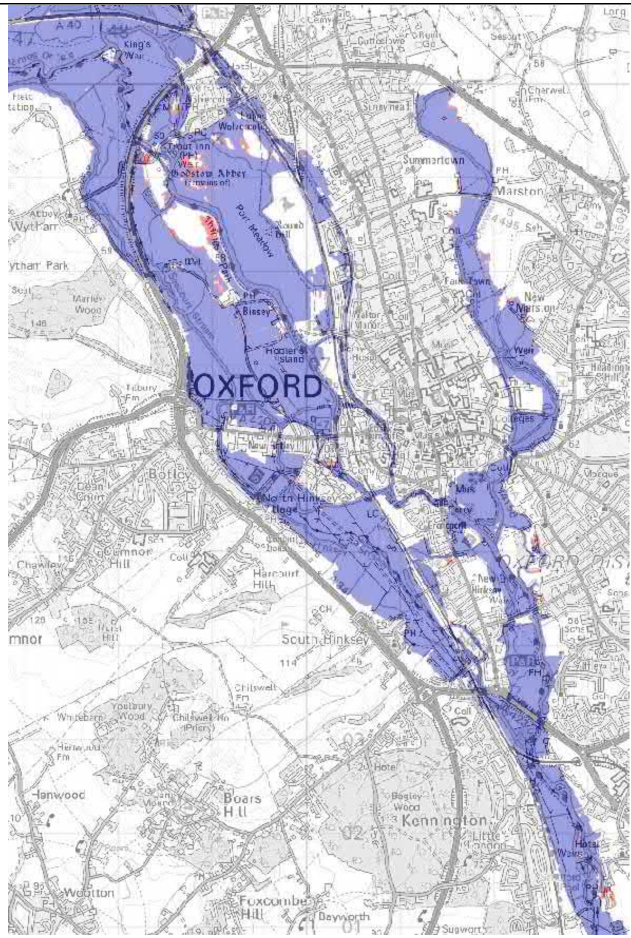
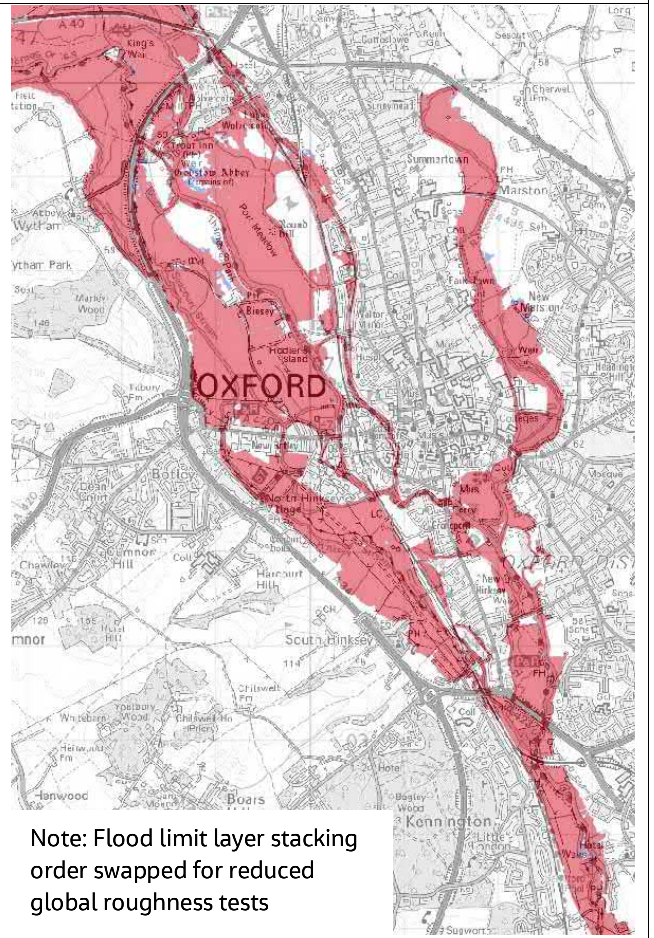


Appendix J. Sensitivity test: changes in flood extent level - 20 year

<table>
<tr><td>1a - 20% increase for 1D channel roughness (scheme sections)</td><td>1b - 20% decrease for 1D channel roughness (scheme sections)</td><td>2a - 50% Blockage of Botley Road (Seacourt Stream)</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

