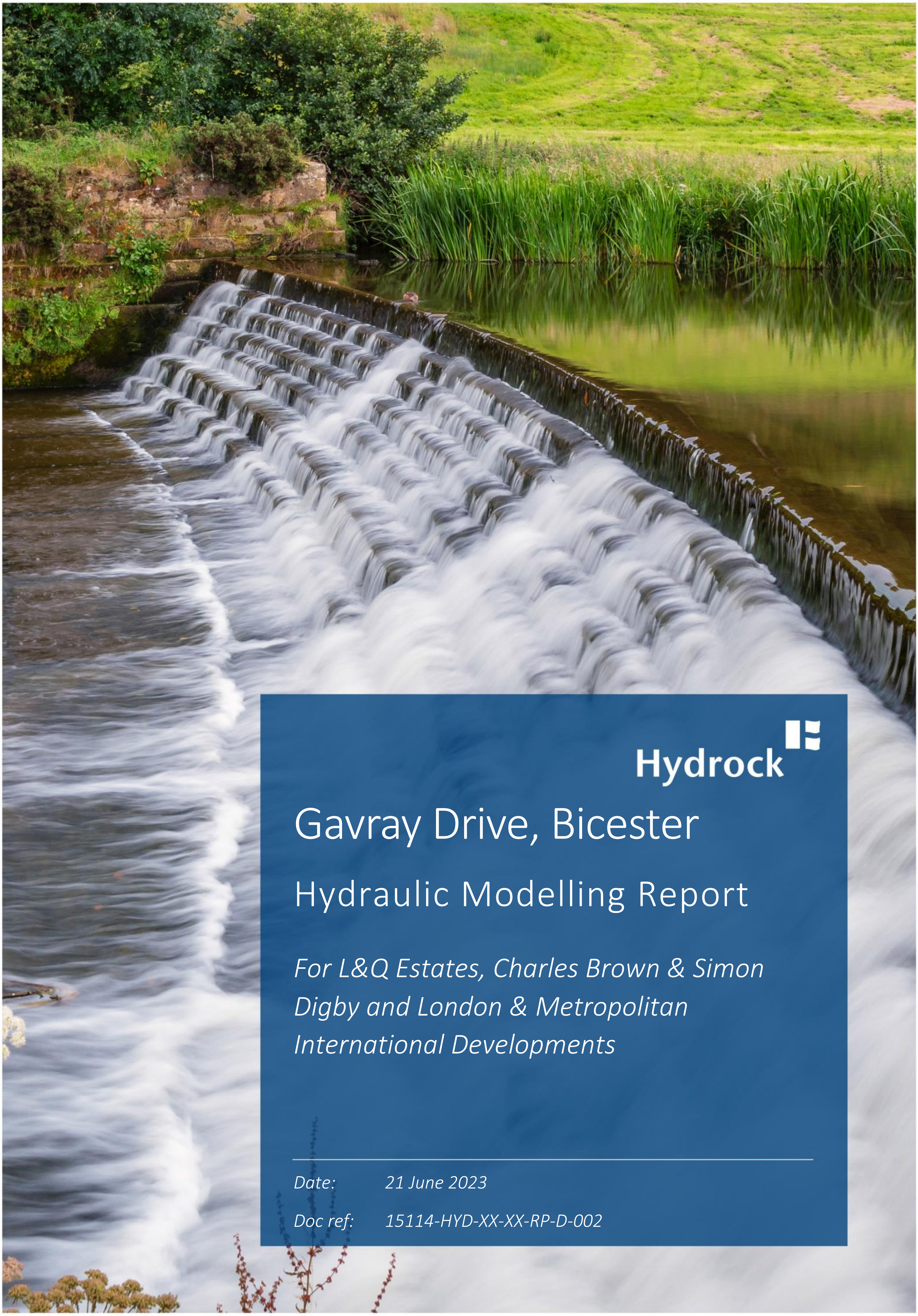

Hydrock

Gavray Drive, Bicester

Hydraulic Modelling Report

For L&Q Estates, Charles Brown & Simon Digby and London & Metropolitan International Developments

Date: *21 June 2023*

Doc ref: *15114-HYD-XX-XX-RP-D-002*

DOCUMENT CONTROL SHEET

Issued by	Hydrock Consultants Limited 5-7 Tanner Street London SE1 3LE United Kingdom	T +44 (0)203 8468456 E london@hydrock.com www.hydrock.com
Client	L&Q Estates, Charles Brown & Simon Digby and London & Metropolitan International Developments	
Project name	Gavray Drive, Bicester	
Title	Hydraulic Modelling Report	
Doc ref	15114-HYD-XX-XX-RP-D-002	
Project no.	15114-IOCB	
Status	S2 - Suitable for Information	
Date	21/06/2023	

Document Production Record		
Issue Number	P02	Name
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Document Revision Record			
Issue Number	Status	Date	Revision Details
P01	S2	03/10/2022	First Issue
P02	S2	21/06/2023	Second Issue Addressing EA comments.

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1. INTRODUCTION

As part of the Outline Planning application for the above site the EA have highlighted the need for a detailed hydraulic modelling study to demonstrate that any ground raising as part of the development will not increase in flood levels in the Langford Brook or to third party land.

The EA have stated that any modelling of the 'post development' scenario (i.e. to include proposed ground levels) should be based on the provided EA modelling of the Langford Brook that was undertaken by JBA Consultants. Any required compensation storage is to be provided for all ground raising within the provided 1 in 100-year plus 15% allowance for climate change return period event.

The current proposals are to lower and area on the right bank on the Langford Brook and to the eastern limit of what is referred to as 'Gavray West'. This area sits outside the proposed development and will ensure suitable volume is 'replaced' whilst also ensuing connectivity to the watercourse.

Much of the area when compensation storage is being proposed is proposed as being public open space (PoS) and crossed by a number of footpaths. It has now been confirmed that all of these are to be at existing (or proposed) site levels, rather than raised, so these result in no loss of floodplain storage.

Hydrock have obtained the Langford Brook model from the EA and, as requested, it is this approved model that has been used to assess the impacts of the areas of ground raising within the 1 in 100 year plus climate change flood extent.

A previous version of this model has been reviewed by the EA and this report has been updated to reflect where changes have been made.

The report details the changes to modelling files only and should be read in conjunction with the submitted Flood Risk Assessment Report (Ref: 15114-HYD-XX-XX-RP-FR-0001_P03) that has been included within the submission.

2. HYDROLOGY

The Environment Agency review suggested that the hydrology should be revisited with the latest methods of calculation. Therefore, an up-to-date FEH calculation was undertaken.

The Flood Estimation Handbook (FEH) Catchment Descriptors and map for the Langford Brook watercourse from the FEH Web Service are included in Table 1 and Figure 1.

