ARCADIS

West of Ifield

Hydraulic Modelling Report

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1 Introduction

1.1 Appointment and Scope

Homes England are preparing a hybrid planning application for the West of Ifield development. Full planning will be sought for the enabling infrastructure which includes the Crawley Western Multi-Modal Corridor (Phase 1) and new bridge crossing of the River Mole. For the purposes of this hydraulic modelling report, these two components of the enabling infrastructure will be referred to as 'the scheme'. Arcadis Consulting (UK) Ltd (Arcadis) has been commissioned by Homes England to carry out hydraulic modelling of the scheme.

The tasks completed to inform this study are:

- Generation of the 1 in 30 annual chance flood flows (refer to Section 2)
- Baseline model updates to the existing approved 1D2D Flood Modeller Pro (FMP) TUFLOW River Mole hydraulic model
- With scheme hydraulic modelling
- Review and assessment of floodplain compensation areas
- Preparation of a hydraulic modelling report including supporting figures
- Submission of the updated modelling to the Environment Agency

1.2 Background

A Flood Risk Assessment for the West of Ifield development (incorporating the scheme) was originally prepared by Ramboll in April 2023[1] (note that this has since been updated) and was informed by hydraulic modelling carried out at the time. The Ramboll hydraulic modelling report is included in Annex 1. The hydraulic model was previously approved by the Environment Agency in November 2022 and shared with Arcadis for the purposes of this project. This model is referred to throughout this report as the 'Ramboll model'. Further information on the modelling is presented in Section 3. The scheme is located to the north west of Ifield, Crawley, West Sussex, approximate NGR TQ 241 377, shown in Figure 1-1.

[1] Ramboll (A 2025) West of Ifield Flood Risk Assessment

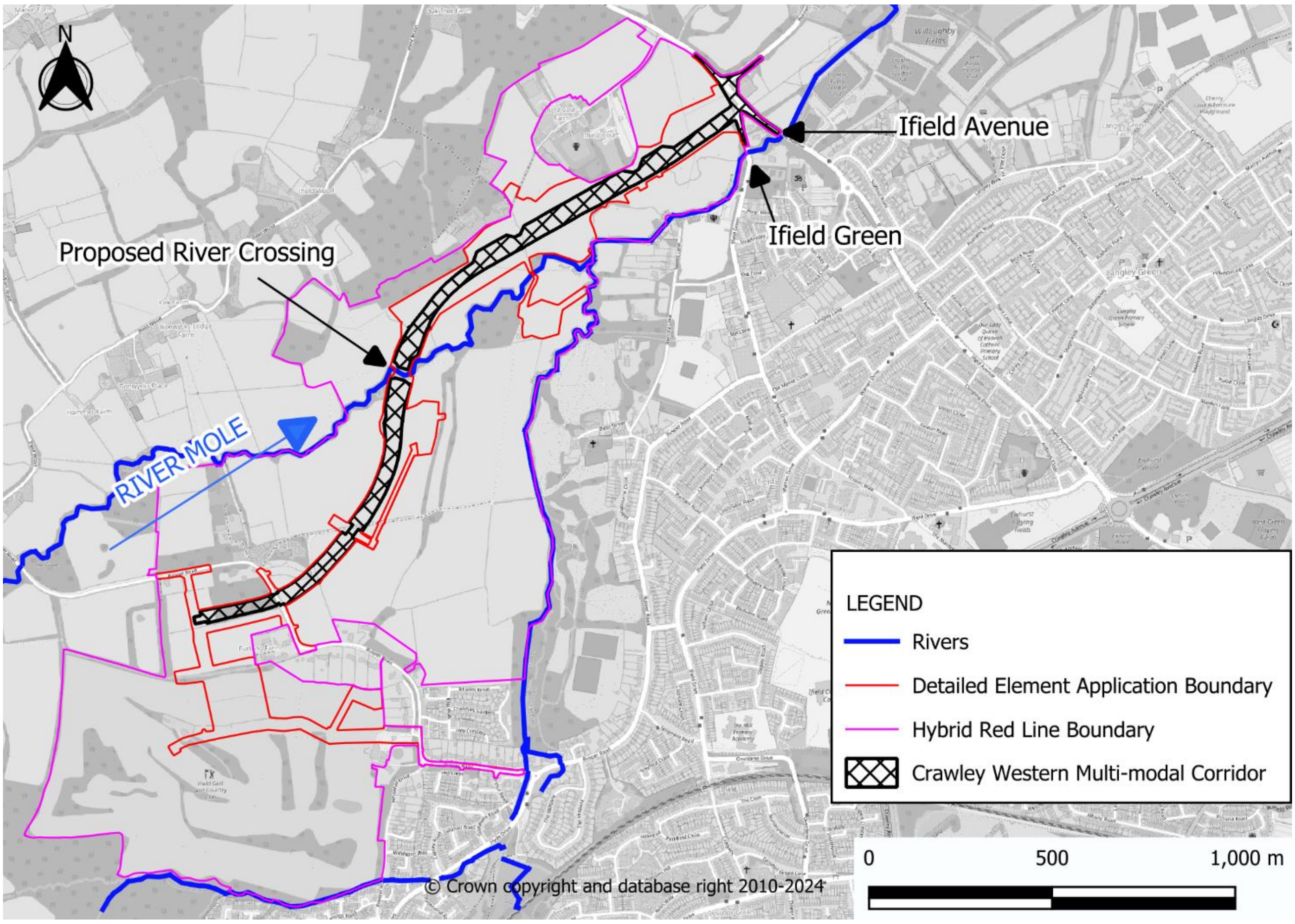

Figure 1-1: Location Map

1.3 Flood History

A full narrative regarding flood history is included in the latest Flood Risk Assessment[2]. Discussion with the Environment Agency in April 2024 indicated that the area in the vicinity of the scheme experiences frequent and rapid flooding with multiple reports of flooding in Ifield Green[3]. As of June 2025, Homes England were not aware of any recent reports of flooding on the site itself.

1.4 Terminology

Flood risk is a product of both the likelihood and consequences of flooding. Throughout this document, flood events are defined according to their likelihood of occurrence. Floods are described according to an ‘annual chance’, meaning the chance of a particular flood occurring in any one year. This is directly linked to the probability of a flood. For example, a flood with an annual chance of 1 in 100 (a 1 in 100 chance of occurring in any one year), has an annual probability of 1% or 1% annual exceedance probability (AEP).

[2] Ramboll (June 2025) West of Ifield Flood Risk Assessment
[3] Meeting held with the Environment Agency, 26th April 2024

2 Hydrology

A full review of the supplied hydrology was outside the scope of this project. It is understood that the hydrology has previously been reviewed in detail and approved by the Environment Agency as part of the Upper Mole Fluvial Flood Modelling Study[4].

2.1 1 in 30 Annual Chance Design Flood

2.1.1 Context

The National Planning Policy Framework (NPPF[5]) was updated in August 2022 and amended the definition of the functional floodplain from the 1 in 20 annual chance flood extent to the 1 in 30 annual chance flood extent. The modelling supplied to inform this study did not include inflows for the 1 in 30 annual chance event therefore Arcadis undertook some additional analysis to generate these flows for all model inflow points.

2.1.2 Flood Estimation Handbook (FEH) Boundaries

The model contains eight inflow boundaries of which six are FEH[6] boundary units. For these units, flow hydrographs were derived for the hydraulic model using the FEH-FSR Rainfall Runoff method based on catchment descriptors. Peak flows for these hydrographs were set based on reconciling them such that routed flows achieved a match to flow estimates generated from FEH Statistical analysis of flow gauge records recorded at three flow gauging station locations in the catchment (39053 Mole at Horley, 39054 Mole at Gatwick Airport and 39086 Gatwick Stream at Gatwick Link).

The growth factors derived as part of the existing hydrology for the three flow gauging stations for the 1 in 20 annual chance and 1 in 50 annual chance (FEH Statistical) events were plotted. A growth curve and trendline equation were derived in order to estimate the 1 in 30 annual chance growth factors and these were applied to QMED to derive the 1 in 30 annual chance flows for each gauging station. These would be used in the model for reconciliation of the newly derived 1 in 30 annual chance flows for the existing FEH boundaries in the model.

Scaling factors and peak flows used in the existing FEH boundaries for the model nodes were plotted for the 1 in 20 and 1 in 50 annual chance events. A growth curve and trendline equation were derived in order to estimate the 1 in 30 annual chance adjusted scaling factor and peak flows. These were adjusted in the FEH boundaries in Flood Modeller Pro, in addition to the rainfall event data which was also updated to reflect a 1 in 30 annual chance storm.

No changes in the scaling factors were noted when comparing the 12 hour and 24 hour storm durations for the existing 1 in 20 annual chance and 1 in 50 annual chance events. Therefore, the same adjusted scaling factors were used to derive the 1 in 30 annual chance peak flow for both storm durations.

2.1.3 Flow Time (QT) Boundaries

Model nodes 03_1831 (Crawter's Brook north of Crawley) and 11_2139D (Ifield Mill Pond) were represented as flow time (QT) boundaries resulting from the fact that that the original River Mole model supplied to Ramboll was cropped to speed up run times and to remove the superfluous areas of catchment. In order to derive the corresponding hydrographs for the 1 in 30 annual chance event for each node, peak flows were

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[4] Upper Mole Fluvial Flood Modelling Study, Jacobs ch2m, 2018
[5] https://www.gov.uk/guidance/national-planning-policy-framework
[6] https://www.ceh.ac.uk/our-science/projects/flood-estimation-handbook

plotted for the 1 in 20 and 1 in 50 annual chance events and a trendline equation was applied to derive the 1 in 30 annual chance event for each node (for both the 12 hour and 24 hour storm durations). Growth factors for the 1 in 20 annual chance to the 1 in 30 annual chance event were calculated for both nodes and storm durations. The 1 in 20 annual chance event hydrographs were extracted from the existing QT boundaries in the model for both nodes and storm durations and scaled according to the corresponding growth factors. The adjusted hydrographs for the 1 in 30 annual chance event were added into a QT boundary for use in the model.

2.2 Climate Change

The scheme is located in the Mole Management Catchment. For the 2080s epoch, the upper end allowance of plus 40% has been applied to the 1 in 100 annual chance flood event[7]. The 2080s epoch is applicable for the highway scheme which is considered to be essential infrastructure with a 100 year lifetime. All model inflows for the 1 in 100 annual chance design flood have been scaled by 40% to assess this.

[7] https://environment.data.gov.uk/hydrology/climate-change-allowances/river-flow?mgtmcatid=3058

3 Hydraulic Modelling

3.1 Model History

The approved River Mole model was supplied to Arcadis for use in this study. As this model was previously approved by the Environment Agency, this model report and the subsequent Environment Agency review process is focussed on the changes made since the approval in November 2022. This model is referred to as the 'updated baseline model' throughout this report.

The updates made to the Ramboll baseline model by Arcadis are:

- Replacing the lidar with the latest lidar downloaded in February 2024[8]. This issue was highlighted by the Environment Agency during their review of the Ramboll model. It was also necessary to update the lidar data to ensure consistency with the DTM data collected by Maltby Land surveys in February 2019 on the site that has been used to design the scheme.
- Amendments to the linking between the 1D model and the 2D model (locations and levels) in the vicinity of the scheme. This was necessary due to the change in lidar and also to comply with best practice modelling guidance.
- Topographic survey data for Ifield Green and Ifield Avenue was supplied by the design team and applied as an ASCII file. This was done to improve the definition of the roads in this location and also to ensure that the proposed highway alignment tied in with the existing ground levels.
- Additional elevation detail was added to the bridge parapets at Ifield Green and Ifield Avenue. This survey data is included within the packaged model data.

3.2 Updated Baseline Model Schematisation

A schematic showing the key features of the updated baseline model which are relevant to this study is presented in Figure 3-1. For context, the scheme is also shown. A list of assumptions and limitations is included in section 7.

[8] https://www.data.gov.uk/dataset/f0db0249-f17b-4036-9e65-309148c97ce4/national-lidar-programme

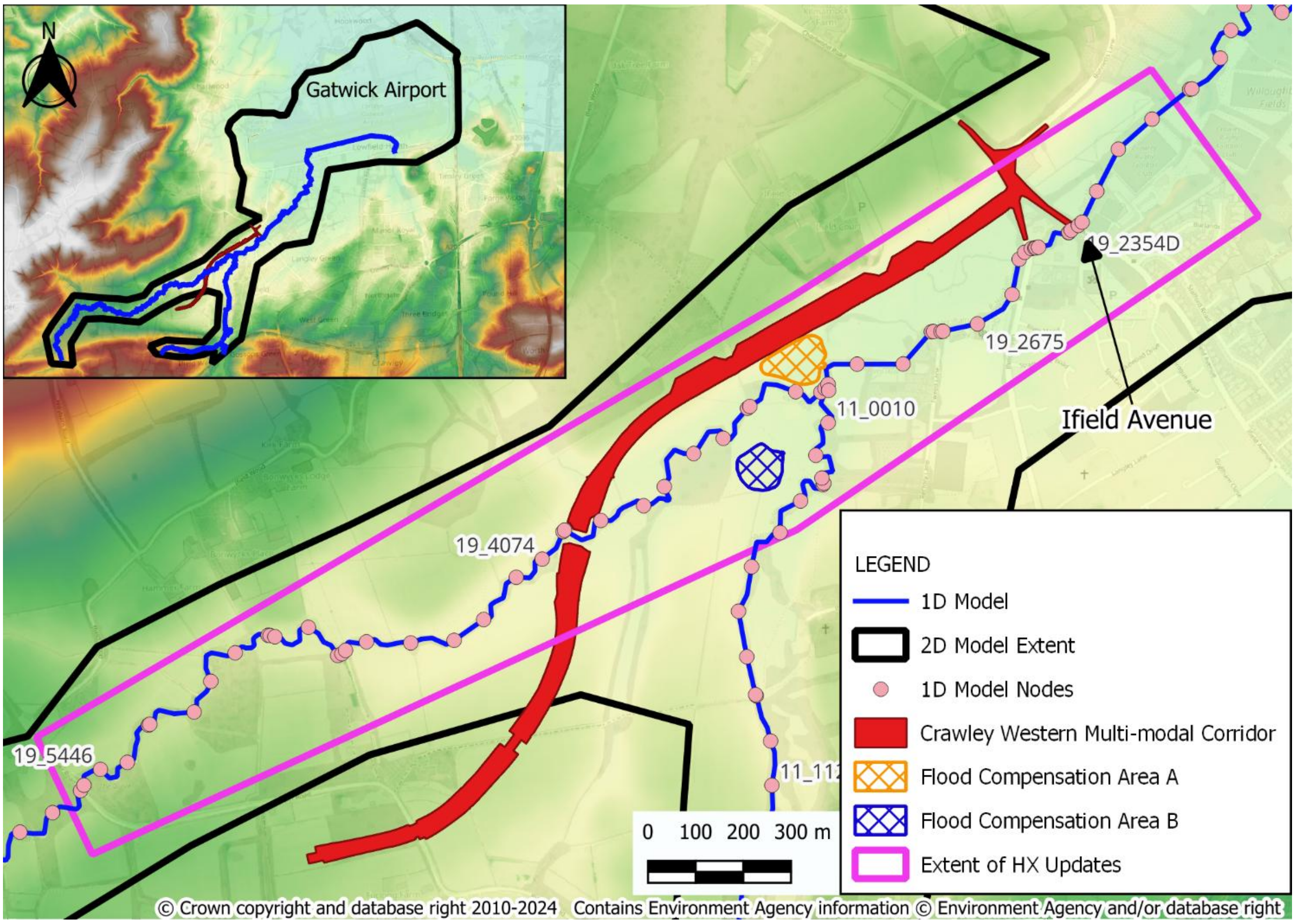


Figure 3-1: Model schematic

3.3 Proposed Scheme Modelling

3.3.1 Highway

The scheme comprises a new highway which will link the southern area of the West of Ifield development site to the existing Ifield Avenue. The highway will be located on an embankment which is raised above surrounding ground levels, tying into existing levels at Ifield Avenue.

The alignment of the highway has been in development since 2019 and has involved extensive consultation with West Sussex County Council and Local Authorities[9]. Community engagement and pre-application discussions have also been held to ensure that the scheme follows a design response that is aligned with local objectives. The final design takes into account multiple constraints including flood risk, scheduled ancient monument north of the River Mole, requirement to incorporate active travel provision, veteran and rare trees, ecological habitats for bats and birds and proximity of existing properties. This latest design therefore represents the optimal balance between all identified constraints.

The highway embankment encroaches onto the existing flood plain of the River Mole at the north eastern end, therefore inclusion of the embankment in the model is key to assessing any impacts. The highway will cross the River Mole at approximate NGR TQ 242 377. The proposed bridge will have a single span with abutments set back approximately 8m from the watercourse and a soffit level of 66.48mAOD which is 2.3m above the 1

[9] West of Ifield Crawley Western Multi Modal Corridor Alignment. Technical note issued to West Sussex County Council, April 2024.

in 100 annual chance plus 40% climate change peak flood level. The depth of water on the floodplain in the 1 in 100 annual chance plus climate change event is less than 4cm in this location meaning that impacts on floodplain storage are negligible however patterns of floodplain conveyance are altered.