2b - 50% Blockage of the New Willow Walk Bridge	2c - 50% Blockage of the New Abingdon Road Culverts	2d - 50% Blockage of Mundays Bridge
		

5 – reduced spillway coefficient	3a - 20% increase for 1D channel roughness (all sections)	3b - 20% decrease for 1D channel roughness (all sections)
		

4a - 20% increase for 2D roughness	4b - 50% increase for 2D roughness	4c - 20% decrease for 2D roughness
		

Note: Flood limit layer stacking order swapped for reduced global roughness tests

Appendix K. Eastwyke Ditch control structure operation

During a flood event, the tilting gate at Eastwyke ditch will be raised (i.e. closed) to protect the area to the east of the railway. The model has been used to test the impact if the tilting gate was not operated during a flood event (i.e. gate is open). Table K.1 lists the models used for the assessment (2018 model) which were run for the 20%, 10%, 5%, 2%, 1.3% and 1% AEP events.

Table K.1: Model used for Eastwyke Ditch control structure operation

Scenario	1D Model	Simulation references
Baseline	Ox_DM2017_v1.DAT	v1_DM2017_rp5, v1_DM2017_rp10, v1_DM2017_rp20, v1_DM2017_rp50, v1_DM2017_rp75, v1_DM2017_rp100
Oxford FAS – Eastwyke Structure Closed	Ox_DD_v7.dat	v8_Ox_DD_rp5, v8_Ox_DD_rp10, v8_Ox_DD_rp20, v8_Ox_DD_rp50, v8_Ox_DD_rp75, v8_Ox_DD_rp100
Oxford FAS - Eastwyke Structure Open	Ox_DD_v7_EW.dat	v8_Ox_DDEW_rp5, v8_Ox_DDEW_rp10, v8_Ox_DDEW_rp20, v8_Ox_DDEW_rp50, v8_Ox_DDEW_rp75, v8_Ox_DDEW_rp100

The modelling has shown that the introduction of the structure (tilting gate and raised banks) with the gate being in an opened setting would reduce the flows at Eastwyke ditch compared to baseline conditions irrespective of the position of the gate.

The flows in Eastwyke ditch through the railway culvert are respectively detailed in Figure K.1 and Figure K.2 for the 10% and 1% AEP events. The blue lines represent the baseline flows, red lines show the reduced flow when the gate is set at its low flow setting of 54.72mAOD which is the modelled Q95 level of the River Thames side to prevent loss of flows from the River Thames during the Q95 conditions. The green lines represent the gate in its closed state i.e. zero flow.