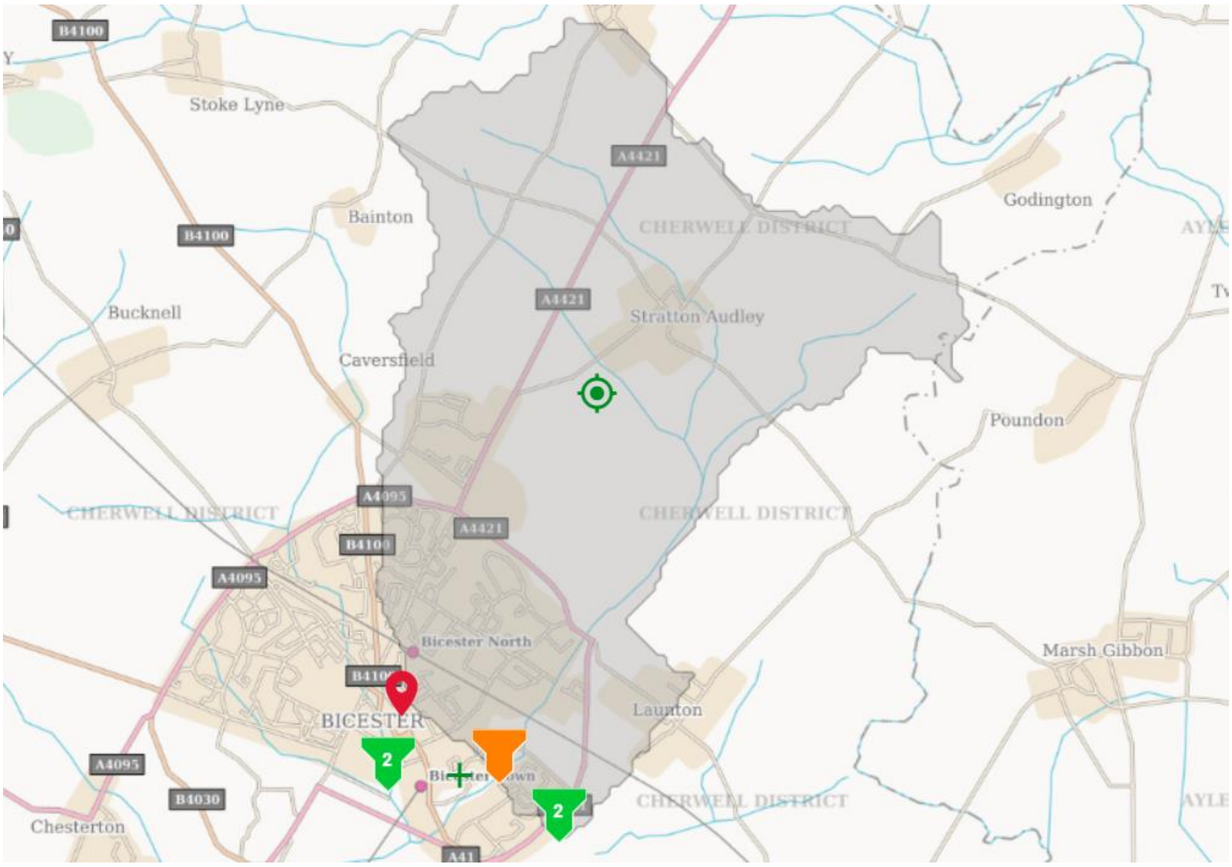

Figure 1: FEH Catchment

Table 1:FEH Catchment Descriptors

Descriptor	Tributary	Description
	459350	Outlet Easting
	222000	Outlet Northing
	SP 59350 22000	Outlet Grid Reference
AREA	19.338	Catchment area (km2)
ALTBAR	85	Mean elevation (m)
ASPBAR	161	Mean aspect
ASPVAR	0.56	Variance of aspect
BFIHOST19	0.629	Base flow index
DPLBAR	4.81	Mean drainage path length (km)
DPSBAR	14.7	Mean drainage path slope
FARL	0.965	Index of lakes
FPEXT	0.181	Prop. of catchment in1% FP
FPDBAR	0.872	Mean flood depth (catchment)
FPLOC	0.805	Avg. dist. of FP to outlet
LDP	9.52	Longest drainage path (km)
PROPWET	0.32	Proportion of time soil is wet
RMED-1H	10.1	Median 1 hour rainfall (mm)
RMED-1D	31.8	Median 1 day rainfall (mm)
RMED-2D	38.6	Median 2 day rainfall (mm)
SAAR	633	Average annual rainfall (mm)
SAAR4170	654	Ditto for 1941-1970 (mm)
SPRHOST	25.22	Percentage runoff
URBCONC1990	0.727	Urban concentration 1990
URBEXT1990	0.054	Urban extent 1990
URBLOC1990	0.496	Urban location 1990
URBCONC2000	0.875	Urban concentration 2000
URBEXT2000	0.100	Urban extent 2000
URBLOC2000	0.459	Urban location 2000

Whilst the above data was obtained using an industry standard approach, a check on key descriptors (AREA, SPRHOST, URBEXT) was undertaken to ensure that the values adopted were appropriate for use. This included the following checks:

- The AREA of the catchment was checked using OS contour mapping and available LiDAR data (Figure 2). This exercise identified little difference between the FEH catchment and that identified using topographical information. In addition, no obvious cross-catchment flows from watercourses, land drainage ditches and as such, the Catchment Descriptors AREA value remains appropriate and was used in these calculations.

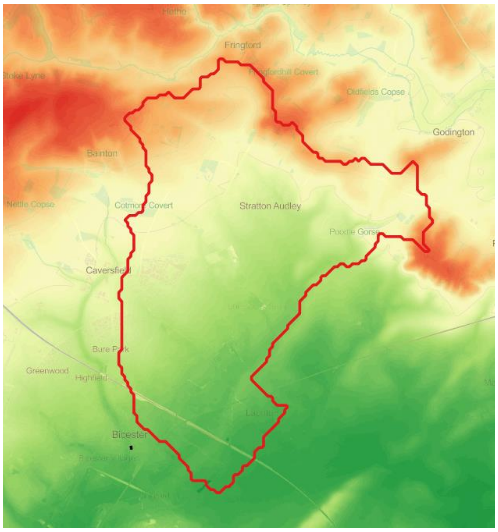

Figure 2: 1m Lidar used to analyse topographical boundaries.

- The Catchment Descriptors provide a SPRHOST of 25.22 which implies the underlying conditions are considered to be relatively permeable. Given the potential impact of this value on calculated flows this was checked using available soil mapping information. This information shows that the majority of the catchment is underlain by 'freely draining line-rich loamy soils', with some areas of the catchment overlain by 'slowly permeable, seasonally wet, slightly acid but base-rich loamy and clayey soils'. This suggests that the underlying ground conditions are relatively permeable, and as such, the SPRHOST value is considered acceptable.
- Figure 3 shows the site bedrock geology to largely consist of mudstone, limestone and sandstone owing to a permeable catchment. This shows that the BFIHost of 0.629 is an accurate representation of the catchment. There are also superficial deposits of Alluvium along the Langford Brook owing to a mixed nature of permeability.