The location and level of the proposed highway is shown in Figure 3-3. A schematic of the Bridge design is included in Annex 2.

The highway alignment has been applied to the 2D model domain as an ASCII file. The bridge abutments sit outside of the 1D FMP domain therefore no changes were required to the FMP model. The impact of the abutments on the floodplain conveyance is accounted for by the application of the highway ASCII file in the 2D domain.

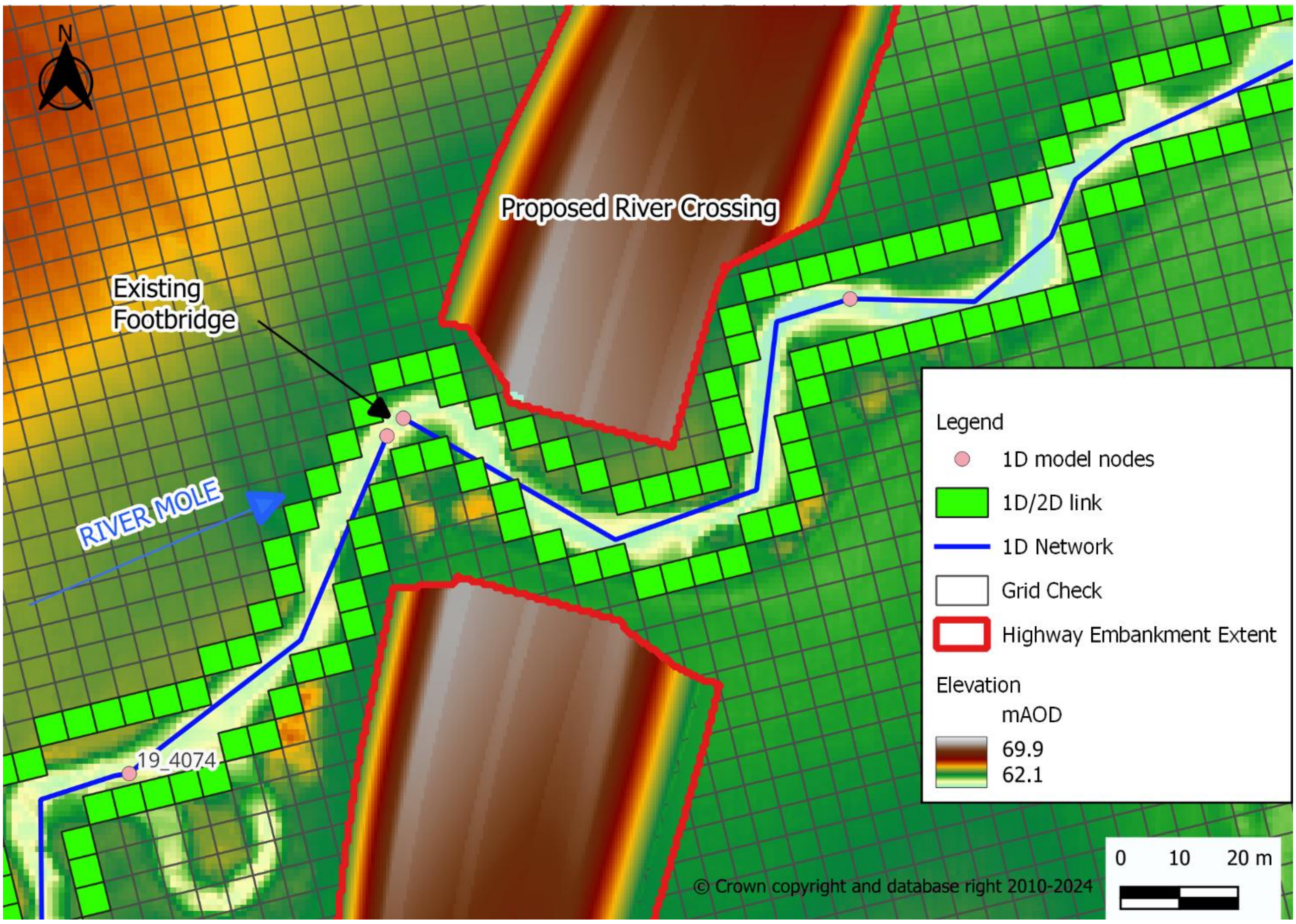


Figure 3-2: Bridge crossing model schematic showing the delineation between the 1D and 2D model domains

3.3.2 Flood Compensation Areas

In addition to the highway embankment, two flood compensation areas (FCA) were proposed as part of the Ramboll modelling to offset the lost flood volume under the highway embankment. The Arcadis design team have made some minor amendments to the levels of these FCAs which have then been applied in the model as separate ASCII files. These are referred to as FCA A and FCA B.

The FCAs are designed to function in a similar way to an online storage solution; water flows out of the River Mole channel and into the FCAs during a flood event. As flood levels recede, water will flow back out of the FCA into the River Mole. A central channel has been included in the design of the FCA, set at the elevation of the adjacent River Mole thus allowing the FCAs to fill and empty passively. A schematic of the Bridge design is included in Annex 2.

Figure 3-3 shows the location of the FCAs and proposed highway embankment elevations.

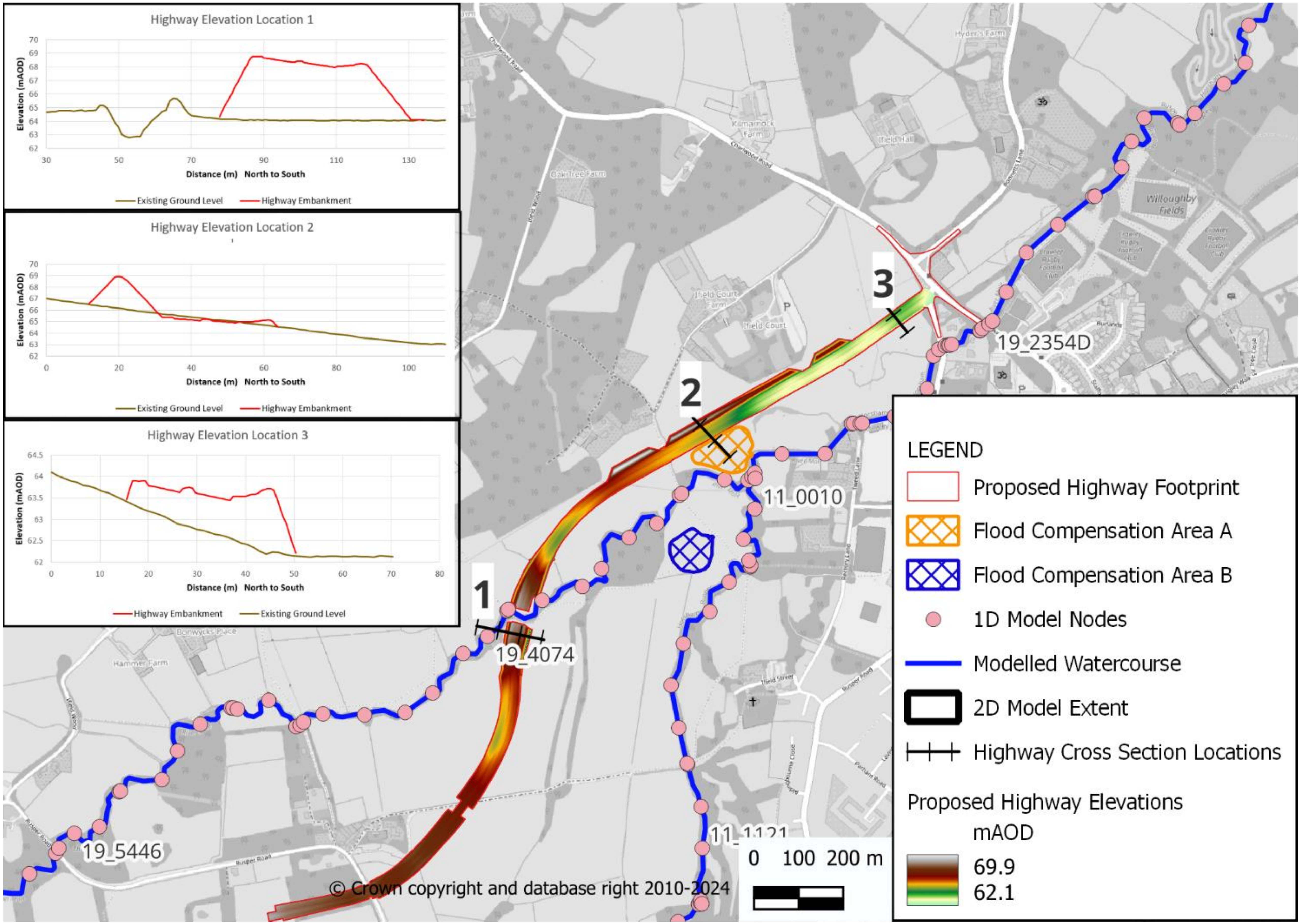


Figure 3-3: Proposed Scheme

3.4 Boundary Conditions

3.4.1 Inflows

A combination of FEH and QT boundaries are used to represent the inflows from the River Mole, Hyde Hill Brook and Bewbush Brook catchments (refer to Ramboll report in Annex 1 for details of catchment locations) upstream of the scheme. No change to the location or magnitude of these inflows has been made as part of this study. Flows for the 1 in 30 annual chance event were estimated and added to the suite of model runs, as described in Section 2.1.

3.4.2 Downstream Boundary

A normal depth boundary is applied to the north of Gatwick Airport. This is approximately 3.5km downstream of the scheme. No changes have been made to the boundary as part of this study.

3.5 Model Simulations

3.5.1 Model Scenarios

Table 3-1 summarises the scenarios modelled for this study. Based on the results of the Ramboll modelling the critical duration at the scheme was assessed to be between the 12 and 24 hour storm depending on location, with 12 hour being critical at Ifield Avenue and 24 hours being the critical duration on the River Mole at the location of the proposed bridge. The model scenarios were therefore run for both 12 and 24 hour durations for all events listed in Table 3-1.

Table 3-1: Summary of modelled design flood scenarios and events

Scenario	Description
Baseline	
1 in 30 annual chance (3.33% AEP)	Existing situation, 1 in 30 annual chance fluvial inflows
1 in 100 annual chance (1% AEP)	Existing situation, 1 in 100 annual chance fluvial inflows
1 in 100 annual chance plus 40% climate change (1% AEP CC)	Existing situation, 1 in 100 annual chance plus climate change fluvial inflows
1 in 1000 annual chance (0.1% AEP)	Existing situation, 1 in 1000 annual chance fluvial inflows
With Scheme	
1 in 30 annual chance (3.33% AEP)	Inclusive of the proposed highway embankment, 1 in 30 annual chance fluvial inflows
1 in 100 annual chance (1% AEP)	Inclusive of the proposed highway embankment, 1 in 100 annual chance fluvial inflows

Scenario	Description
1 in 100 annual chance plus 40% climate change (1% AEP CC)	Inclusive of the proposed highway embankment, 1 in 100 annual chance plus climate change fluvial inflows
1 in 1000 annual chance (0.1% AEP)	Inclusive of the proposed highway embankment, 1 in 1000 annual chance fluvial inflows
With Scheme and FCA A	
1 in 30 annual chance (3.33% AEP)	Inclusive of the proposed highway embankment and FCA A, 1 in 30 annual chance fluvial inflows
1 in 100 annual chance (1% AEP)	Inclusive of the proposed highway embankment and FCA A, 1 in 100 annual chance fluvial inflows
1 in 100 annual chance plus 40% climate change (1% AEP CC)	Inclusive of the proposed highway embankment and FCA A, 1 in 100 annual chance plus climate change fluvial inflows
1 in 1000 annual chance (0.1% AEP)	Inclusive of the proposed highway embankment and FCA A, 1 in 1000 annual chance fluvial inflows
With Scheme, FCA A and FCA B	
1 in 30 annual chance (3.33% AEP)	Inclusive of the proposed highway embankment, FCA A and FCA B, 1 in 30 annual chance fluvial inflows
1 in 100 annual chance (1% AEP)	Inclusive of the proposed highway embankment, FCA A and FCA B, 1 in 100 annual chance fluvial inflows
1 in 100 annual chance plus 40% climate change (1% AEP CC)	Inclusive of the proposed highway embankment, FCA A and FCA B, 1 in 100 annual chance plus climate change fluvial inflows
1 in 1000 annual chance (0.1% AEP)	Inclusive of the proposed highway embankment, FCA A and FCA B, 1 in 1000 annual chance fluvial inflows

3.5.2 Model Run Parameters

The model has been run using the HPC solver with an initial timestep of 0.5 seconds. The updated model has been run using FMP version 7, double precision and TUFLOW HPC, build 2023-03-AB-iSP-w64. The Ramboll model was run using FMP version 4, double precision and TUFLOW Classic, build 2018-03-AE-iDP-w64. These were the latest software versions at the time the modelling was completed and issued to the Environment Agency.

No other changes to the run parameters used in the Ramboll model were required for this study.

4 Model Proving

4.1 Model Performance

To confirm that the model converges on a solution, the performance of the simulation has been closely monitored throughout the modelling process. Convergence, in this context, refers to the ability of the modelling software to generate a solution that closely approximates the exact solution within a predetermined error tolerance as defined by the software manufactures. It is important to note that the HPC (Heavily Parallelised Compute) solver, by default, uses adaptive timestepping to progress through the simulation. The timestep is adjusted so that it complies with the mathematical stability criteria of the 2D shallow water equation explicit solution. Hence, instead of focusing solely on convergence, attention is directed towards monitoring the performance of specific parameters, namely timestep (dt), Courant Number (Nu), The Shallow Wave Celerity Number (Nc), and Diffusion Number (Nd).

Model outputs from the 1 in 100 annual chance updated baseline model are shown in Figure 4-1 and indicate the model is within the recommended parameters suggested by TUFLOW, Nu<1.0, Nc<1.0, Nd <0.3. The model is controlled by the numerical diffusion value (Nd <0.3) which is expected for this model where the water in the cells is deeper than they are wide. After the initial 15 minute stabilisation period the model timestep (dt) stabilises at a value of 1 second. The stability exhibited by the model parameters indicates the model is converging well.

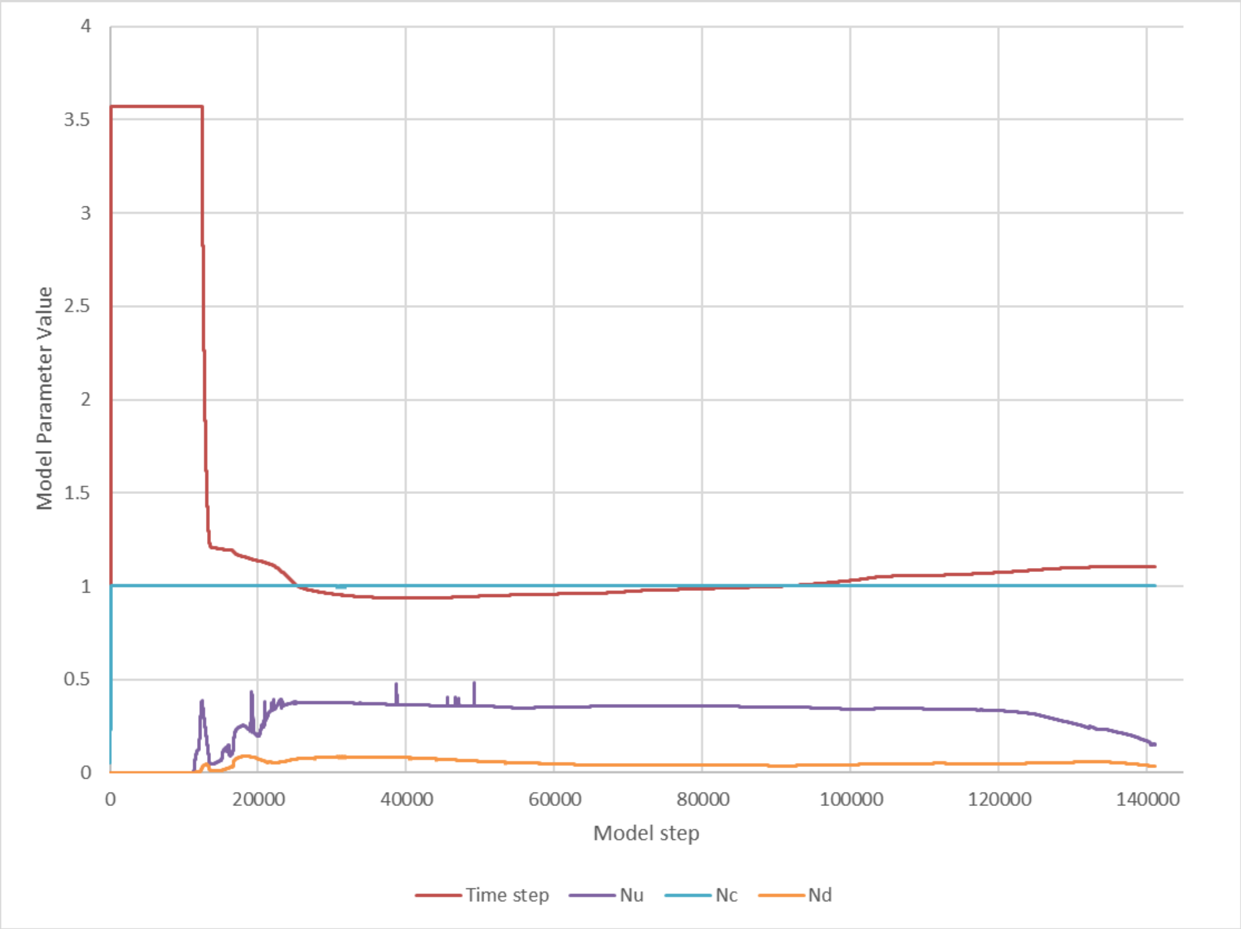


Figure 4-1: HPC parameters – 1 in 100 annual chance event (updated baseline model)

4.2 Sensitivity Analysis

Sensitivity analysis was completed by Ramboll[10] which found that:

- Changes in model inflows did not generate significant changes in flood extents in the West of Ifield site area upstream of Ifield Green Road
- The impacts of the downstream boundary sensitivity test were constrained to the area downstream of the Gatwick Airport culvert, some distance from the site.
- The sensitivity of the modelled flood depths to changes in roughness was between 0.01m to 0.10m for much of the model area. The area in the vicinity of the Gatwick Airport culvert was more sensitive to changes in roughness.