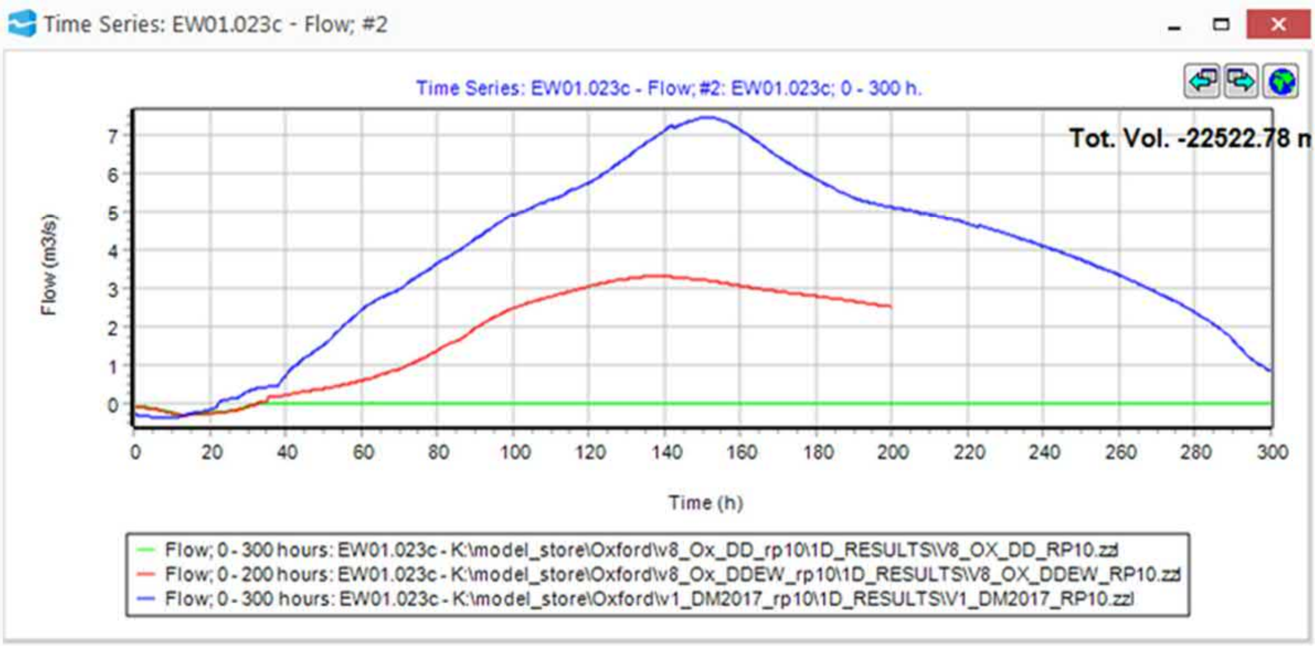


Figure K.1: 10% AEP flows through the railway culvert upstream of Eastwyke ditch control structure

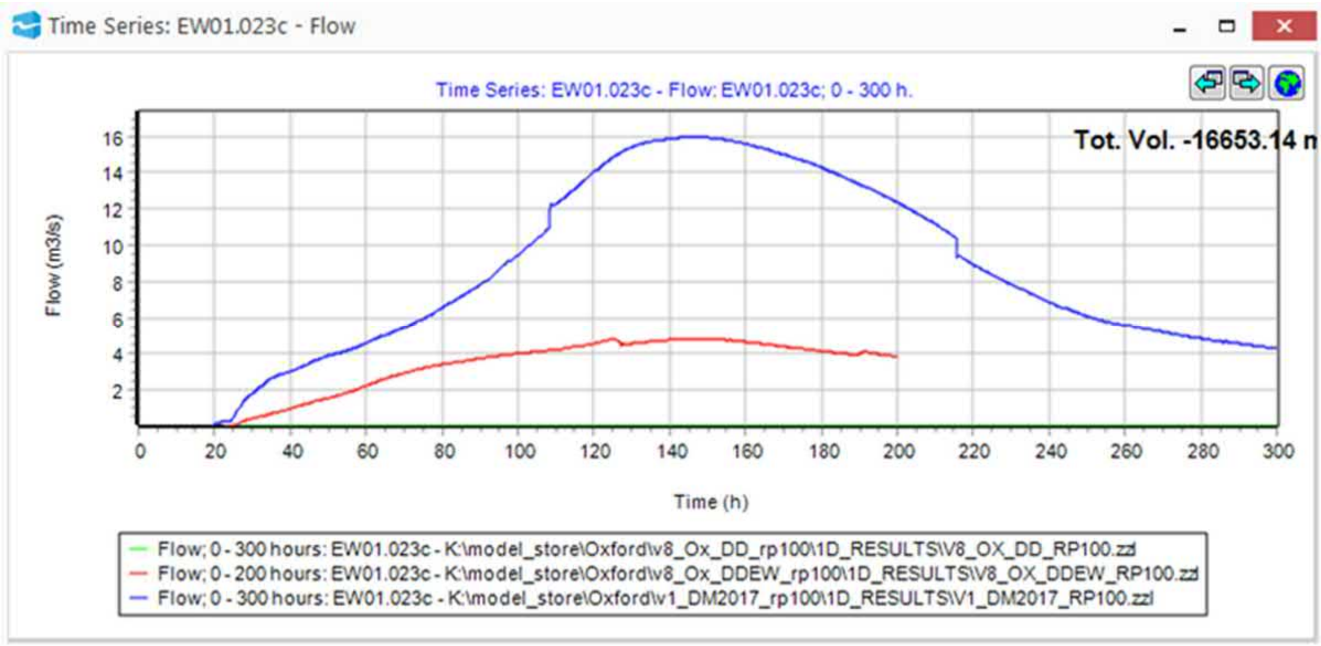


Figure K.2: 1% AEP flows through the railway culvert upstream of Eastwyke ditch control structure

Figure K.3, Figure K.4 and Figure K.5 compare the modelled flood extents, the light blue shading is the Baseline Do Minimum (DM2017) scenario which reflects the current/existing flood extents without the scheme. The green shading is the flood extents of the current scheme (Oxford FAS) with the new Eastwyke Ditch gate being fully closed. The purple shading shows the flood extents of the current scheme model with the Eastwyke Ditch gate being opened and set to the low flow setting (Oxford FAS Eastwyke Open). The purple shading indicates the locations where the flooding extents would be increased due to the gate being set to the low flow setting

.