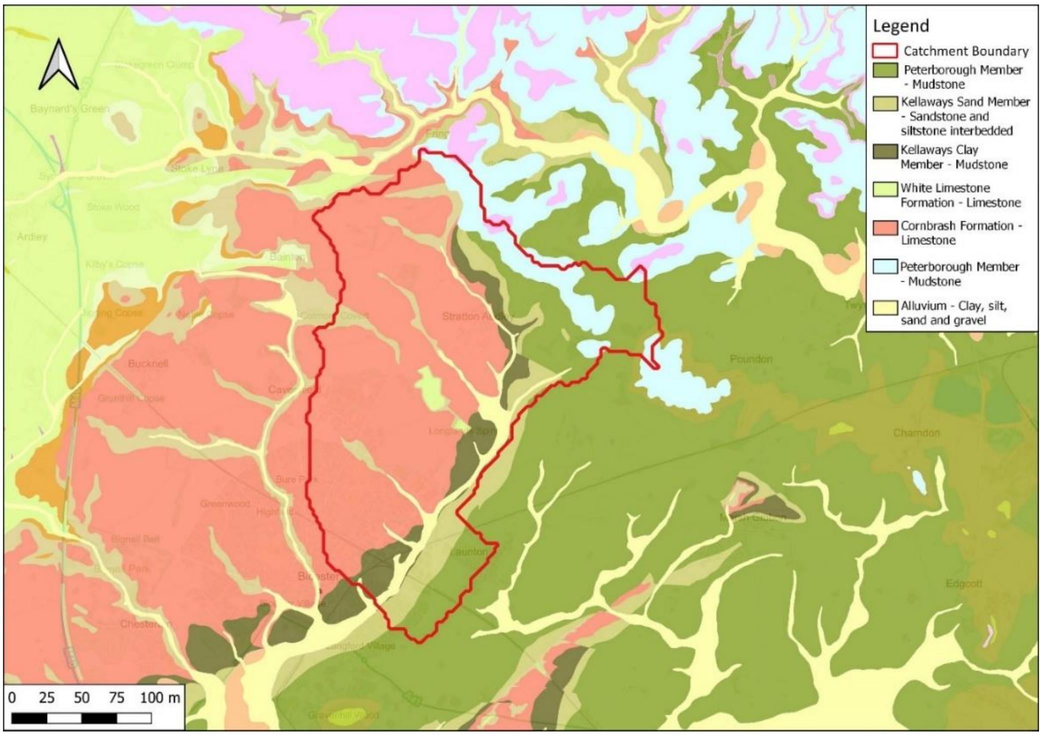

Figure 3: Catchment Superficial and Bedrock Geology.

- In order to verify the URBEXT value, a review of OS mapping and the FEH URBEXT2000 mapping was undertaken to identify any significant areas where recent development has occurred. Recent areas of urban development were identified that were not included in the calculation of the FEH URBEXT2000 value. As such, the urban area was measured using os mapping (3.745km^2). This represents an URBAN value of 0.194 and an URBEXT2000 value of 0.122 (moderately urbanised).

1.1.1 FEH Statistical Method

A WINFAP-FEH v5 hydrological assessment of flows (using the latest dataset version) was undertaken in order to provide an estimation of peak flows for the catchment.

1.1.1.1 Estimating QMED

In order to improve the Catchment Descriptor Method estimate of QMED, a gauge on Gavray Drive was used to estimate QMED. Levels were translated into flows through use of the Manning's n equation. This provided a much higher estimate of QMED of 4.144 m^3/s.

1.1.1.2 Pooled Analysis

Pooled analysis was undertaken in order to calculate growth curves for the catchment. WINFAP provided an initial pooling group, shown in Figure 4. The initial pooling group is heterogeneous (H2 = 2.49) but within the acceptable range.

AM Data | Catchment Descriptors

	Station	Distance (SDM)	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Discordancy
1	36010 (Bumpstead Brook @ Broad Gree	0.352	54	7.545	0.372	**0.374**	0.168	**0.167**	1.244
2	26016 (Gypsey Race @ Kirby Grindalyth	0.536	24	0.103	0.304	**0.304**	0.240	**0.240**	0.119
3	26014 (Water Forlornes @ Driffield)	0.553	23	0.437	0.315	**0.316**	0.164	**0.163**	0.327
4	39033 (Winterbourne Stream @ Bagnor)	0.762	59	0.403	0.338	**0.338**	0.375	**0.375**	1.218
5	33054 (Babingley @ Castle Rising)	0.764	45	1.136	0.229	**0.229**	0.183	**0.182**	1.271
6	36004 (Chad Brook @ Long Melford)	0.784	54	4.873	0.301	**0.302**	0.170	**0.169**	0.402
7	27073 (Brompton Beck @ Snainton Ings	0.786	41	0.820	0.212	**0.213**	0.006	**0.005**	0.730
8	25019 (Leven @ Easby)	0.801	43	5.677	0.334	**0.335**	0.373	**0.372**	0.836
9	26013 (Driffield Trout Stream @ Driffield)	0.840	11	2.700	0.281	**0.282**	0.196	**0.195**	2.818
10	7011 (Black Burn @ Pluscarden Abbey)	0.860	9	5.205	0.491	**0.491**	0.521	**0.521**	2.357
11	33032 (Heacham @ Heacham)	0.877	53	0.449	0.297	**0.298**	0.129	**0.128**	0.179
12	36003 (Box @ Polstead)	0.910	61	3.900	0.311	**0.313**	0.082	**0.080**	0.903
13	30004 (Lymn @ Partney Mill)	0.926	59	7.240	0.223	**0.223**	0.021	**0.020**	0.596
14									
15									
16									
17									

Figure 4: Final Pooling Group

1.1.1.3 Growth Curve Distributions

Comparison of the growth curve distributions in Figure 5 found the Kappa 3 distribution to provide the best fit (Z value is closest to 0). This provided growth curve fittings shown below in Table 2.

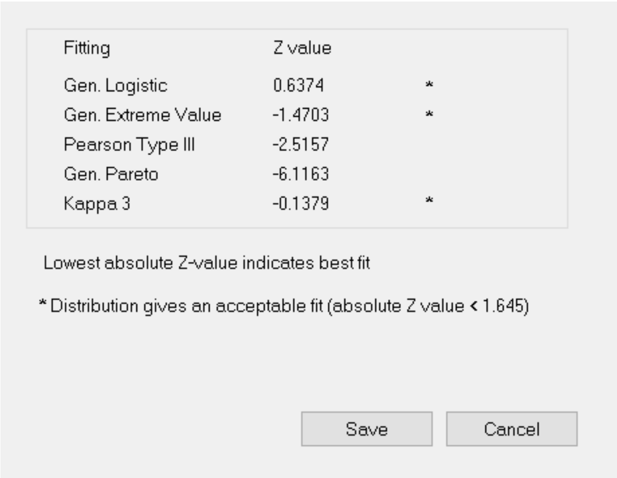

Figure 5: Goodness of Fit

Table 2: Growth Curve Distributions

Return Period (AEP)	Growth Curve Fitting
20yr (5% AEP)	2.223
100 (1% AEP)	3.213
1,000 (0.1% AEP)	5.056

1.1.1.4 Peak Flows

The Statistical Method provided peak flows shown below in Table 3.

Table 3: FEH Statistical Method Peak Flows

Return Period (AEP)	Peak Flow (m3/s)
20yr (5% AEP)	9.211
100 (1% AEP)	13.314
1,000 (0.1% AEP)	20.951

1.1.2 Rainfall Runoff Method

The Revitalised Flood Hydrography (ReFH) v2 was used for the assessment of design events for the catchment. For the catchment, a 11hrs duration and timestep of 1hr was found to be the critical storm and in the absence of any other information this is considered appropriate. Peak flows calculated using the Rainfall Runoff Method are shown below in Table 4.

Table 4: Rainfall Runoff Peak Flows

Return Period (AEP)	Peak Flow (m3/s)
20yr (5% AEP)	3.73
100 (1% AEP)	5.25
1,000 (0.1% AEP)	8.87

1.1.3 Flood Frequency Analysis on the Langford Brook Gauge

A flood frequency analysis using the Gringorton plotting position formula was undertaken to understand the return periods of the largest events at the gauge. A graphical representation of this can be found in Figure 1. Our statistical analysis showed that a 20-year return period has a peak flow of 9.21

m3/s. The flood frequency analysis showed that a 20-year return period has a peak flow of 10.53 m3/s. The similarity of these two flows gives confidence to the hydrological inflows into the model. Due to the short record of the gauge, there is not high confidence in a single site analysis and therefore we can be more confident in our statistical analysis which also included information from other sites with longer records.