As only minor changes have been made to the Ramboll model it is not expected that the conclusions of the sensitivity tests would be altered and therefore no further sensitivity testing has been carried out for this study.

4.3 Validation

The updated baseline model results were compared to the results from the previously approved Ramboll baseline model for the 12 hour storm duration. This demonstrated that the model flood extents are very similar. Peak water levels in the vicinity of Ifield Avenue have increased by approximately 70mm and this is

[10] Ramboll (May 2022) West of Ifield – Upper River Mole - Hydraulic Modelling Summary Report

largely due to the change in lidar which typically shows an increase of 50mm when compared to the lidar used in the Ramboll model. Along the River Mole, changes to the 1D2D linking and 1D channel widths have resulted in the retention of slightly more water within bank and a consequent minor reduction in flood extents. A comparison of the modelled flood extents from the baseline Ramboll model and the modelled flood extents from the updated baseline model for the 1 in 100 annual chance, 1 in 1000 annual chance and 1 in 100 annual chance plus 40% climate change flood events are presented in Figure 4-2, Figure 4-3 and Figure 4-4 respectively.

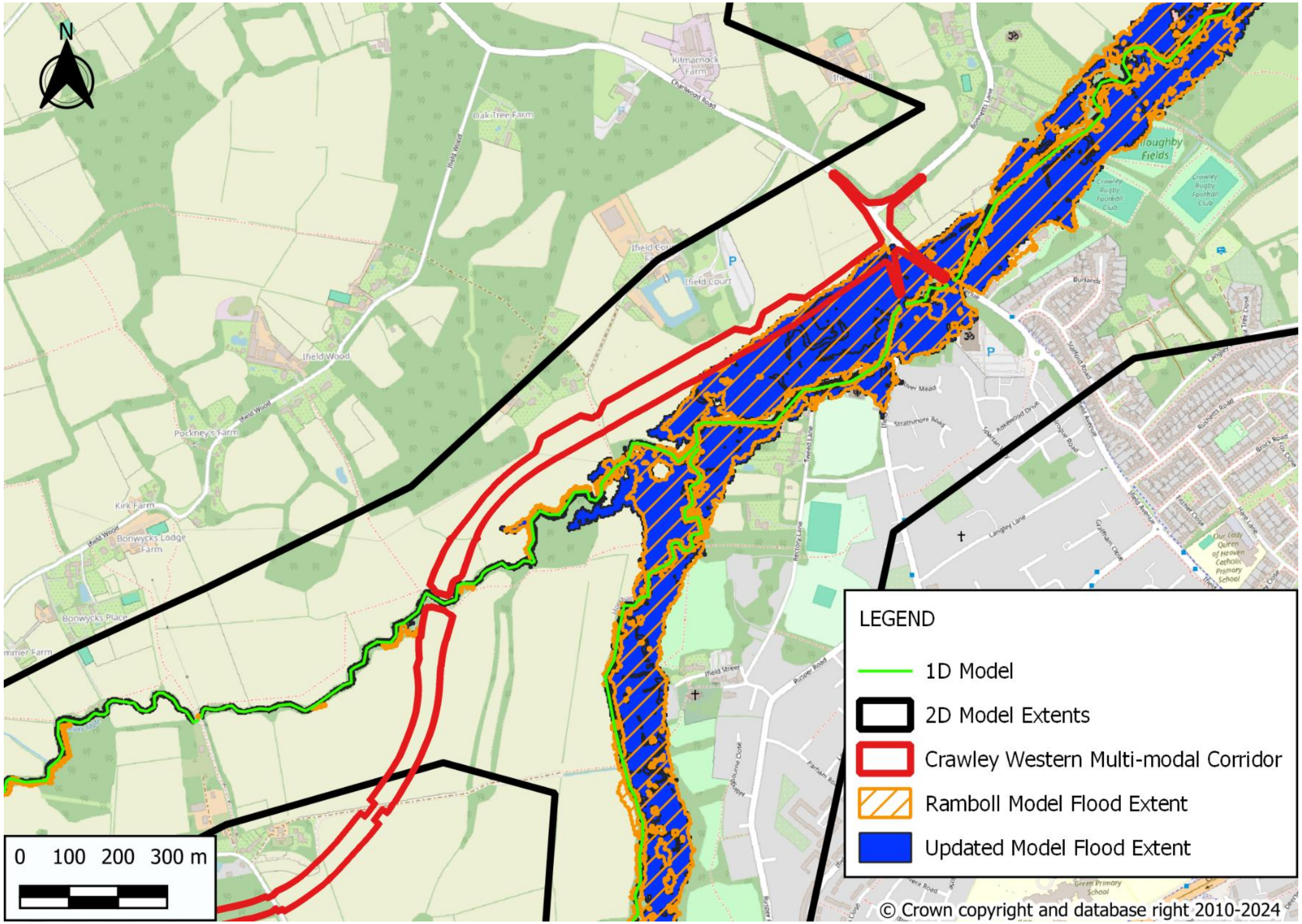


Figure 4-2: Comparison of baseline flood extents 1 in 100 annual chance event

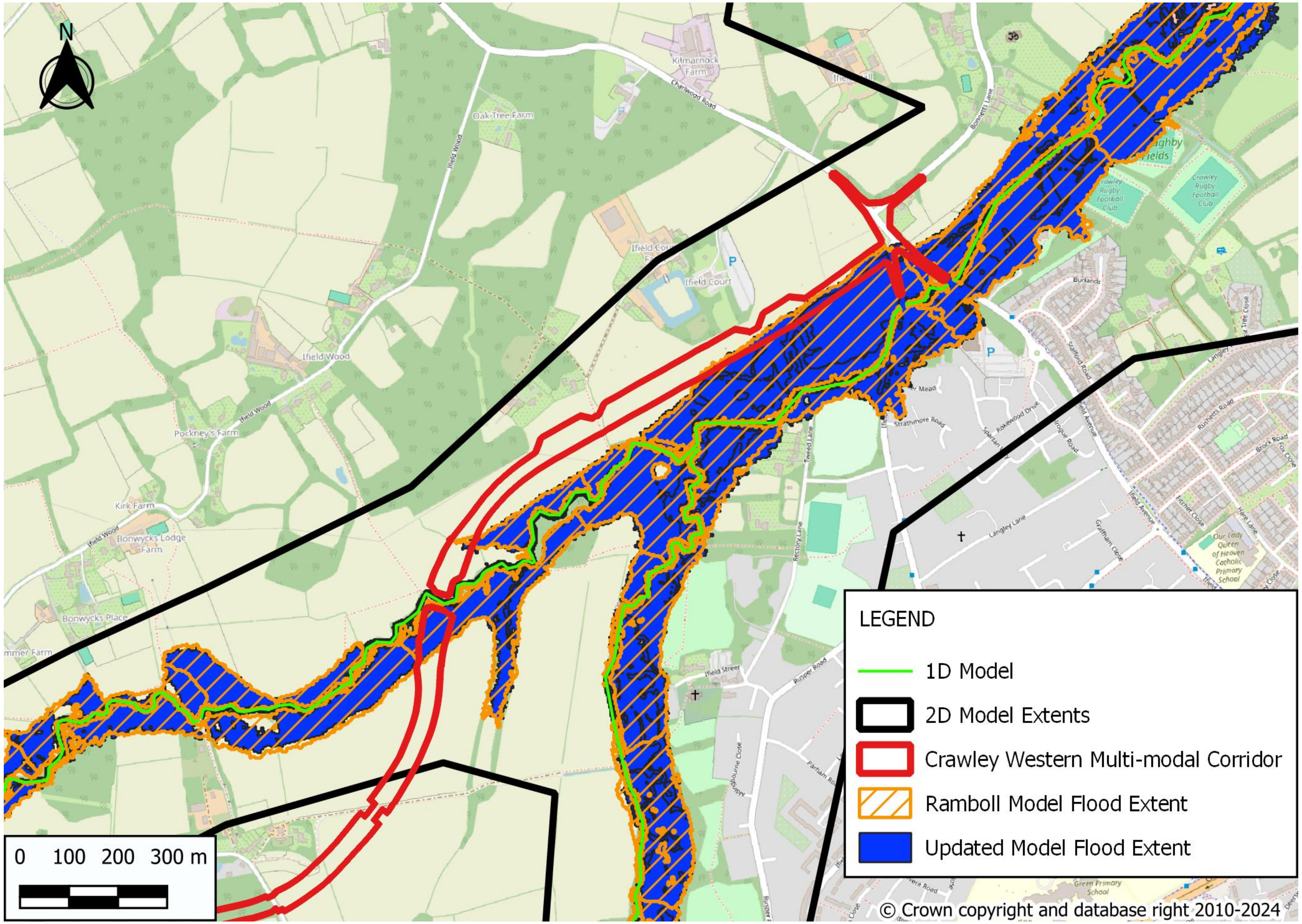


Figure 4-3: Comparison of baseline flood extents 1 in 1000 annual chance event

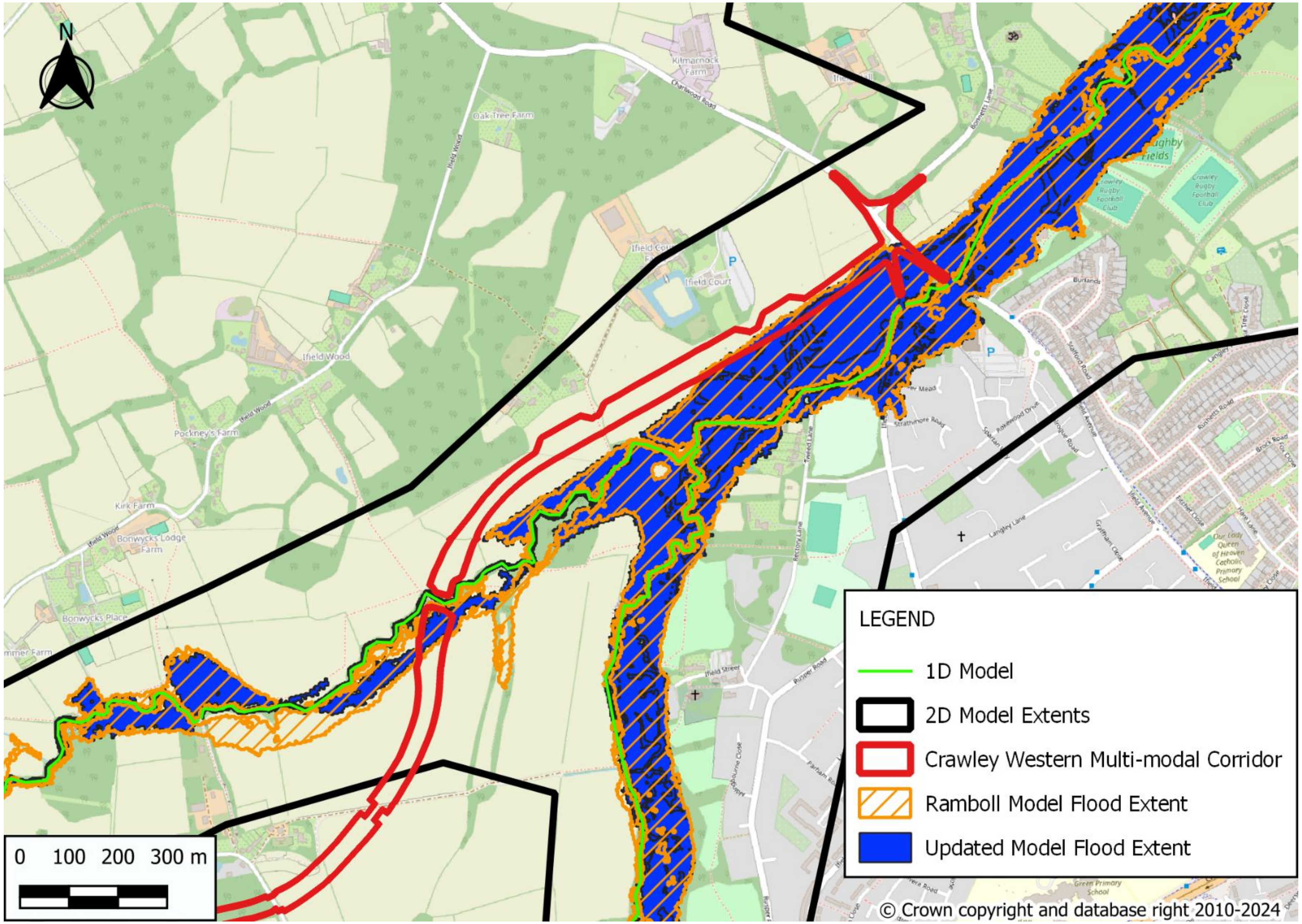


Figure 4-4: Comparison of baseline flood extents 1 in 100 annual chance event plus climate change

5 Model Results

5.1 Updated Baseline

Mapped baseline flood extents for the 1 in 30, 1 in 100 (with and without climate change) and 1 in 1000 annual chance events are included in Annex 3.

5.2 With Scheme

A comparison of the change in flood depths with the scheme in place for the 1 in 100 annual chance event plus climate change has been made. This is in accordance with Government guidance which states that:

The appropriate allowance to assess off-site impacts and calculate floodplain storage compensation depends on land uses in affected areas. Use the higher central allowance when the affected area contains essential infrastructure[11].

It is noted that the Environment Agency requested that the upper end allowance of 40% be used in assessing the impacts of the scheme rather than the higher central allowance referred to in the text above. This is also consistent with the modelling carried out by Ramboll.

The modelled flood depths for the with scheme scenario have been subtracted from baseline scenario to create a depth difference map (Figure 5-1) for the 1 in 100 annual chance plus climate change event. The green colours on the difference map refer to areas where the depth has reduced in the with scheme scenario compared to the baseline and yellow and orange colours where depths have increased as a result of the with scheme scenario. A full set of drawings showing the results for both the 12 hour and 24 hour storm duration are included in Annex 3.