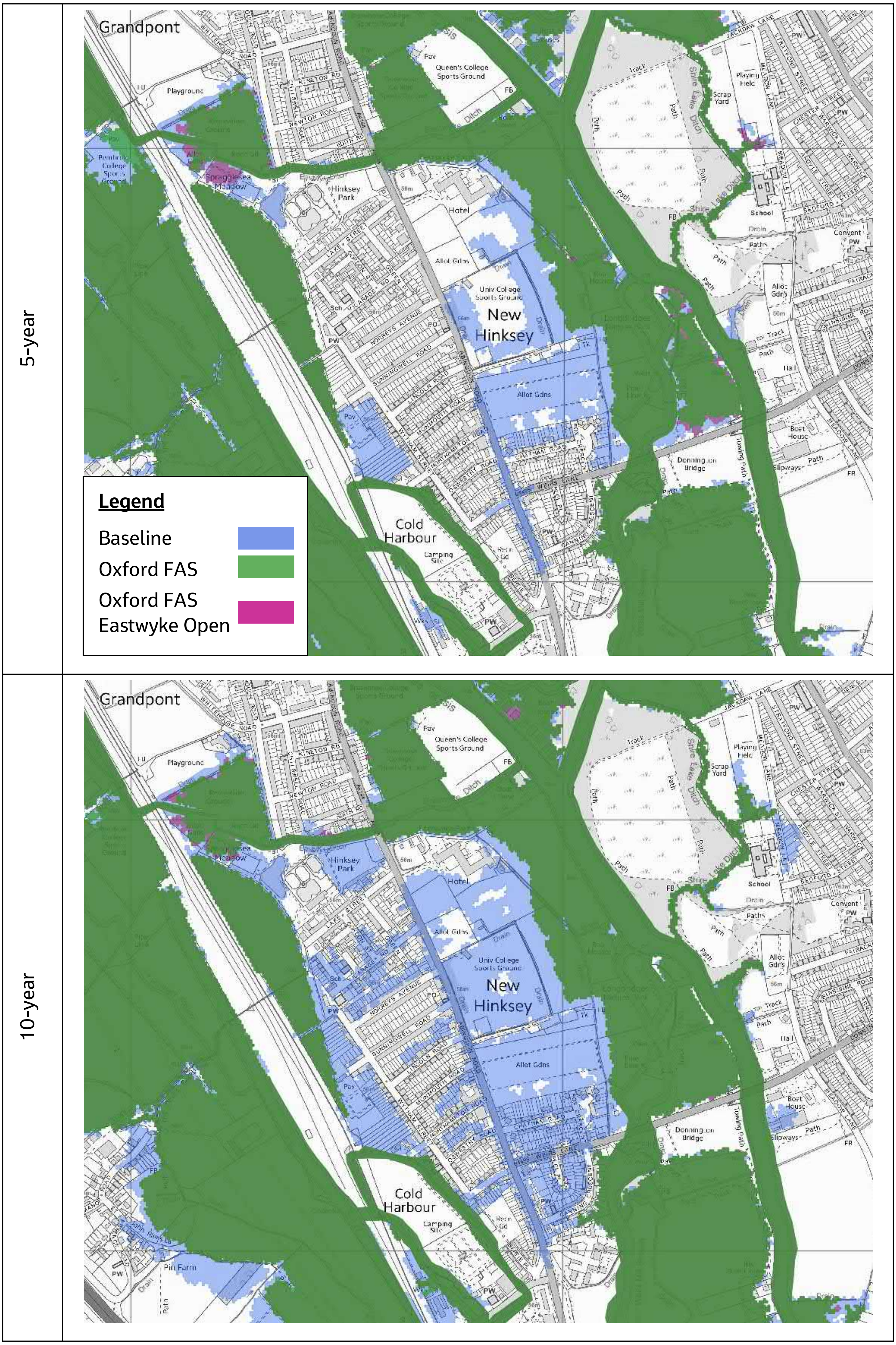


Figure K.3: Eastwyke Ditch - 20% AEP and 10% AEP flood extent comparison

Figure K.4: Eastwyke Ditch - 5% AEP