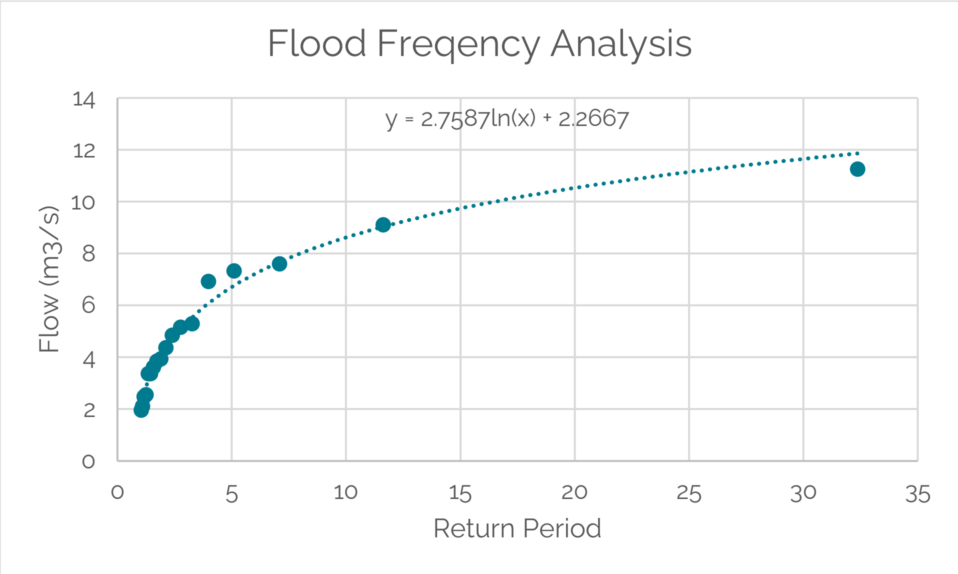

Figure 6: Flood Frequency Analysis on the Langford Brook gauge.

A flood frequency analysis on gauged data shows the highest flows occurring at the gauge was ~32-year return period. Therefore, the higher return periods used in this analysis will rely on a hydraulic model. The previous rating curve was generated using the hydraulic model for the higher flows and was accepted by the Environment Agency. Therefore, as the hydraulic model has not been altered, only truncated, this rating curve will remain acceptable.

1.1.4 Summary

Comparison of the peak flows calculated using the Statistical Method and the Rainfall Runoff Method show the flows calculated using the Rainfall Runoff Method to be considerably lower than those calculated using the Statistical Method. The choice between methods is not always clear cut. Given the larger flows calculated by the Statistical Method and the lack of local data to compare with the flows, the Statistical Method was selected as the conservative approach.

In line with standard practise, flows were calculated for the 1 in 20 year (Flood Zone 3b), 1 in 100 year (Flood Zone 3), and 1 in 1,000 year (Flood Zone 2) flood event.

The impact of climate change on flows was calculated in line with current guidance by multiplying the 1 in 100 year calculated flow by 1.15 to take account of the predicted 15% increase in flows for the 2080's Central EA climate change allowances.

Table 5 compares our estimated peak flows with the previous calculation from the Environment Agency model. This shows slightly higher inflows from our model. Table 6 shows the weighting of the peak flows that have been applied to each FEP. This is the same weighting as the EA model.

Table 5: Final Peak Flows comparison to EA peak flows.

Return Period (AEP)	Peak Flow (m3/s)	EA peak flows
20yr (5% AEP)	9.21	3.73
100 (1% AEP)	13.31	11.99
100 (1% AEP) + 15% Central CC	15.31	13.78
1,000 (0.1% AEP)	20.951	20.05

Table 6: Area weighting for each FEP.

Return Period (AEP)	Weighting of Peak Flow (%)
LB_US	32.60
LA.2	13.77
LA.3	53.63

3. MODEL APPROACH AND SUMMARY

The EA's model is a linked 1D-2D model that uses Flood Modeller Pro and TUFLOW. This approach has been maintained in the updated modelling. Following a review of the model undertaken by the Environment Agency, a number of concerns with the approved model were made. Following this review, it appeared that a large number of concerns existed on watercourses with no hydraulic connectivity to the site.

Therefore, it was decided that the model should be truncated to incorporate only the Langford Brook to provide a detailed site-specific model.

This section discusses the Environment Agency concerns which relates to the truncated model and what were done to address them.

3.1 Trimming 1D Cross Sections

An analysis shows that the models 1D sections were large and included floodplain. It is best to represent the floodplain in the 2D domain using LiDAR data. Therefore, the 1D cross sections were trimmed to the banks, using deactivation markers.

3.2 Ensuring Smooth Conveyance

A number of model nodes had areas of negative changes to conveyance. These were addressed by incorporating panel markers.

3.3 Channel Roughness

A review of the channel roughness used in the original model was undertaken. Throughout the model the in-channel Manning's N roughness is 0.05, which should be used in channels with some weeds and stones. The banks of the channel are given the Manning's N roughness of 0.06, which should be used in areas with light brush and trees. These are both consistent with visual inspection of the watercourses and therefore was kept unchanged.

3.4 Floodplain Roughness

A review of the floodplain roughness used in the original model was undertaken. This review indicated that the Manning's N value were in typical range. The buildings are represented with a Manning's N roughness value of 0.15, however a number of developments were missed in original model. This has been corrected in the updated model.

3.5 2D Grid

The grid size has been reduced to a 2m grid to aid model stability and improve channel representation. The grid has been rotated to improve optimisation with the Langford Brook.

3.6 Timesteps

Therefore, the 1D timestep was reduced to 0.5 second and the 2D timestep to 1 second to reflect the change in grid size.

3.7 1D Downstream boundary

The 1D downstream boundary is a normal depth boundary. This generates a flow-head relationship based on the slope of the two last cross sections. The backwater effect calculation states that the downstream boundary has no effect after 77m upstream. The site is further than 77m from the downstream boundary and therefore will not have an effect on levels at the site.

3.8 2D Downstream boundary

The 2D boundary is a stage-discharge boundary snapped to the bottom of the code layer. The boundary uses a slope of 0.01 which was determined using LiDAR.

3.9 Sluice at LA.4474

A bridge unit has been modelled as a sluice in the previously approved model in order to aid stability. Survey of this model have not been provided and it is on third party land therefore, survey cannot be undertaken and consequently this structure cannot be represented as a bridge. This structure is approximately 1km upstream of the site with other structures closer to the site causing the constriction to flow. Therefore, the structure will not greatly impact flooding at the site.

3.10 Flood Storage Area

It has been highlighted by the Environment Agency that there is a Flood Storage Area upstream of the site. This has not been accurately represented in the original model as it just fills up naturally according to the ground levels taken from LiDAR. However, according to the Environment Agency the flood storage area is in poor condition. Therefore, it was decided to keep this omitted from the model as it will provide a conservative flood level.

3.11 LiDAR Update

The LiDAR data for the original model was flown before 2009. It is likely that there has been land alteration causing different flow routes. Therefore, a 1m LiDAR flown in 2020 was used for the digital terrain model.

3.12 Ponds

All ponds on OS mapping have been filled in at the start of the simulation using z shapes. LiDAR was used to find the approximate bank full level

3.13 Finished Floor Levels and Compensatory Storage

Finished floor levels of the development and compensatory storage have been used in the proposed scenario. This has been done through the use of an asc file. The layouts of the buildings are not final as this is for outline planning so individual buildings have not been included as z-shapes. No water reaches the site on the proposed scenario and therefore it is not necessary to show individual buildings as a z shape.

4. MODEL WARNINGS AND STABILITY

4.1 1D Warnings

Two warning were identified in the 1D domain. This section explains how they would affect model results.

Warning 2302 - Time to peak, is not an integer multiple of the data interval, 0.500. The unit hydrograph peak, Up, may possibly be significantly reduced. The time to peak was created using FEH methods and is deemed to be accurate. Therefore, no changes are needed.