[11] Flood risk assessments: climate change allowances. Accessed at https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances, May 2024

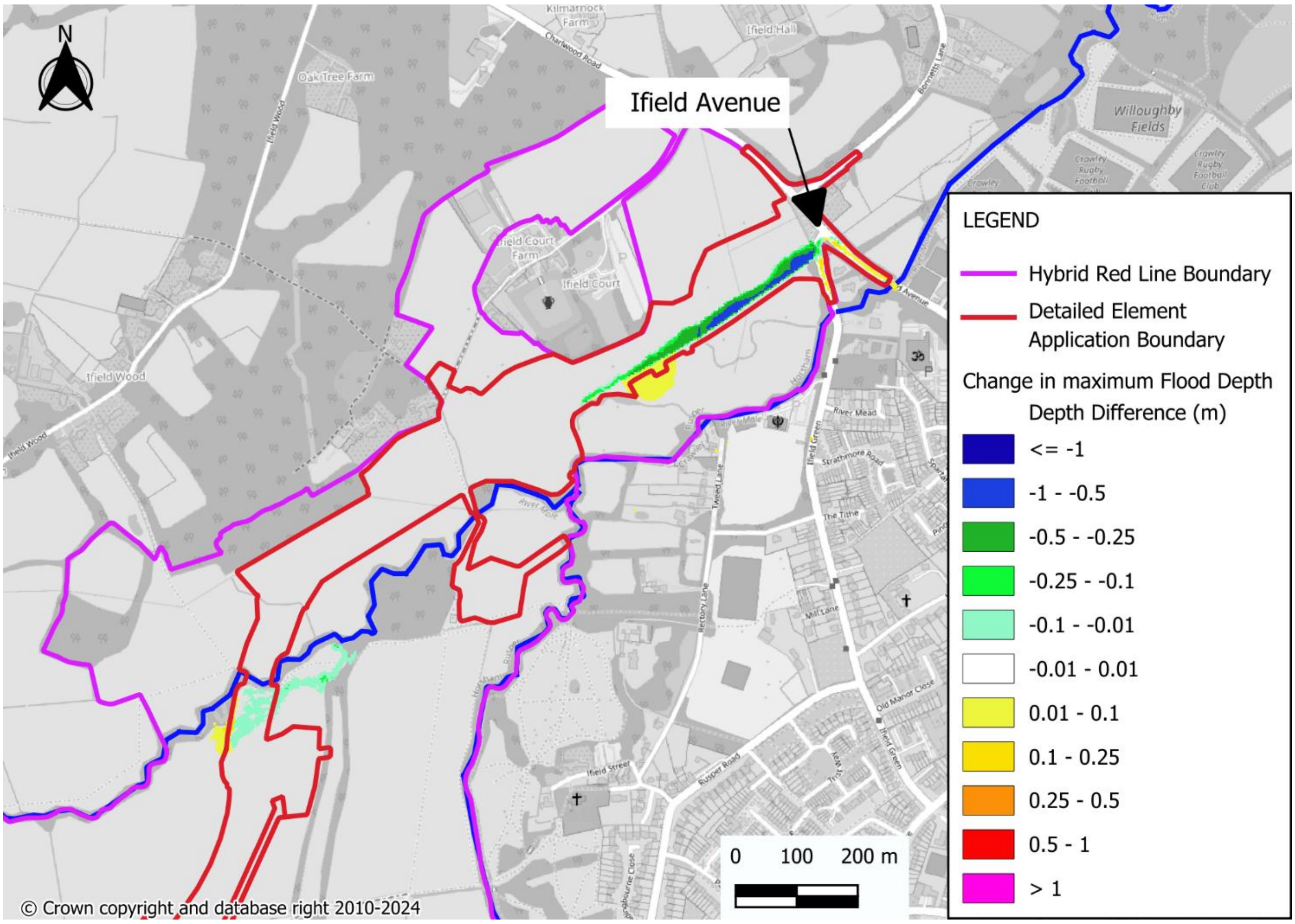


Figure 5-1: Depth difference plot, with scheme peak flood depths minus updated baseline peak flood depths (1 in 100 annual chance plus climate change 12 hour storm duration)

An assessment of the change in flow rates and volumes passing downstream of Ifield Avenue has been made to confirm that no unacceptable third party impacts are predicted to occur as a result of the scheme. Figure 5-2 presents the hydrographs for the 1 in 100 annual chance event inclusive of climate change for the updated baseline and with scheme scenarios. The changes in the peak flows and volumes passing downstream of Ifield Avenue are negligible with no change in the peak flow and an increase in total volume of 0.04%.

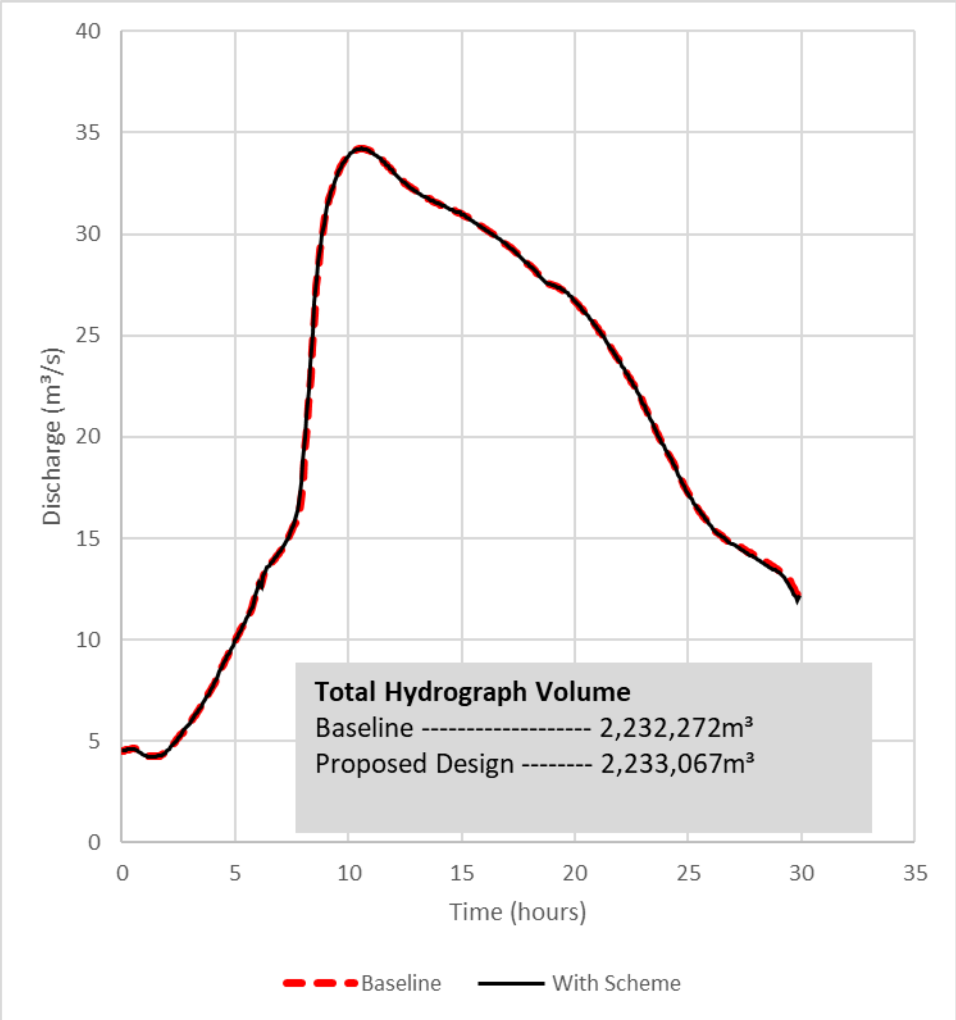


Figure 5-2: Flow hydrograph at Ifield Avenue, updated baseline and with scheme scenarios 1 in 100 annual chance plus climate change, 12 hour storm duration

5.3 With Scheme and FCA A

A comparison of the change in flood depths with the scheme and FCA A in place for the 1 in 100 annual chance event plus climate change has been made. A depth difference plot is shown in Figure 5-3.

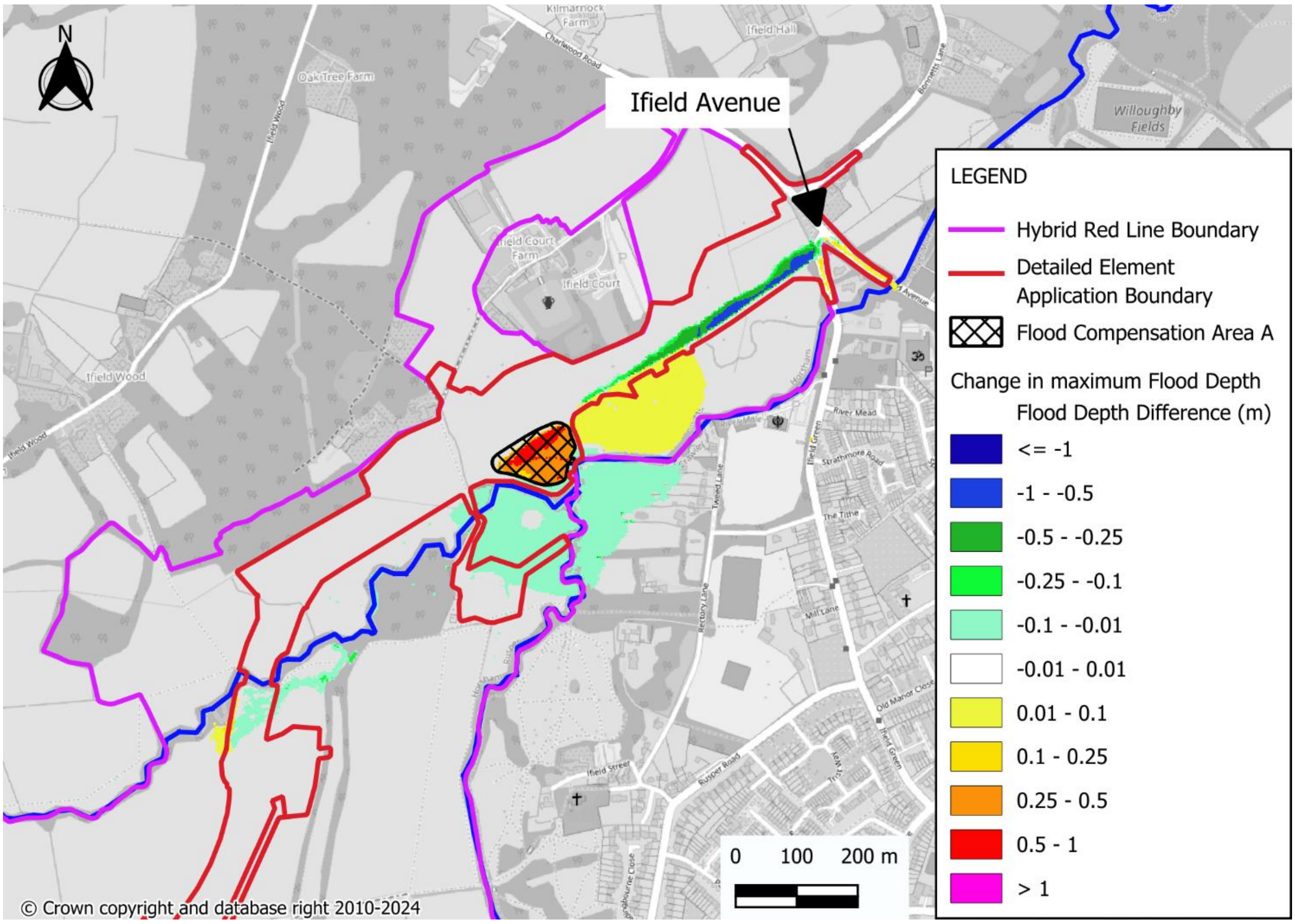


Figure 5-3: Depth difference plot, with scheme and FCA A peak flood depths minus updated baseline peak flood depths, (1 in 100 annual chance plus climate change 12 hour storm duration)

Figure 5-4 presents the hydrographs for the 1 in 100 annual chance event inclusive of climate change for the updated baseline and with scheme and FCA A scenarios. The changes in the peak flows and volumes passing downstream of Ifield Avenue are negligible with no change in peak flow predicted and the total volume predicted to reduce by 0.02%.

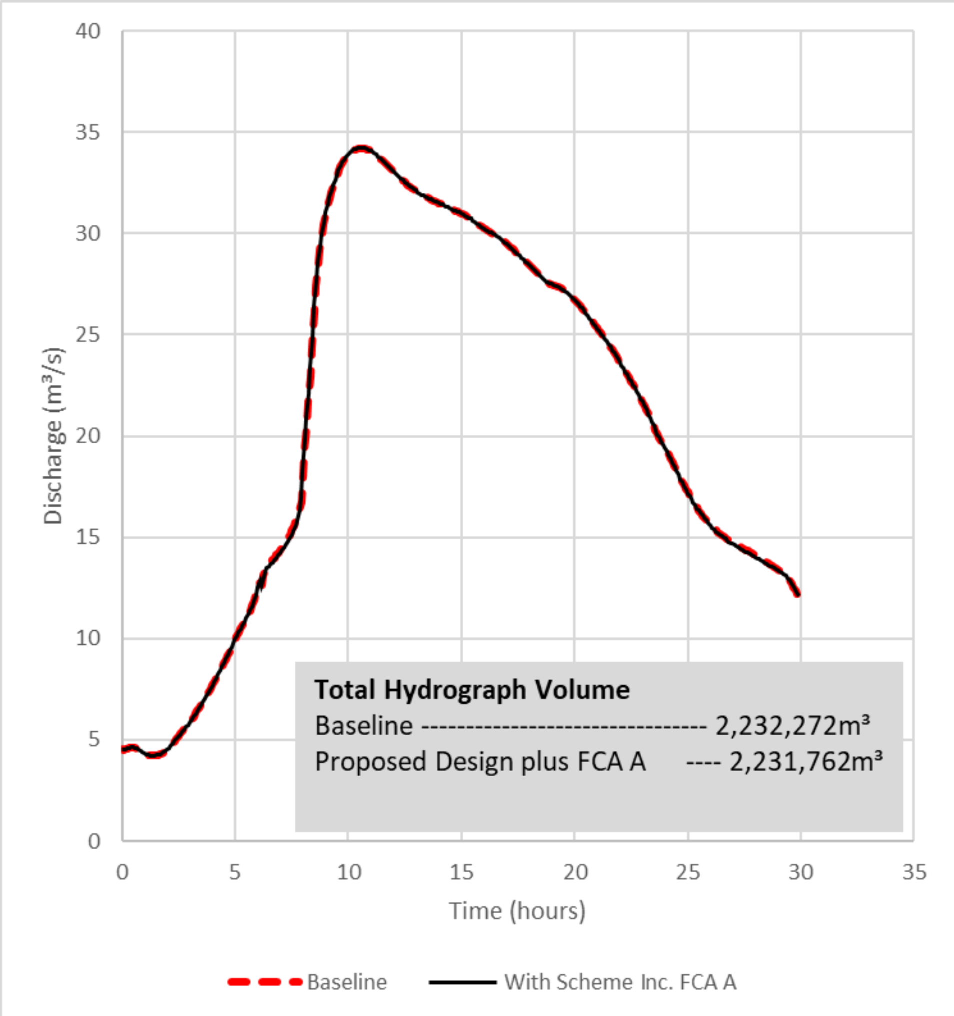


Figure 5-4: Flow hydrograph at Ifield Avenue, updated baseline and with scheme and FCA A scenarios, 1 in 100 annual chance event plus climate change, 12 hour storm duration

Flood water is predicted to enter FCA A when the flow in the River Mole reaches 9m3/s; this is approximately double the initial flow rate applied to the model. For context the 1 in 5 annual chance peak flow upstream of FCA A is approximately 12m^3/s. The FCA is predicted to become active in the 1 in 5 annual chance (smallest design flood event modelled) however FCA A only becomes partially inundated for a duration of 4 hours (12 hour critical storm).

5.4 With Scheme FCA B and FCA A

Mapped flood extents for the with scheme model for the 1 in 30, 1 in 100 (with and without climate change) and 1 in 1000 annual chance events are included in Annex 3. This demonstrates that the scheme is not predicted to flood in all events up to and including the 1 in 1000 annual chance. Note that the flood extents for the with scheme, with scheme and FCA A and with scheme and FCA A and FCA B are very similar and the differences are virtually indistinguishable when mapped. Therefore, only the with scheme and FCA A and B are included.

A comparison of the change in flood depths with the scheme, FCA A and FCA B in place for the 1 in 100 annual chance event plus climate change has been made. A depth difference plot is shown in Figure 5-5.

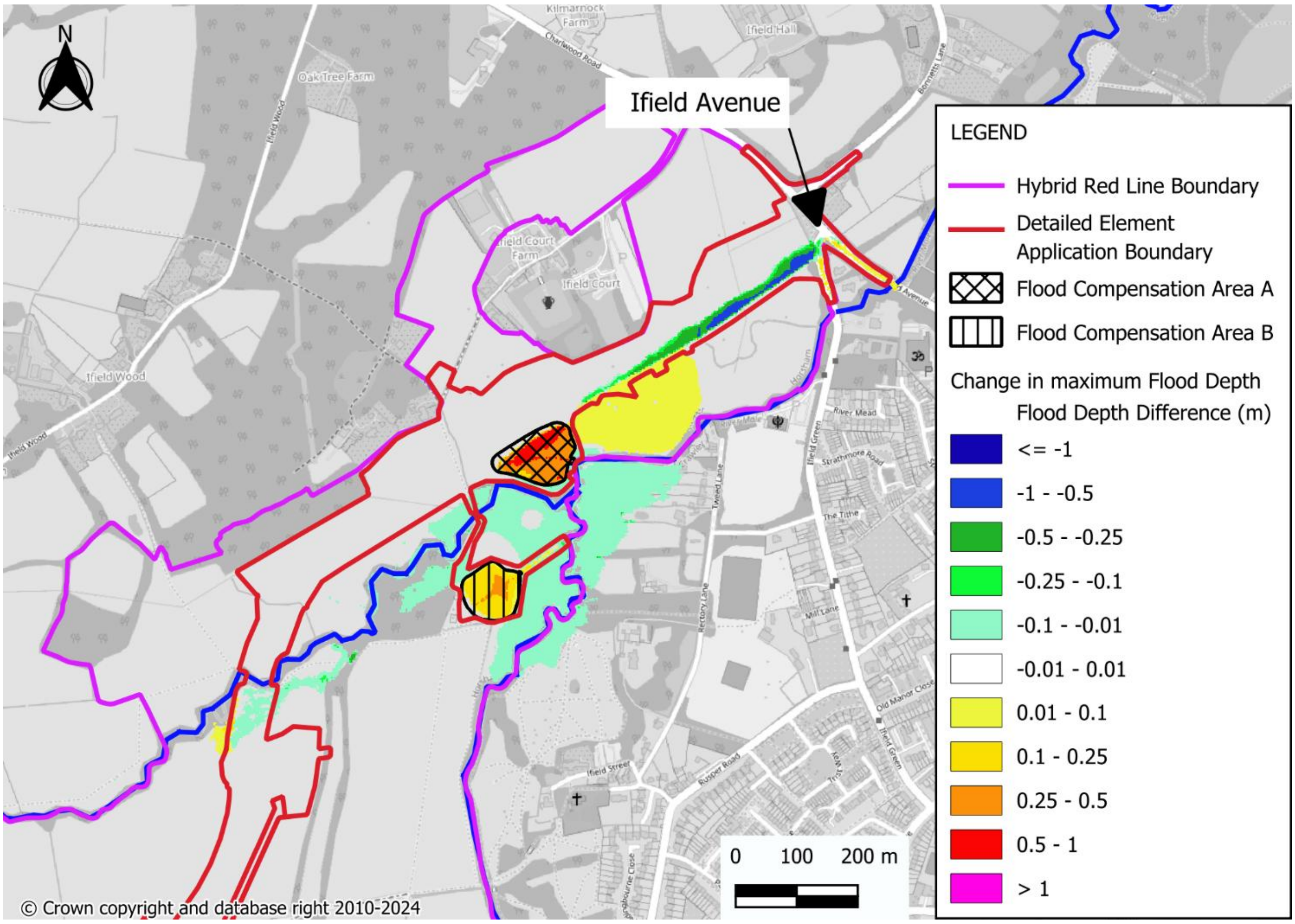


Figure 5-5: Depth difference plot, with scheme FCA A and FCA B peak flood depths minus updated baseline peak flood depths, (1 in 100 annual chance event plus climate change 12 hour storm duration)

Figure 5-6 presents the hydrographs for the 1 in 100 annual chance event inclusive of climate change for the updated baseline and with scheme and FCA A scenarios The changes in the peak flows and volumes passing downstream of Ifield Avenue are negligible with no change in peak flow predicted and the total volume predicted to reduce by 0.03%.