and 2% AEP flood extent comparison

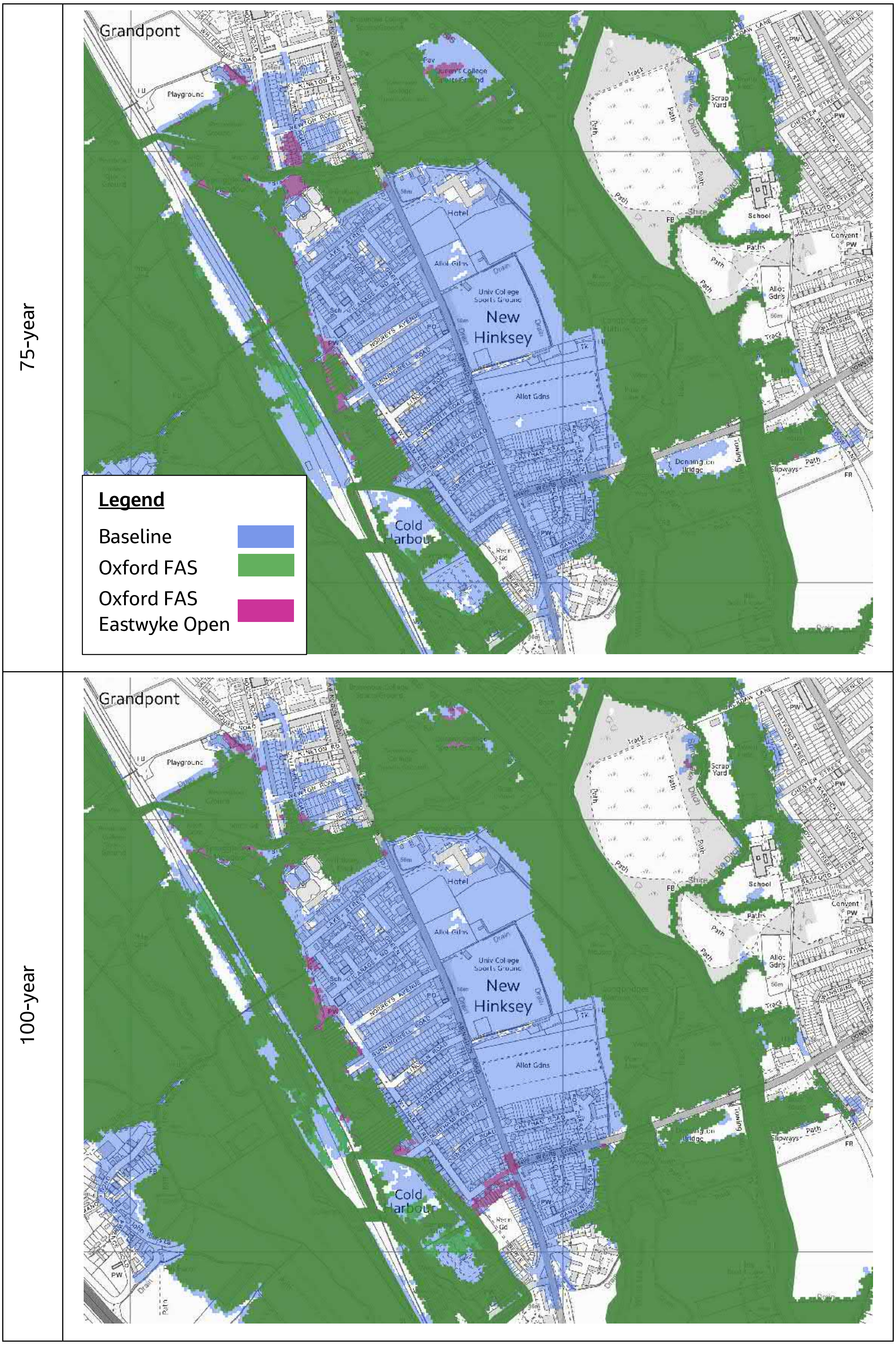


Figure K.5: Eastwyke Ditch – 1.3% AEP and 1% AEP flood extent comparison