Warning 2229 - Value of trash screen height is set to 0; areas will be calculated using piezometric head. No alterations of the structures were made from the original Environment Agency model and it is assumed that there are no trash screens present. Therefore, this warning does not need rectifying.

4.2 2D Warnings

A number of warnings were identified in the 2D domain. This section explains how they would affect model results.

WARNING 0305 - Projection of .mif file is different to that specified by the MI Projection == command. This is due to converting some of the MIF files into shapefiles to edit and converting it back into MIF files. A check was of the files were undertaken and it does not affect the model.

WARNING 2073 - Null Shape object ignored. Only Regions, Lines, Polylines & Multiple Polylines used. This is also due to converting some of the MIF files into shapefiles to edit and converting it back into MIF files. A check was of the files were undertaken and it does not affect the model.

WARNING 2075/2076 - *3D breakline with snapped point(s) does not have a point at its start*/end. *2D line assumed.* This uses the nearest snapped point. A check was of the files were undertaken and it does not affect the model.

CHECK 2099 - Ignored repeat application of boundary to 2D cell. This does not affect the model results; it occurs when a boundary line registers a 2D cell twice.

4.3 Mass Balance

Figure 7 shows that the cumulative mass error is very low and is well within the +/- 1% tolerance. There is an initial spike of 1.6% which occurs 3.5 hours into the simulation which is long before the peak flow at 8.5 hours. This is likely due to the low flows which Flood Modeller Pro does not handle very well.

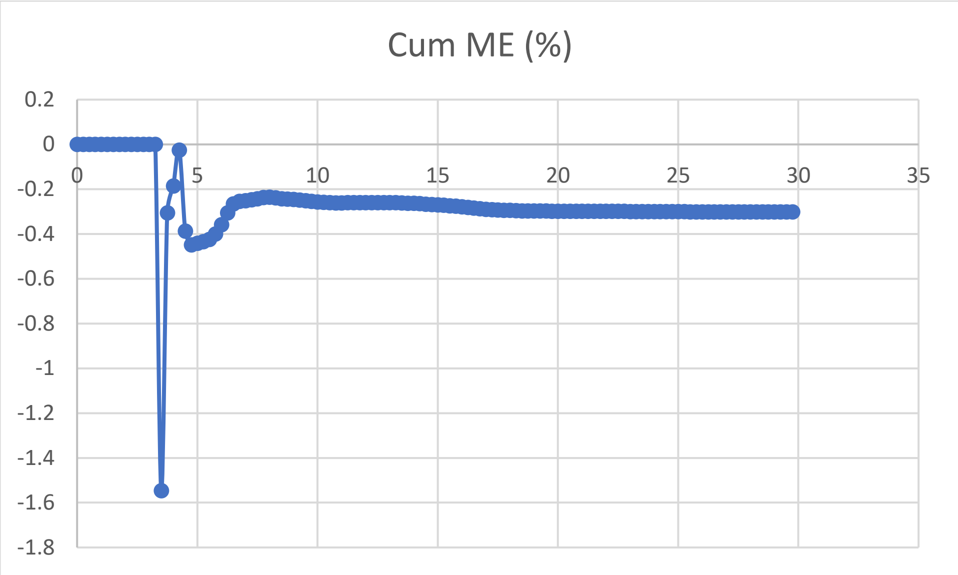

Figure 7: Cumulative Mass Error for the 100yr +15% Climate Change Proposed Scenario.

4.4 DVol

Figure 8 shows a very smooth volume change in the 2D. This indicates good model stability.

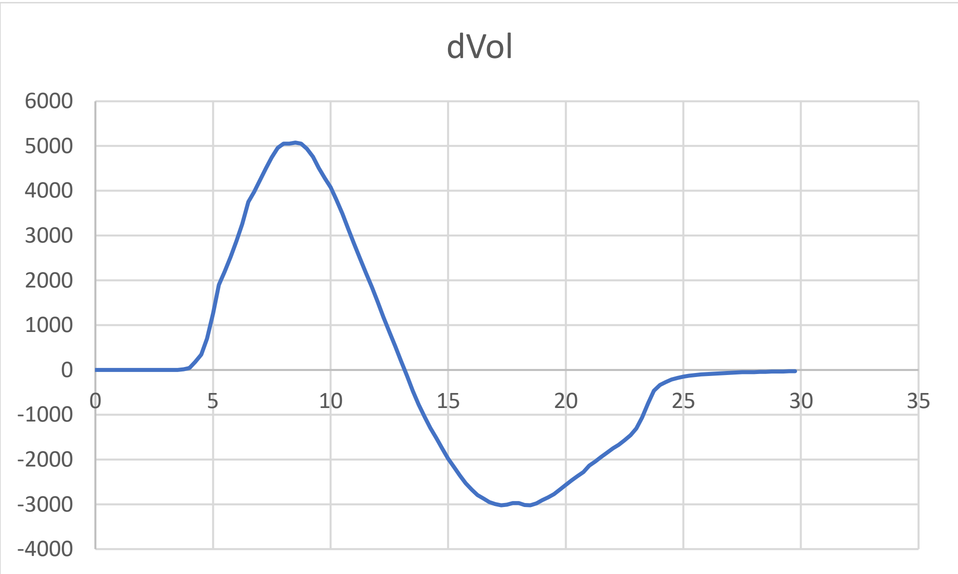

Figure 8: Dvol for 100yr +15% Climate Change Proposed Scenario.

5. SENSITIVITY TESTS

A number of sensitivity tests were run on the 100 year plus 15% climate change proposed scenario.

5.1 Manning's N Roughness Coefficient

An analysis of ±20% manning's N roughness coefficient value sensitivity runs indicates a change in ±180mm in the site. This shows that the modelled depths are moderately sensitive to the Manning's N roughness coefficient. The modelled extents adjacent to the development area are ensitive to the Manning's N roughness particularly in the East of the site (Figure 9). However, other areas of the model extents and depths are more sensitive to Manning's N roughness. The modelled confidence limits for Mannings n roughness for the entire model are ±950 mm but generally lying between ±50mm to ±180mm.