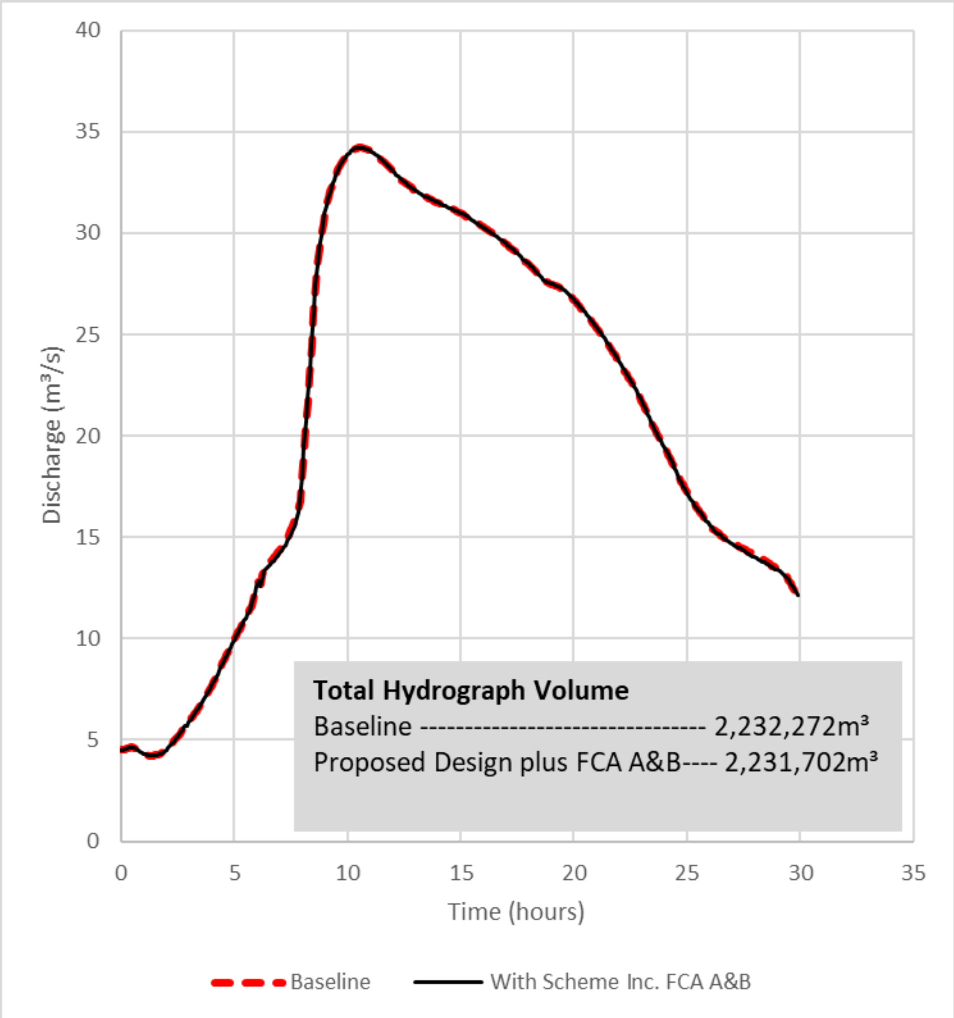
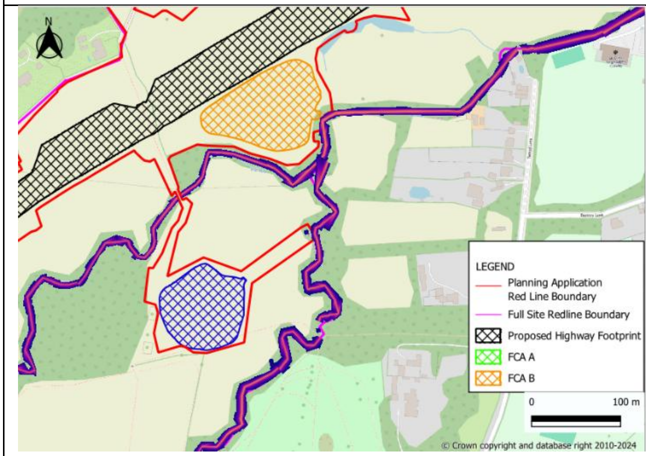


Figure 5-6: 1% AEP CC Flow hydrograph at Ifield Avenue, updated baseline and with scheme, FCA A and FCA B scenarios, 1 in 100 annual chance event plus climate change, 12 hour storm duration

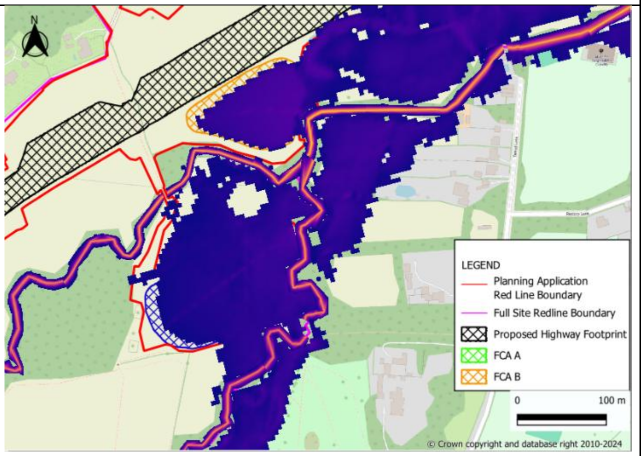
Flood water is predicted to enter FCA B when the flow in the River Mole reaches 7m^3/s; this is approximately double the initial flow rate applied to the model. The FCA is predicted to become active in the 1 in 5 annual chance (smallest design flood event modelled), however the FCA is only partially flooded and only for a duration of three hours. FCA B receives flood water from the channel connecting it with the River Mole as well as from some overland flow from upstream.

The fill and empty flow mechanisms are presented in Figure 5-7 and Figure 5-7 which show flood progression plots for the 1 in 30 annual chance and 1 in 100 annual chance including climate change flood events. The FCAs drain passively and are largely empty 24 hours later.

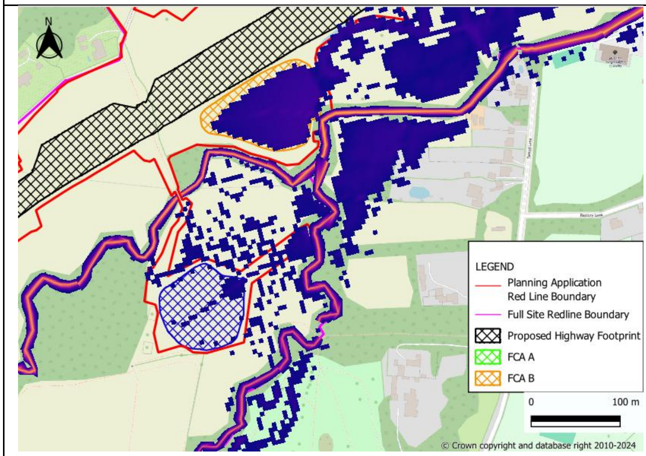
1 in 30 annual chance event 12 hour storm duration



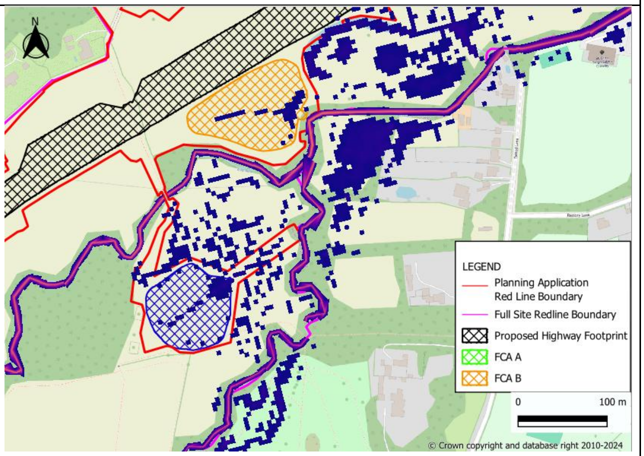
Flood extent at +06 hours



Flood extent at +10 hours



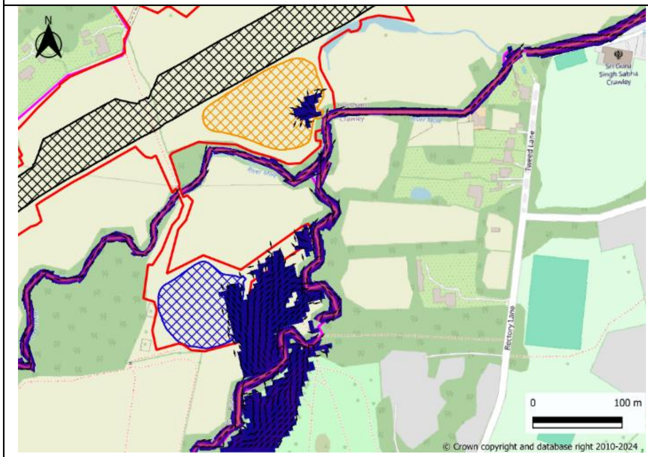
Flood extent at +20 hours



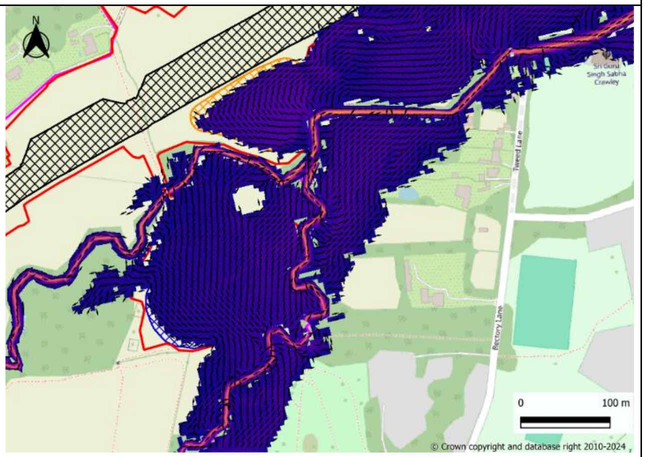
Flood extent at +30 hours

Figure 5-7: Flood progression plot, 1 in 30 annual chance event, 12 hour storm duration

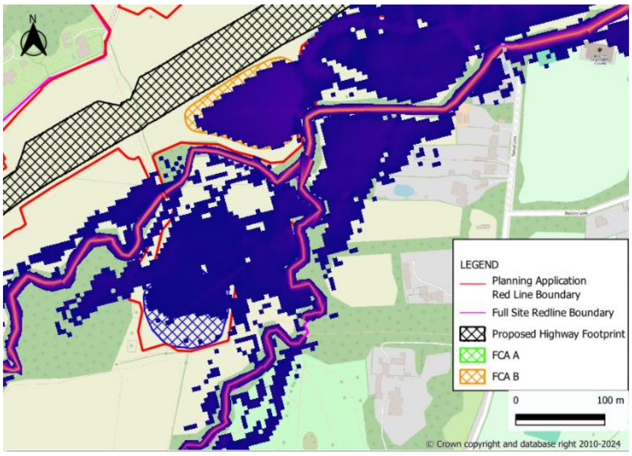
1 in 100 annual chance event plus climate change 12 hour storm duration



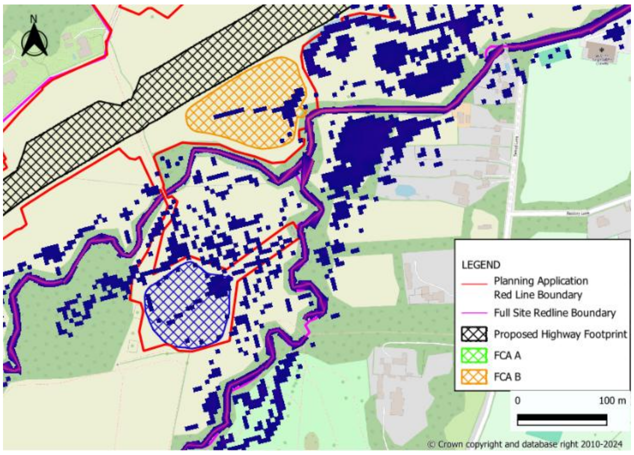
Flood extent at +6 hours



Flood extent at +10 hours



Flood extent at +24 hours



Flood extent at +36 hours

Figure 5-8: Flood progression plot, 1 in 100 annual chance event plus climate change, 12 hour storm duration

5.5 Management of Impacts

The modelling has demonstrated that, although the scheme increases peak flood depths in the 1 in 100 annual chance event inclusive of an allowance for climate change, these increases occur within the application boundary and will therefore be managed as part of the site development. Development proposals will be constrained to areas outside the floodplain meaning that the risk to residents and users of the development is mitigated.

The FCAs have been designed to provide a replacement flood storage volume in excess of the volume removed by the scheme embankment in the 1 in 100 annual chance plus climate change event. Table 5-1 provides a summary of the floodplain storage volume taken up by the scheme in 100mm elevation bandings compared to the storage provided by the FCAs at the same elevation banding.

Due to the extensive floodplain of the River Mole in the vicinity of the scheme, it is not possible to situate the FCAs fully outside of the floodplain whilst also keeping the elevations as close as practical to the elevations at which the floodplain storage is lost. Table 5-1 demonstrates that the proposed FCAs provide a greater total volume of floodplain storage compared to the volume taken up by the scheme during the 1 in 100 annual chance plus climate change flood event albeit not at exactly the same elevation. The fourth column in Table 5-1 takes into account the water surface slope between the FCAs (which are located upstream) and the point at which the proposed embankment encroaches into the floodplain. As there is an existing water surface slope (1 in 1000) between the FCAs and the location where the floodplain storage is lost, this can be taken into account when considering how the FCAs store water and therefore the relative elevation of the FCAs can be adjusted by the water surface slope for a like for like comparison. When taking into account this water surface slope, the FCA level for level calculations are shown to create a greater volume per elevation slice with the exception of the lowest 100mm elevation slice.

Table 5-1: FCA Volume Assessment

Elevation (mAOD)	Volume removed by the scheme (m^3)	Volume provided by the FCAs (m^3)	Volume provided by the FCAs (m^3) based on the water surface slope
62.1	48	-	21
62.2	82	-	40
62.3	293	-	260
62.4	556	21	818
62.5	851	40	1,471
62.6	1,390	260	2,188
62.7	1,927	818	2,785
62.8	2,725	1,471	3,180
62.90*	2,863	2,188	3,615
63	2,863	2,785	4,014
63.1	2,863	3,180	4,499
63.2**	2,863	3,615	4,568
63.3	2,863	4,014	
63.4	2,863	4,499	
63.5***	2,863	4,568	

** Peak water level (1 in 100 annual chance plus climate change) adjacent to where the highway embankment encroaches into the floodplain (no increase in lost volume occurs above this elevation)*
*** Peak water level in FCA A*
**** Peak water level in FCA B*

Inclusion of the currently proposed flood storage areas provide a marginal benefit in reducing the total volume of flow which passes downstream of Ifield Avenue in the 1 in 100 annual chance event plus climate change.

In summary, the volume of floodplain storage removed by the scheme is insignificant compared to the volume of flooding from the River Mole in the 1 in 100 annual chance event plus climate change is significant in comparison to the volume of floodplain storage removed by the scheme. The development proposals act mainly to alter the pattern of flooding on the site as opposed to fundamentally changing the flood mechanisms and receptors.