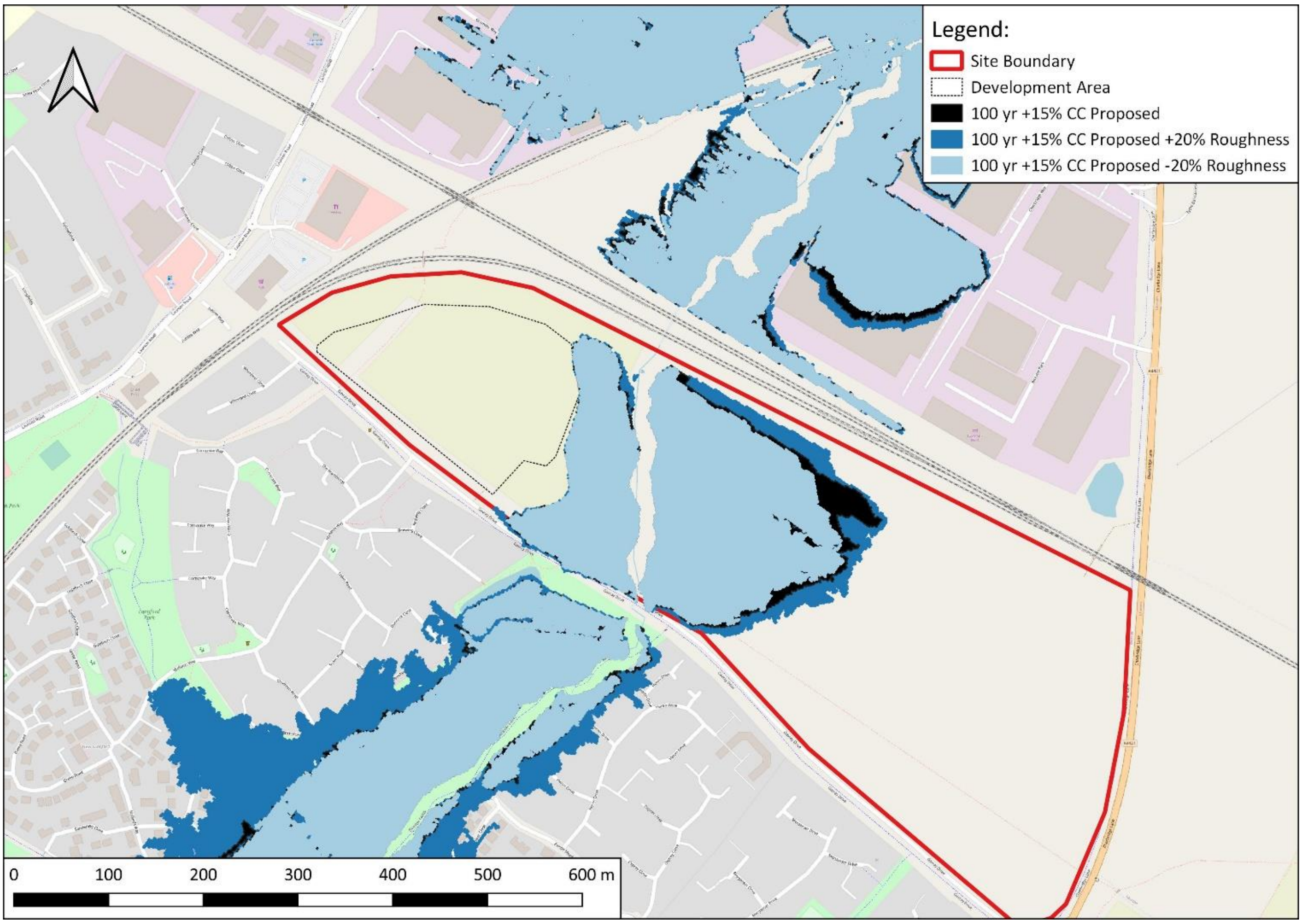

Figure 9: 1 in 100 Year +15% Climate Change Proposed Scenario compared to the Roughness Sensitivity Test.

5.2 Downstream Boundary

An analysis of ±20% downstream boundary sensitivity runs indicates no change to flood depth at the site. This shows that the modelled depths are sensitive to the downstream boundary. Figure 10 shows the downstream boundary has no effect on the flood extents at the site. The modelled confidence limits for the downstream boundary for the entire model are ±18mm.

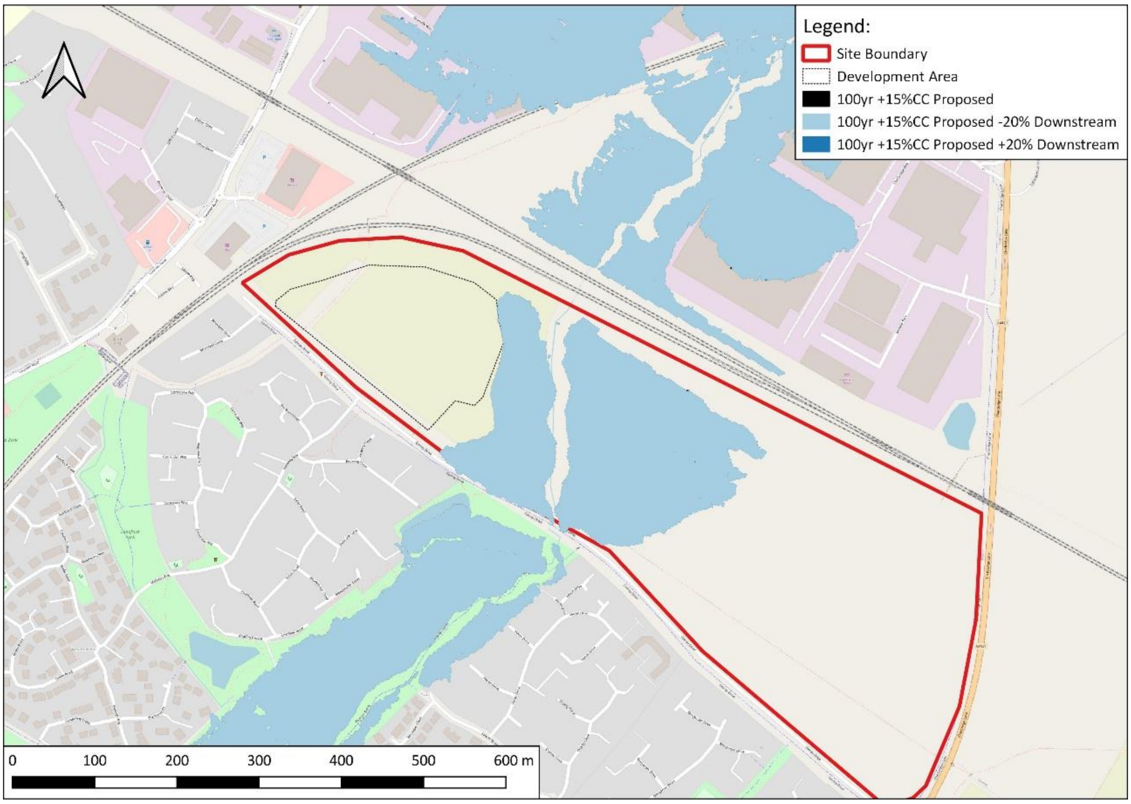

Figure 10: 1 in 100 Year +15% Climate Change Proposed Scenario compared to the Downstream Boundary Sensitivity Test.

5.3 Blockage Scenario

The flood relief culverts on Gavray drive were removed to provide a 100% blockage scenario. Figure 11 shows the blockage does not significantly affect the flood extent adjacent to the proposed developments. An analysis shows that the blockage increases the depths adjacent to the developments by an average of 20mm.