6 Environment Agency Model Review

The model was issued to the Environment Agency for review in October 2024. The Environment Agency returned the model review (Ifield Non-real time Hydraulic Model Review.xlsm) in November 2024 with the following comment:

"We have completed our review of the model and have determined the overall modelling approach for the proposed development is suitable. We have included a copy of the model review coversheet which sets out the elements of the model reviewed and any comments on those elements. We appreciate the model for the proposed development is based on an Environment Agency model. You will note there are a number of points within the model review spreadsheet where comments have been made but are logged as 'green'. These points are considered to have a negligible impact on the model results, but we would ask these comments are acknowledged and the limitations section of the model reporting is updated to reflect these findings."

The model review was returned with responses where required and no further action was required. Copies of the correspondence with the Environment Agency are provided in Annex 4.

7 Assumptions and Limitations

The modelling presented above includes a number of assumptions which are outlined below:

- The hydraulic modelling is based on the previously approved Environment Agency River Mole model. This model was previously subject to a robust calibration and verification process and therefore, as only minor changes have been made to the baseline model, it was not considered necessary to redo the calibration. Validation of the updated model against the supplied Environment Agency model demonstrated that there was no significant change to the results.
- The hydrology supplied with the Ramboll model has been assumed to be suitable for the purposes of this assessment.
- The Manning's n roughness coefficients applied to the 1D river channel and banks, and the Ordnance Survey MasterMap data used to define the spatial distribution of floodplain roughness remain unchanged from the original Environment Agency model. No additional information has been identified that contradicts the values used and therefore the model approach remains valid.
- All structures, apart from the bridges at Ifield Green and Ifield Avenue which were updated as part of the Arcadis modelling, remain as per the supplied Environment Agency model.

8 Conclusions

The existing hydraulic model of the River Mole, Ifield, Crawley has been updated for use in assessing the impacts of the Crawley Western Multi-Modal Corridor and proposed crossing of the River Mole (the scheme). These two components form part of the enabling infrastructure (Phase 1) for the West of Ifield development.

The updated modelling has been approved for use in this study by the Environment Agency.

Model results show that the Crawley Western Multi-Modal Corridor is not at risk of flooding for all modelled events up to and including the 1 in 1000 annual chance event.

The embankment of the Crawley Western Multi-Modal Corridor encroaches into the floodplain of the River Mole. An assessment of the volume of floodplain storage removed by the embankment during the 1 in 100 annual chance event inclusive of a 40% allowance for climate change has been made and used to inform the design of floodplain compensation areas.

The proposed floodplain compensation areas are hydraulically connected to the River Mole and are designed to fill and empty passively. They are operational in the smallest design flood event modelled, the 1 in 5 annual chance.

Modelled peak flood depths are increased as a result of the scheme regardless of whether the floodplain compensation areas are in place. However, the presence of the floodplain compensation areas do provide a minor benefit in terms of reducing the total volume of flow which passes downstream of Ifield Avenue.

Any increases in flood depths resulting from the scheme occur within the West of Ifield site boundary and are within areas already predicted to flood and thus remote from developed areas.

Annex 1

Ramboll Hydraulic Modelling Report

Intended for
Homes England

Document type
Report

Date
May 2022

HOMES ENGLAND
WEST OF IFIELD - UPPER RIVER MOLE – HYDRAULIC MODELLING SUMMARY REPORT

RAMBOLL Bright ideas. Sustainable change.

HOMES ENGLAND
WEST OF IFIELD - UPPER RIVER MOLE – HYDRAULIC MODELLING SUMMARY REPORT

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APPENDICES

Appendix A
EA Upper Mole FEH Calculation Record

Appendix B
EA/GAL Upper Mole Fluvial Flood Modelling Study – Final Report – Version: 1.2 (September 2018)

Appendix C
Crawley Western Relief Road Design – Ramboll 2022

Appendix D
Ramboll Model Review EA Upper Mole

Appendix E
EA correspondence

1. INTRODUCTION

1.1 Background

1.1.1 Ramboll have been commissioned by Turner and Townsend project management limited (working on behalf of Homes England) to complete hydraulic modelling on the River Mole and tributaries including Ifield Brook. The works are required in order to understand the impact of potential flood alleviation strategies proposed as part of a proposed development on land to the west of Ifield, West Sussex.

1.1.2 Homes England intends to redevelop approximately 201 hectares (ha) of land located west of Ifield within the administrative area of Horsham District Council (HDC) in West Sussex for a residential-led mixed use settlement. The proposed Development (herein described as 'West of Ifield') is part of the UK government's nationwide initiative to deliver new housing stock across the country as was announced by the Department of Communities and Local Government (DCLG) in 2016.

1.1.3 The site is bound by Charlwood Road in the northeast, beyond which lies Gatwick Airport. The site lies to the north of the Horsham-Crawley railway line. The existing residential areas of Ifield and Langley Green, associated with the town of Crawley, are located to the east. Ifield West and ancient woodland are located to the south, with the River Mole and further ancient woodland present to the west.

1.1.4 The site is predominantly occupied by a mixture of arable and pastoral fields and includes the Ifield Golf Course and Country Club in its southernmost portion. The River Mole is present across the western part of the site and flows from south-west to north-east. With regards to fluvial flooding, the majority of the application site is within Flood Zone 1[1] (comprising areas with an annual probability of flooding less than 0.1% (1 in 1,000)). Areas of Flood Zone 2 (annual probability of flooding between 1% and 0.1%) and Flood Zone 3 (annual probability of flooding greater than 1%) are also present associated with both the River Mole and Ifield Brook, the latter of which runs in a northerly direction within the east side of the application site. Figure 1-1 shows the EA Flood Risk from Rivers and Sea.

1.1.5 The Flood Zone 2 and 3 extents are associated with the two main rivers passing through the site, the River Mole and Ifield Brook. An unnamed watercourse is present, flowing in a northerly direction to confluence with the River Mole approximately 600m upstream of the Ifield Brook confluence. Flows for the unnamed watercourse were incorporated into the flows for the River Mole.

[1] As defined within the National Planning Policy Framework (NPPF): https://www.gov.uk/guidance/flood-risk-and-coastal-change#flood-zone-and-flood-risk-tables

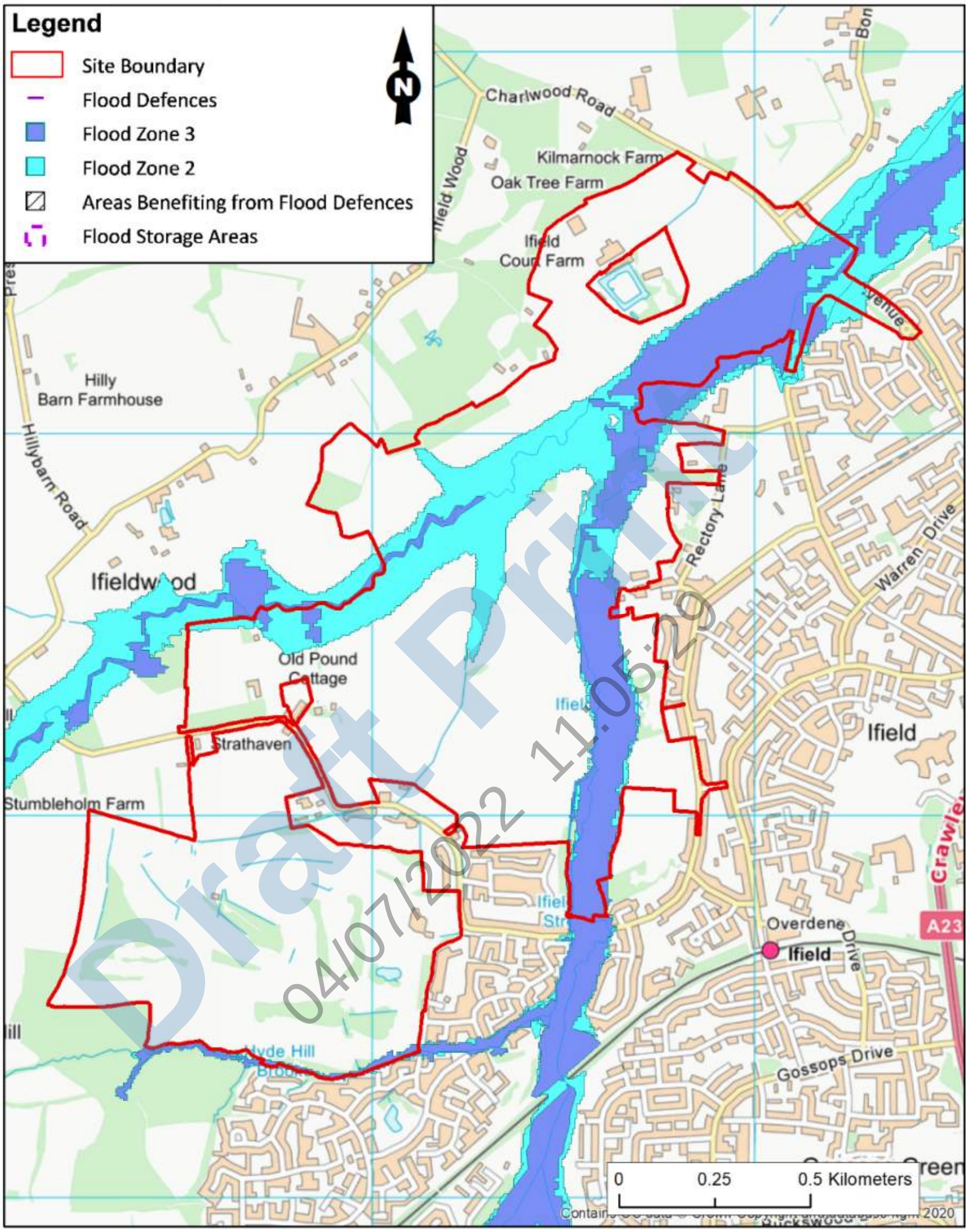
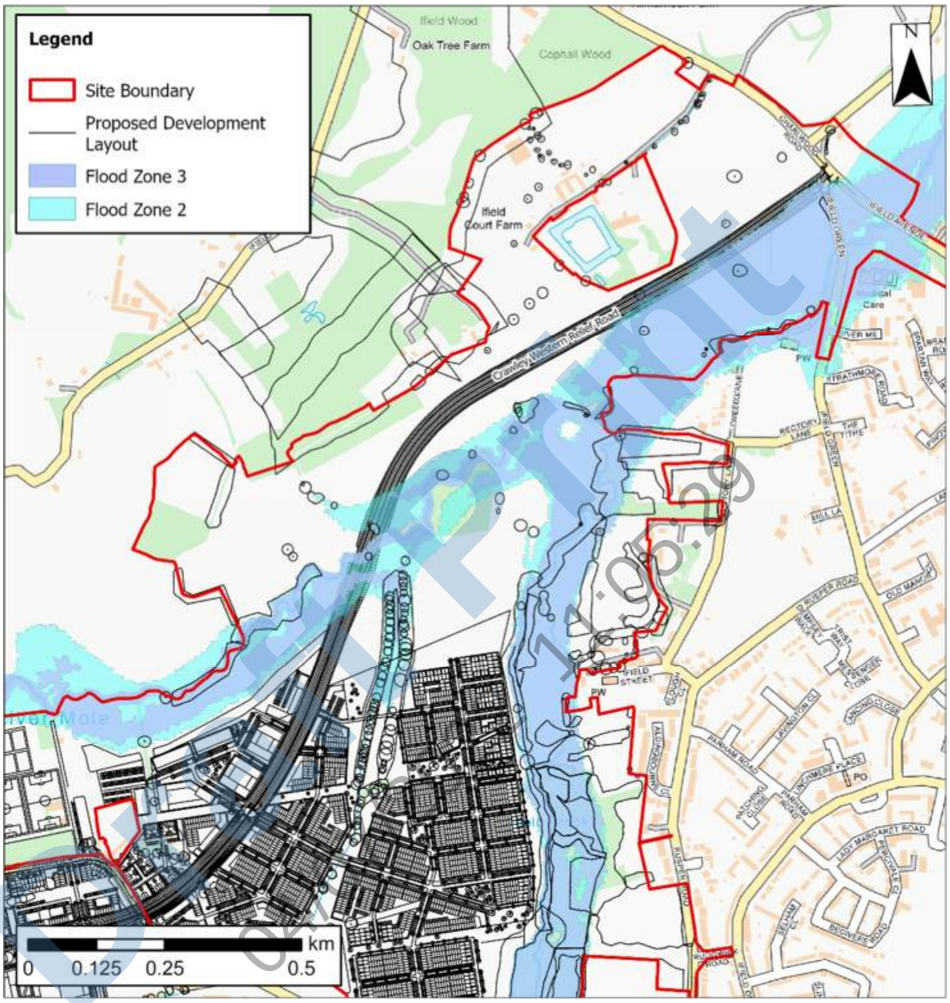


Figure 1-1: EA Flood Risk from Rivers and Sea

1.1.6 Figure 1-2 shows the indicative plan for the proposed West of Ifield development including the Crawley Western Relief Road (herein described as 'CWRR') and the EA flood risk from rivers and sea. The residential-led mixed use settlement is out of the floodplain, located on the higher ground between the River Mole and Ifield Brook. The CWRR links the West of Ifield development to Charlwood Road, crosses the River Mole and overlaps the EA Flood Zones. As a result of building within the floodplain, it is acknowledging that flood compensation will be needed to manage risk.



*Indicative plan for proposed development

Figure 1-2: Indicative plan for the proposed West of Ifield development, including the Crawley Western Relief Road with the EA Flood Risk from Rivers and Sea

1.1.7 Prior to Ramboll's involvement, Arcadis Consulting Ltd completed preliminary testing using the Environment Agency (EA) 1D-2D Flood Modeller Pro-TUFLOW (FMP-TUFLOW) model of the Upper Mole (September 2018) to assess various flood mitigation options for proposed development.

1.1.8 The hydraulic model issued to Arcadis by the EA was issued to Ramboll as part of the handover process (28th September 2020). Initially, the project was intending to utilise the hydraulic model to build on the previous work completed by Arcadis Consulting however, following a review (Appendix D) of the EA 1D-2D FMP-TUFLOW model, several concerns with the model were identified. It was agreed, following discussions with the EA and Homes England, that the model would be updated for the purposes of the West of Ifield study and to follow best practice guidance.

1.1.9 The updated hydraulic modelling will be used to determine the impact the CWRR incurs on flood risk resulting from the loss in floodplain volume and analyse the efficacy of flood compensation areas (FCA's) to alleviate any increases in flood risk.

1.2 Aims

1.2.1 The location of the proposed CWRR overlaps with EA Flood Zones 2 and 3. The aim of this study is to utilise hydraulic modelling to investigate flood mitigation options for the proposed West of Ifield development which would be acceptable to key stakeholders and the EA.

1.3 Objectives

1.3.1 To satisfy the study aim, the objectives of the hydraulic modelling are;

i. Update the baseline EA 1D-2D FMP-TUFLOW hydraulic model of the Upper Mole so that is a suitable basis for assessment.
   - Update the 2D domain floodplain roughness from a blanket roughness to land use mapping,
   - Correct representation of Ifield Mill Pond embankment,
   - Truncate the model to cover the West of Ifield Area to remove issues of model instability far removed from the area of interest for this study,
   - Utilise the existing hydrology developed as part of the EA modelling study of the Upper Mole as the boundary data for the West of Ifield study, but update the 1 in 100-year climate change follow latest government guidance.

ii. Utilise the updated 1D-2D FMP-TUFLOW hydraulic model to establish the Baseline flood risk and the Development flood risk (with no flood mitigation), simulating the baseline undefended scenario and the development scenario for a range of return period fluvial events.

iii. Analyse the hydraulic modelling results to understand the flood risk impact resulting from the development (specifically the CWRR) compared to the baseline flood risk and identify potential flood mitigation options.

iv. Utilise the updated 1D-2D FMP-TUFLOW hydraulic model to assess a range of fluvial flood mitigation options.

v. Analyse the hydraulic modelling results to evaluate each flood mitigation approach.

vi. Develop a technical report covering the model updates completed, modelling results and an assessment of the flood mitigation options.

2. MODEL APPROACH AND JUSTIFICATION

2.1 General approach

2.1.1 A risk-based approach has been adopted, whereby the level of modelling detail supporting the flood risk assessment at a specific site reflects the magnitude of the likely impacts of the proposed development's flood alleviation schemes on peak flood levels and the sensitivity of nearby receptors to flooding.

2.2 Hydrological approach

2.2.1 The hydrological assessment completed as part of the EA Upper Mole fluvial modelling study included a review and update of the hydrology for the area. This was a comprehensive study which involved the creation of a new hydrological model for the Upper Mole, representing both the urban and rural characteristics of the catchment. The hydrological model was calibrated and validated in conjunction with the hydraulic model using three historic flow events. The hydrological analysis, including the FEH Calculation record, is reported in the EA's Upper Mole Modelling Project Report (Appendix A).