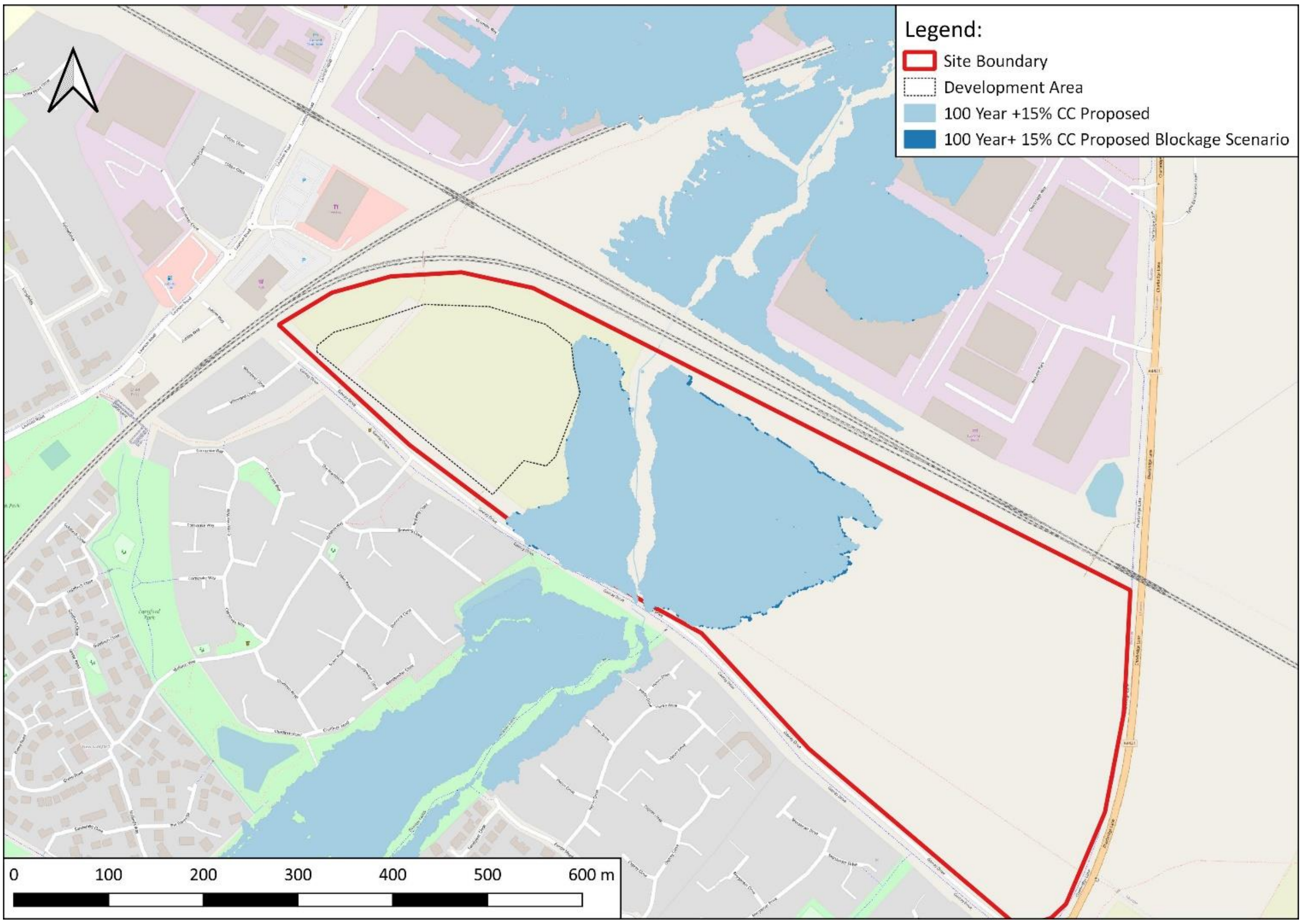

Figure 11: 1 in 100 Year +15% Climate Change Proposed Scenario compared to the Blockage Scenario.

6. RESULTS

6.1 100 Year +15% Climate Change Results

Figure 12 shows that the development does not flood in the proposed scenario for the 100 year plus 15% climate change scenario.

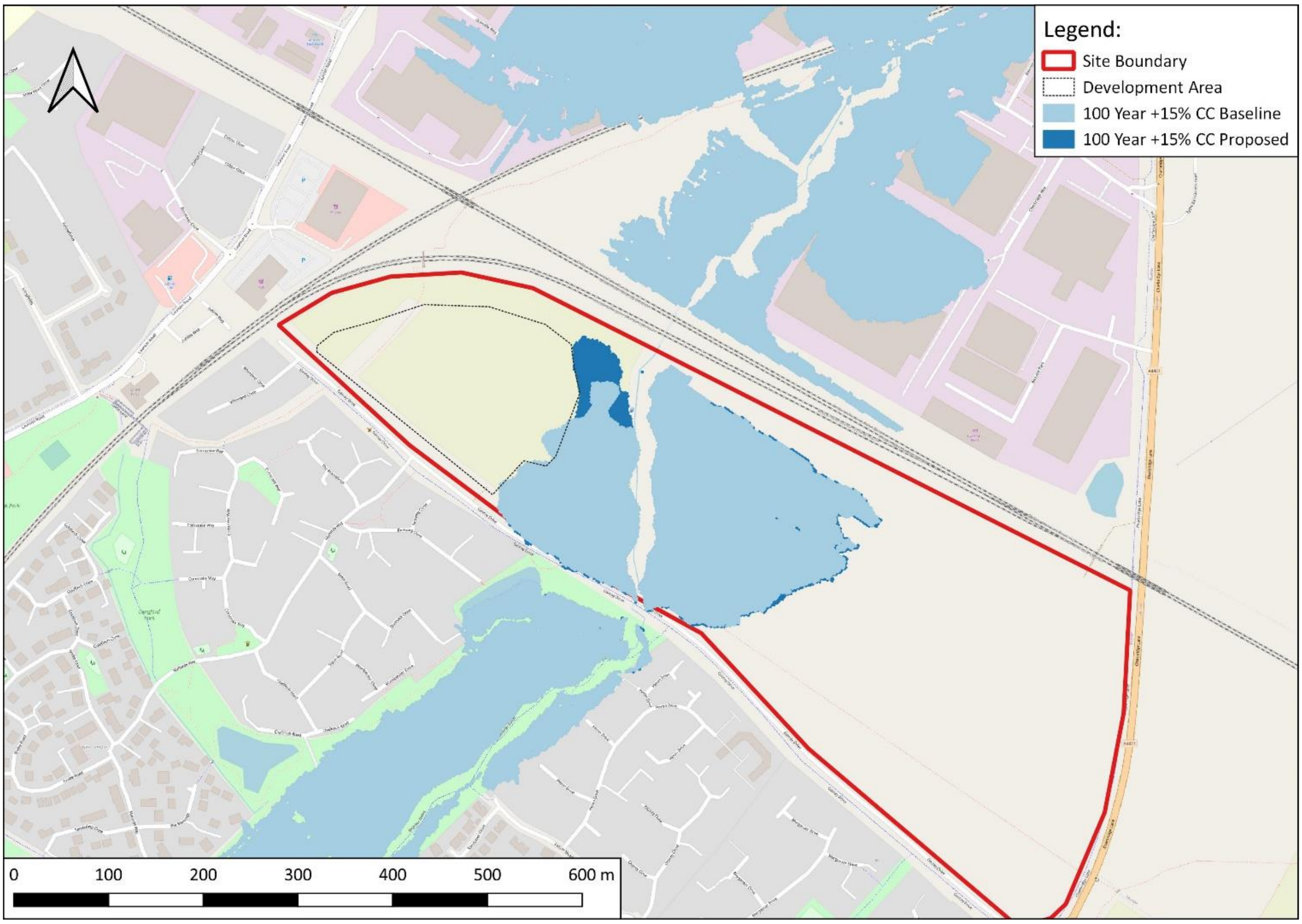

Figure 12: 100 Year +15% Climate Change Baseline and Proposed Scenario Extents

Figure 13 shows the difference in flood depths between the baseline and proposed. This shows that the proposed scenario does not make a difference in levels upstream and downstream of the site. The average difference in depth around the site is 1mm which is due to model tolerances.

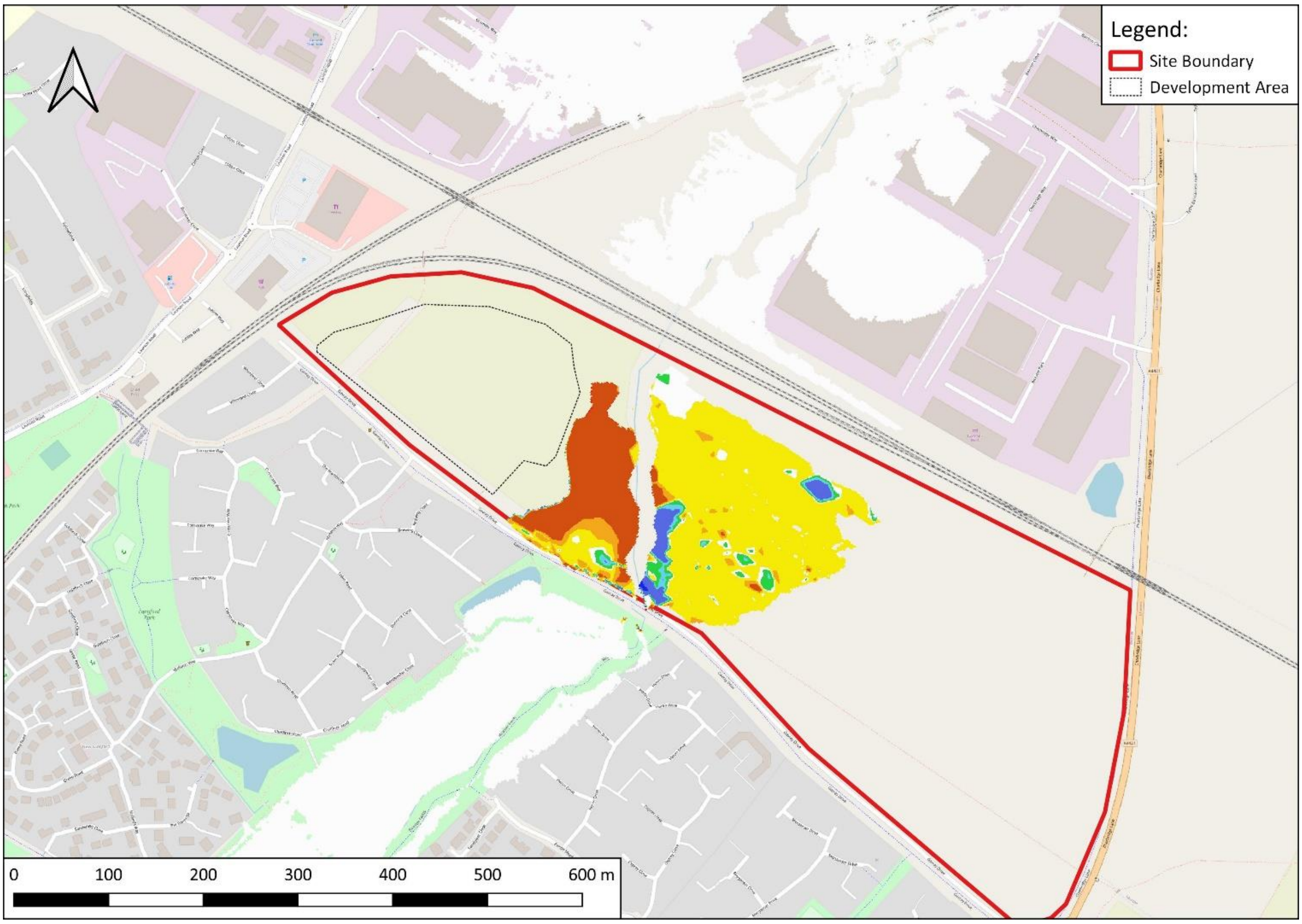

Figure 13: Depth Comparison for 100 Year +15% CC Scenario Between Baseline and Proposed Scenarios

6.2 1000 Year Results

Figure 14 shows that the development does not flood in the proposed scenario for the 1000 year scenario.

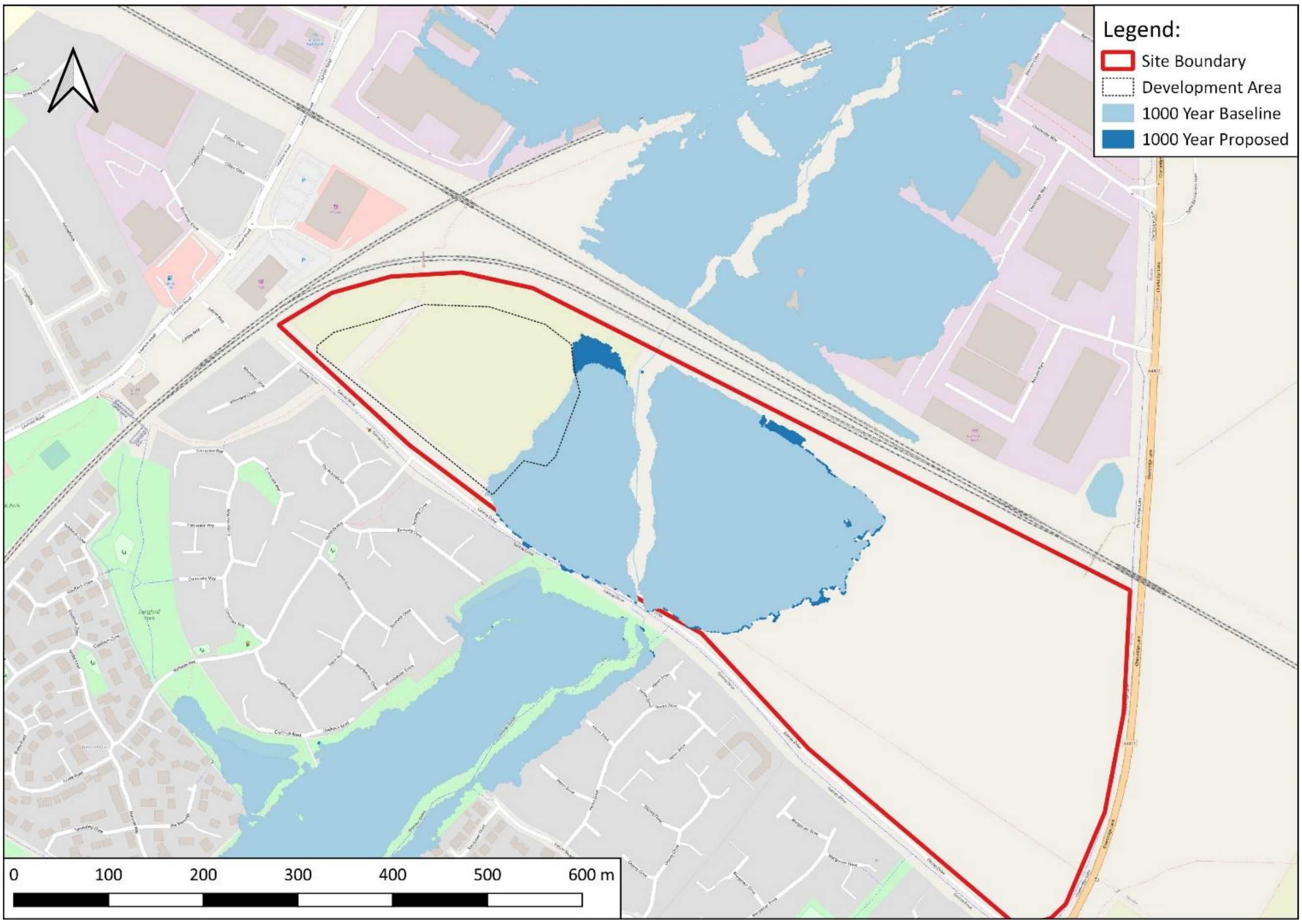

Figure 14: Depth Comparison for 100 Year +15% CC Between Baseline and Proposed Scenarios

7. CONCLUSIONS

Detailed hydraulic modelling of the site and the surrounding watercourse has shown that in all scenarios, flooding is not predicted on-site after the proposed development is completed.

The proposed development does not increase flood depths or extents immediately upstream or downstream of the site.

The model has good model convergence and low mass error, indicating a stable model. The model is not sensitive to changes in the downstream boundary. The model is slightly sensitive to changes in Manning's n roughness coefficient, downstream boundary and to the blockage of the flood relief culverts on Gavray Drive.