2.2.2 It was considered that the hydrological analysis did not need to be amended and no updates were completed. This was with the understanding that the hydrological model was calibrated and validated using the EA's baseline hydraulic model. The minor updates required to meet the objectives of the study, detailed in Section 3 of this report, were not anticipated to affect those elements of the model used for validation so additional calibration is considered unnecessary.

2.2.3 The design events simulated were the 20%, 5%, 1.33%, 1%, 0.5% and 0.1% Annual Exceedance Probability (AEP) event.

2.2.4 The climate change allowances were updated to follow the latest Government guidance. The development site is located within the Mole Management Catchment. To be conservative, the 2080 upper end allowance for climate change peak river flows was applied, set at 40%.

2.3 Hydraulic modelling approach

2.3.1 A hydrodynamically linked 1D-2D Flood Modeller Pro (FMP)-TUFLOW model was used to understand the impact on flood risk from the proposed development. FMP and TUFLOW are industry-standard hydraulic modelling software packages for flood risk modelling and are well understood by the EA. The original model provided by the EA was constructed using this software.

2.3.2 The hydraulic modelling approach was chosen with consideration of the trade-off between computational demands, the required spatial extent and the accuracy of results. A 1D-2D model was selected for the following reasons:

- A 1D model linked to a 2D domain allows flow interactions between individual watercourses and structures to be accurately modelled, effectively representing the complex flow routes expected along the watercourses and within the floodplain of the study area.
- The 1D-2D linked model allows for an accurate simulation of in-channel hydraulics, coupled with detailed out-of-bank representation of flood routes, depths, flows and velocities. This provides a robust simulation of the effect of key hydraulic features both in and out of bank.
- A combined 1D-2D approach enables robust estimation of hazard in the floodplain, including the combined impact of coincident velocities and depths.

2.3.3 The EA 1D-2D FMP-TUFLOW model was built as part of the EA Upper Mole fluvial modelling study (Appendix B). The EA study included the construction of a new hydrodynamic model of the Upper Mole and the completion of a new hydrological analysis, with the aim of increasing confidence in model outputs and enabling assessment of the benefits of defences. The purpose of the study was to develop a greater understanding of flood risk in the area, particularly related to Gatwick

Airport, and provide updated flood risk information for the catchment. The updated data was used to update EA Flood Maps (as presented online[2]) and provide greater detail when responding to planning applications and help Asset Performance team to address maintenance and ownership concerns. Refer to Appendix B for details on model setup parameters. Unless noted in this report, Ramboll has largely used the same approach in the modelling completed.

2.3.4 It was significantly more time-effective to utilise this model, which has been tested and accepted by the EA, as a baseline for understanding the flood risk impact of the proposed West of Ifield development. Updates and changes were required to meet the objectives of the study, detailed in Section 3 of this Report, to summaries:

- Update the 2D domain floodplain roughness from a blanket roughness of 0.05 manning's n to utilise OS land use mapping to define floodplain roughness,
- Assess and correct representation of Ifield Mill Pond embankment,
- Truncate the model to cover the West of Ifield Area to remove issues of model instability far removed from the area of interest for this study,
- Utilise the existing hydrology developed as part of the EA modelling study of the Upper Mole as the boundary data for the West of Ifield study. Update the 1 in 100-year climate change following latest government guidance.

2.3.5 The EA 1D-2D FMP-TUFLOW model was truncated to the area of interest for this study, and updated OS Mapping used to detail floodplain roughness for the 2D domain.

2.3.6 The undefended scenario was chosen to represent the baseline scenario for this study as the undefended floodplain is the scenario considered for the purpose's development planning. A 'defended' model configuration incorporating the UMFAS elements will be simulated as a sensitivity test only.

2.4 Model conceptualisation

2.4.1 The 1D-2D FMP-TUFLOW model used in this study (herein described as the West of Ifield (WoI) FMP-TUFLOW model) was developed from an existing EA 1D-2D FMP-TUFLOW model of the Upper Mole to assess the impacts of the proposed Homes England West of Ifield development (including associated infrastructure), specifically the development of flood alleviation schemes to manage peak flood levels and effects on third parties. The following scenarios have been considered:

- Baseline scenario
  - Representing the current undefended setup of the Upper Mole catchment
- Development scenario
  - Representing the inclusion of the Crawley Western Relief Road (CWRR) embankment proposed to cross the River Mole floodplain, connecting the proposed housing development to Charlwood Road.
- Three flood alleviation scheme options
  - CWRR with Flood Compensation Area (FCA) A
  - CWRR with FCA-B
  - CWRR with FCA-A and FCA-B

2.4.2 Details of the FCAs tested for the project are provided in Section 3.

[2] https://flood-map-for-planning.service.gov.uk/

3. HYDRAULIC MODEL BUILD

3.1 Modelling software

3.1.1 Hydraulic modelling has been undertaken using the Flood Modeller 1D (version 4.6) and TUFLOW 2D (version 2018-03-AE-iDP-w64) software suites.

3.2 Model Extent

3.2.1 For the purposes of the Homes England West of Ifield study, it was not required to model the full Upper Mole catchment area. A truncated version of the EA FMP-TUFLOW 2019 model in the area of interest was instead proposed. The extents were set with consideration to the backwater effect from key structures to ensure that the impacts from the proposed development scheme were effectively modelled.

3.2.2 The downstream extent of the model was positioned downstream of the long culvert and siphon that takes the Mole beneath the Gatwick runway. The downstream extent is approximately 3.5 km downstream of the site, and is significantly further than the estimated backwater effect, calculated to be approximately 1.1 km, (0.7 x D/S, (D = depth, S = slope)).

3.2.3 Figure 3-1 shows the WoI FMP-TUFLOW Model truncated model extent (blue) and the EA FMP-TUFLOW 2019 model extent (green). The WoI FMP-TUFLOW Model contains numerous tributaries that confluence with the River Mole. To improve simulation times, the upstream extents of some tributaries were truncated. This was only considered at locations further than the calculated backwater effect length of 1.1 km away from the site and, where no overland flow was simulated from upstream for any scenario or event.

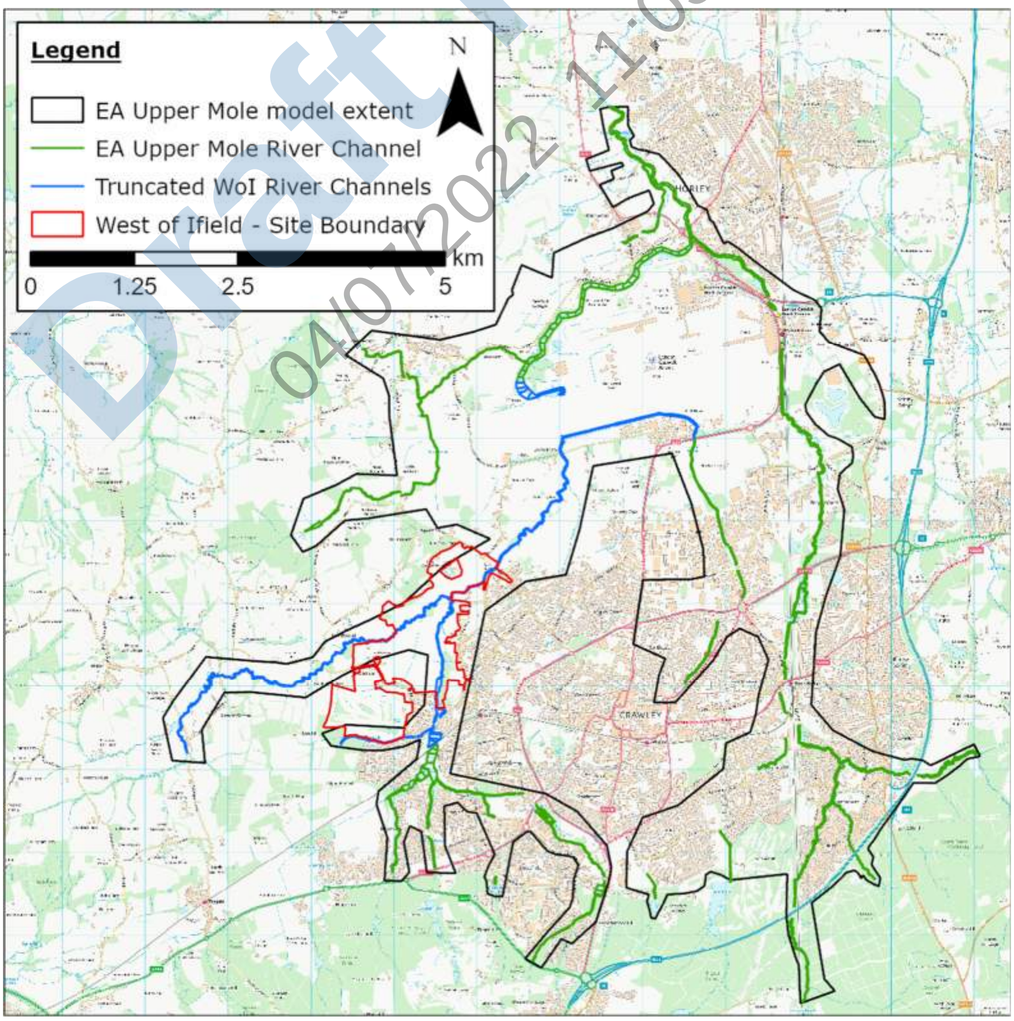


Figure 3-1: West of Ifield truncated FMP-TUFLOW model extent

3.3 1D channel

3.3.1 The WoI FMP-TUFLOW Model in-bank 1D channel modelling approach is the same as that followed for the EA FMP-TUFLOW 2019 model. The following summarises the approach applied for the EA FMP-TUFLOW 2019 model:

- The in-bank channel cross-sections and structures such as bridges and culverts have been modelled using appropriate units in Flood Modeller.
- Overall definitions of channel geometry are based on field surveyed cross-sections.
- All coefficients were set for the EA FMP-TUFLOW 2019 model based on the information in the survey and applying engineering judgment using published references.
- Data from legacy models or from existing studies have been incorporated where more recent survey was unavailable.
- Interpolated cross-sections were added where necessary to ensure that the propagation of the flood-wave was fully captured.
- Where appropriate, in-line spill units were included at structures to allow water to overtop in the event of high wate levels.
- Longitudinal head losses were calculated by conduit units.
- Panel markers were added where appropriate to improve channel conveyance and overall model stability.
- Left-Right bank markers were added at all sections to define the bank-top and improve the model dataset.
- In-channel roughness values (Manning's n coefficient) were carried forward from the EA's model, set at 0.040 for the flood modeller 1D channel bed and the channel bank roughness values were set to 0.060. These values were adjusted where applicable during the calibration process.

3.3.2 Full details of the model setup and parameterisation are available in EA's Upper Mole Fluvial Modelling Study – Final Report, Appendix B.

3.4 2D Floodplain

3.4.1 The WoI FMP-TUFLOW Model 2D domain floodplain modelling approach is the same as that followed for the EA FMP-TUFLOW 2019 model. The following summarises the approach applied for the EA FMP-TUFLOW 2019 model.

- The 2D ground model representing the floodplain (derived as a Digital Terrain Model (DTM)) is linked to the FMP in-bank 1D-channel.
- 2m filtered LiDAR data was used to inform the ground levels of the 2D domain within the mode, thereby representing the 'base earth' ground surface. The EA FMP-TUFLOW 2019 model report states that the LiDAR was manually inspected during the development of the 2D model and assessment of the model results. Where inaccuracies were identified, these were adjusted to provide a better depiction of the true ground levels.
- Specific topographical modifications have been applied to adjust the base model terrain. These included:
  - Modifying bank levels to correspond to 1D domain.
  - Specifying the Ifield Mill Pond Embankment crest.
  - Specifying bridge decks.
  - Specifying known low points allowing floodplain flow.
  - Modifications to fill gaps and clear errors in the base model terrain.
- To set the entire 2D model floodplain extent to be "dry" at model start-up, A global initial water level was specified for the 2D domain.

3.4.2 The 2D modelling approach applied in the WoI FMP-TUFLOW model differs in one aspect, the 2D floodplain roughness. The EA FMP-TUFLOW 2019 model applied a global 0.050 manning's n roughness factor to the full model extent, with the exception of the 2D domain in the immediate Gatwick area, where detailed mapping was adopted to specify roughness factors. The EA FMP-TUFLOW 2019 model development found that the model flood depths and extents were sensitive to floodplain roughness, but at the time of its development, model stabilities issues meant that only a global manning's n roughness would be applied.

3.4.3 For the purposes of the WoI FMP-TUFLOW Model, it was considered that detailed mapping data should be used to specify the roughness factors in the 2D domain, as the proposed development at West of Ifield will involve a change in land use, which could impact the flood characteristics in the local and wider area. This has been agreed with the EA (Appendix E).

3.4.4 The WoI FMP-TUFLOW model has utilised OS mapping[3] to specify the roughness factors in the 2D domain. The specific roughness factors applied are the same as those applied in the Gatwick area of the model (Chow, 1959). Figure 3-2 shows the roughness factors applied in the WoI FMP-TUFLOW model. Sensitivity testing was carried out on the model roughness values, detailed in Section 5.2 of this report.

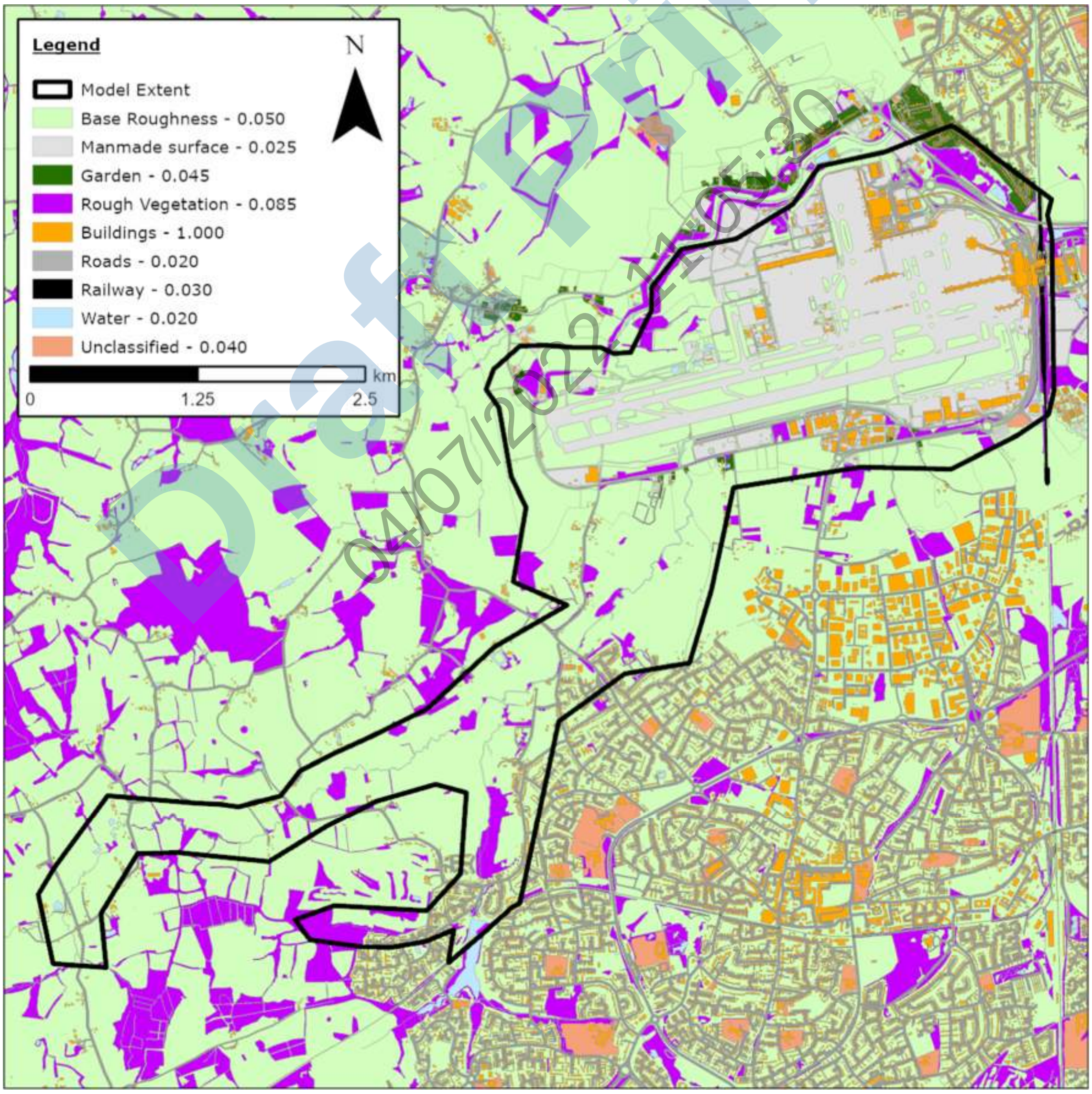


Figure 3-2: WoI FMP-TUFLOW Model Roughness

[3] Contains Ordnance Survey data © Crown copyright and database right 2020

3.5 Model Boundaries

3.5.1 The truncation of the EA FMP-TUFLOW 2019 for the purposes of this study required the FMP IED files and downstream boundary location to be updated to reflect the new model extents.

Downstream Boundary

3.5.2 The downstream boundary of the truncated model is located at cross section MOLE_3200 (NGR 525512, 140657). This location was chosen with consideration to the backwater effect and key structures.

3.5.3 The backwater effect downstream of the Homes England West of Ifield site boundary was calculated using the backwater length calculation 0.7*D/S, where D = depth, S = slope. This provided a backwater length of approximately 1.1 km. MOLE_3200 is approximately 3.5 km downstream of the Homes England West of Ifield site boundary and is therefore significantly further than the estimated backwater effect.

3.5.4 The boundary is also downstream of the long culvert and siphon that takes the River Mole beneath the Gatwick runway and is a key control structure. The structure is downstream of the 1.1 km backwater length from the Homes England West of Ifield site boundary. However, it was considered important to retain the Gatwick culvert within the truncated model to assess the impact of the Homes England West of Ifield proposed scheme at Gatwick Airport.

3.5.5 The downstream boundary condition has been implemented as a Normal Depth boundary unit, with a value based on the channel slope at the downstream reach of the channel. The bed slope applied was user defined, calculated between the downstream extent cross-section, MOLE_3200 and cross-section MOLE_3995.

Inflow Boundaries

3.5.6 FMP IED files were provided as part of the EA FMP-TUFLOW 2019 model. Truncation of this model for the purposes of the Homes England West of Ifield study required the IED files to be updated to reflect the model truncation. Table 3.1 and Table 3.2 detail the IED file updates completed, summarised as follows:

- 7 FEHBDY inflows boundaries were retained (3 Upstream, 4 Lateral).
- 10 FEHBDY inflow boundaries were removed as the upstream section of the river reach was truncated. FEHBDY boundaries replaced with flow time boundaries (QTBDY) applied at cross downstream cross-sections, utilising results extracted from the EA FMP-TUFLOW 2019 modelling study.
- 24 FEHBDY inflow boundaries were removed as the river reach is outside truncated model domain.

Table 3.1: Model Inflow boundaries retained or updated in the IED files as part of the model truncation process

EA FMP-TUFLOW 2019			WoI FMP-TUFLOW	Notes
ID	**Boundary**	**Type**		
1-1	FEHBDY	Upstream	1-1	Retained
1-2	FEHBDY	Upstream	1-2	Retained
1-8i	FEHBDY	Lateral	1-8i	Retained
1-9i	FEHBDY	Lateral	1-9i	Retained
1-14ia	FEHBDY	Lateral	1-14ia	Retained – lateral flow on a truncated river reach, adjustments completed in FMP model DAT file.
2-7ia	FEHBDY	Lateral	2-7ia	Retained – lateral flow on a truncated river reach, adjustments completed in FMP model DAT file.
2-1	FEHBDY	Upstream	Removed from IED, replaced with QTBDY at cross-section 03_1831	Upstream reach truncated. Truncated river reach starts at 03_1831. Flows extracted from EA FMP-TUFLOW 2019 model results and implemented as a flow time boundary (QTBDY)
1-3	FEHBDY	Upstream	Removed from IED, replaced with QTBDY at cross-section 11_2139D	Upstream reach truncated. Truncated river reach starts at 11_2139D. Flows extracted from EA FMP-TUFLOW 2019 model results and implemented as a flow time boundary (QTBDY)
1-4a	FEHBDY	Upstream		
1-5a	FEHBDY	Upstream		
1-6a	FEHBDY	Upstream		
1-7a	FEHBDY	Upstream		
1-10i	FEHBDY	Lateral		
1-11i	FEHBDY	Lateral		
1-12i	FEHBDY	Lateral		
1-13i	FEHBDY	Lateral		

Table 3.2: Model Inflow boundaries removed from the IED files as part of the model truncation process

ID	Boundary	Type	ID	Boundary	Type
1-3	FEHBDY	Upstream	2-10	FEHBDY	Upstream
1-4a	FEHBDY	Upstream	2-11	FEHBDY	Upstream
1-5a	FEHBDY	Upstream	3-1	FEHBDY	Upstream
1-6a	FEHBDY	Upstream	3-2	FEHBDY	Upstream
1-7a	FEHBDY	Upstream	3-3a	FEHBDY	Upstream
1-10i	FEHBDY	Lateral	3-4a	FEHBDY	Upstream
1-11i	FEHBDY	Lateral	3-5a	FEHBDY	Upstream
1-12i	FEHBDY	Lateral	3-6a	FEHBDY	Upstream
1-13i	FEHBDY	Lateral	3-7ia	FEHBDY	Lateral
2-1	FEHBDY	Upstream	3-8i	FEHBDY	Lateral
2-2	FEHBDY	Upstream	3-9i	FEHBDY	Lateral
2-3	FEHBDY	Upstream	3-10i	FEHBDY	Lateral
2-4i	FEHBDY	Lateral	3-11i	FEHBDY	Lateral
2-5ia	FEHBDY	Lateral	3-12i	FEHBDY	Lateral
2-6ia	FEHBDY	Lateral	3-13i	FEHBDY	Lateral
2-8a	FEHBDY	Upstream	3-14i	FEHBDY	Lateral
2-9ia	FEHBDY	Lateral	3-15i	FEHBDY	Lateral

3.5.7 Table 3.1 details eight FEHBDY model inflows that were removed from the IED file as the upstream section of the river reach was truncated. These FEHBDY boundaries were replaced with flow time boundaries (QTBDY) applied at downstream cross-sections. The QT time series applied at these inflow boundaries were extracted from the EA FMP-TUFLOW 2019 modelling study modelling results.

3.5.8 Two lateral flow FEHBDY model inflows that were retained and unmodified in the IED files provide inflows for lateral flows along a truncated river reach. Appropriate adjustments were required in the FMP model DAT file:

- The “Custom Weight Factors” in the FMP DAT Lateral Flow Unit were adjusted to account for few lateral flow nodes required.
- The “Flow Multiplier” in the FMP DAT QTBDY Unit was adjusted to proportion the inflow from the IED file to the fewer lateral flow nodes required.

3.5.9 Table 3.3 and Table 3.4 show the updates applied at lateral flow boundaries 2-7ia, and 1-14i in the FMP DAT file as part of the model truncation.

Table 3.3: Lateral flow updates applied at lateral flow boundary 2-7ia in the FMP DAT file as part of the model truncation

2-7ia	Multiplication factor	0.67
Lateral	**JBA - 2019**	**WoI - 2022**
2-7iaa	0.12	0.18
2-7iab	0.11	0.164
2-7iac	0.11	0.164
2-7iad	0.11	0.164
2-7iae	0.11	0.164
2-7iaf	0.11	0.164
2-7iag	0.11	Removed
2-7iah	0.11	Removed
2-7iai	0.11	Removed

Table 3.4: Lateral flow updates applied at lateral flow boundary 1-14i in the FMP DAT file as part of the model truncation

1-14i	Multiplication factor	0.889
Lateral	**JBA - 2019**	**WoI - 2022**
1-14iaa	0.112	0.125
1-14iab	0.111	Removed
1-14iac	0.111	0.125
1-14iad	0.111	0.125
1-14iae	0.111	0.125
1-14iaf	0.111	0.125
1-14iag	0.111	0.125
1-14iah	0.111	0.125
1-14iai	0.111	0.125

3.6 Production of flood extents

3.6.1 Flood extents have been derived using the direct output options available in TUFLOW to produce ASCII outputs for the maximum depth, height, velocity and hazard[4]. Depth grid ASCIIs have then been converted into polygons and cleaned. Any dry 'islands' less than 50m^2 have been filled.

3.7 Assumptions

3.7.1 The underlying data and parameterisation in the original EA FMP-TUFLOW 2019 model is assumed to be acceptable for use and forms the basis of the WoI FMP-TUFLOW model used in this study.

3.7.2 Existing LiDAR is assumed to be accurate within reasonable tolerances (±5-15 cm vertical accuracy).

3.7.3 For smaller tributaries, the watercourse bed profile is reasonably represented by the LiDAR to the extent that it would not significantly effect model performance in the areas of primary interest for this study.

[4] As defined in Government guidance: https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/flood-risk-assessment-guidance-for-new-development

4. MODEL SCENARIOS

4.1 Model scenarios

4.1.1 Five FMP-TUFLOW 1D/2D model scenarios have been considered to assess the impact of the Homes England West of Ifield proposed scheme. Table 4.1 provides a summary of each modelled scenario.

Table 4.1: Summary of the Homes England West of Ifield Hydraulic model scenarios

Modelled Scenario	TUFLOW Reference	Description
Baseline (Undefended)	BAS	The undefended scenario of the Upper Mole, a truncated version of the EA FMP-TUFLOW 2019 model, representing the River Mole without the Upper Mole Flood Alleviation Scheme (UMFAS) or the Gatwick Stream Flood Alleviation Scheme (FAS).
Development – Road	DEV2	The Upper Mole with the West of Ifield Scheme, specifically the Crawley West Relief Road (CWRR)
Development – Road and FCA-A	DEV2_FASA	The Upper Mole with the West of Ifield Scheme, specifically the Crawley West Relief Road (CWRR) and FCA-A.
Development – Road and FCA-B	DEV2_FASB	The Upper Mole with the West of Ifield Scheme, specifically the Crawley West Relief Road (CWRR) and FCA-B.
Development – Road and FCA-A and B	DEV2_FAS	The Upper Mole with the West of Ifield Scheme, specifically the Crawley West Relief Road (CWRR) and FCAs A and B.

4.1.2 Table 4.2 Details the range of fluvial return period events simulated. This study followed the EA's approach, simulating a range of storm periods for each return period event to reflect the range of sub-catchment sizes within the model domain. The flood risk maps for each return period would then assimilate the results from each storm period.

Table 4.2: Fluvial return period events simulated for the Homes England West of Ifield hydraulic modelling study

Return Period (1 in x-year)	Storm Duration (hr)			
	3	6	12	24
5	5yr3hr	5yr6hr	5yr12hr	5yr24hr
20	20yr3hr	20yr6hr	20yr12hr	20yr24hr
75	75yr3hr	75yr6hr	75yr12hr	75yr24hr
100	100yr3hr	100yr6hr	100yr12hr	100yr24hr
200	200yr3hr	200yr6hr	200yr12hr	200yr24hr
1000	1000yr3hr	1000yr6hr	1000yr12hr	1000yr24hr
100CCUpper 2080	100CCUpper 2080yr3hr	100CCUpper 2080yr6hr	100CCUpper 2080yr12hr	100CCUpper 2080yr24hr

4.2 Baseline Scenario

4.2.1 The baseline scenario utilised the undefended model setup because development planning must consider the undefended floodplain during the decision-making process. A 'defended' model configuration incorporating the UMFAS elements was simulated as a sensitivity test only.

4.3 Development Scenarios

4.3.1 As a result of building within the floodplain, it is acknowledging that flood compensation will be needed to manage risk. This section outlines the Homes England West of Ifield scheme proposed to reduce flood risks to property in the local area (Figure 4-1). The Homes England West of Ifield Scheme model scenario includes the following;

- 2D TUFLOW floodplain
  - Topography altered to incorporate the proposed CWRR road layout.
  - Model Roughness altered to incorporate the proposed CWRR road layout.
  - Topography altered to incorporate FCA with the West of Ifield site.
- 1D FMP channel
  - Two new flat deck bridges under the proposed CWRR, crossing the River Mole at river cross-section (NRG 524260, 137820).

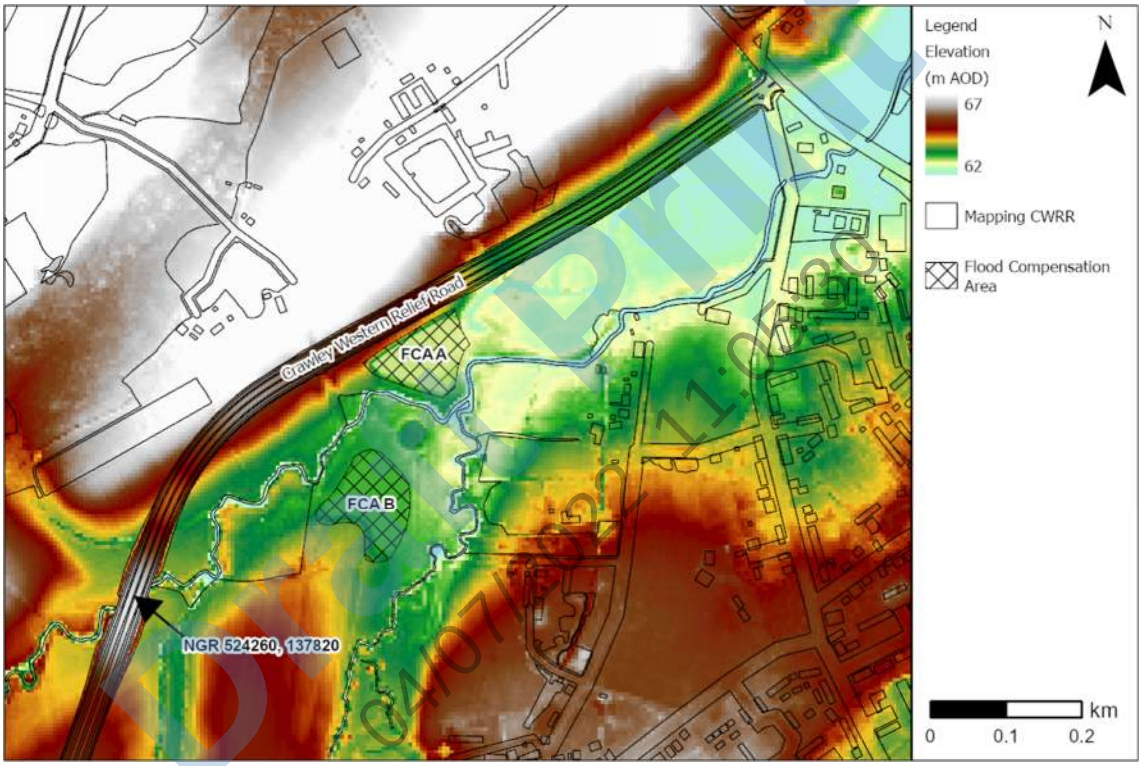


Figure 4-1: Baseline (top) and Road (bottom) scenario topography at River Mole passing through the West of Ifield site

CWRR Road Layout

4.3.2 The CWRR has been represented in the 2D floodplain through topographical changes to the base model DTM and model roughness. Design drawings showing the road layout, longitudinal section and a typical cross section of the proposed CWRR were provided for this study by the Ramboll Transport team (Appendix C). The information from these drawings have been used to represent the CWRR in the 2D floodplain.

Bridge structures

4.3.3 Figure 4-1 shows the proposed CWRR crosses the active River Mole floodplain, requiring the construction of a new flat deck bridge at approximately NGR 524260, 137820, shown on Figure 4-1.

4.3.4 Figure 4-2 shows the proposed channel and bridge cross sections for the bridge. Table 4.3 provides the structure details used in the hydraulic model. It should be understood that the CWRR Bridge has not been formally designed so the bridge details below were chosen to allow a clear span of the channel. Further modelling will be required once the final bridge design is complete.

Table 4.3: Proposed CWRR Bridge structure details (Subject to further design)

Bridge Structure	CWRR Bridge
Width	8.281 m
Soffit	65.5 mAOD
Deck	66.75 mAOD

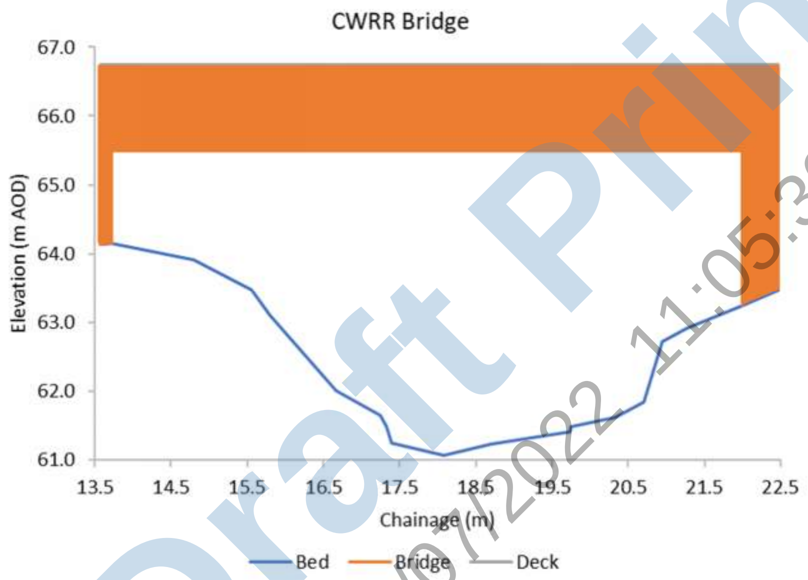


Figure 4-2: Proposed CWRR bridge model cross-sections

Flood Compensation Areas

4.3.5 Two FCA’s have been assessed for the West of Ifield flood alleviation scheme in order to safeguard third parties against flood risks. Figure 4-3 shows the FCA locations and topography. Table 4.4 shows the statistics for the FCAs, including the area and volume of soil/rock that would need to be removed.

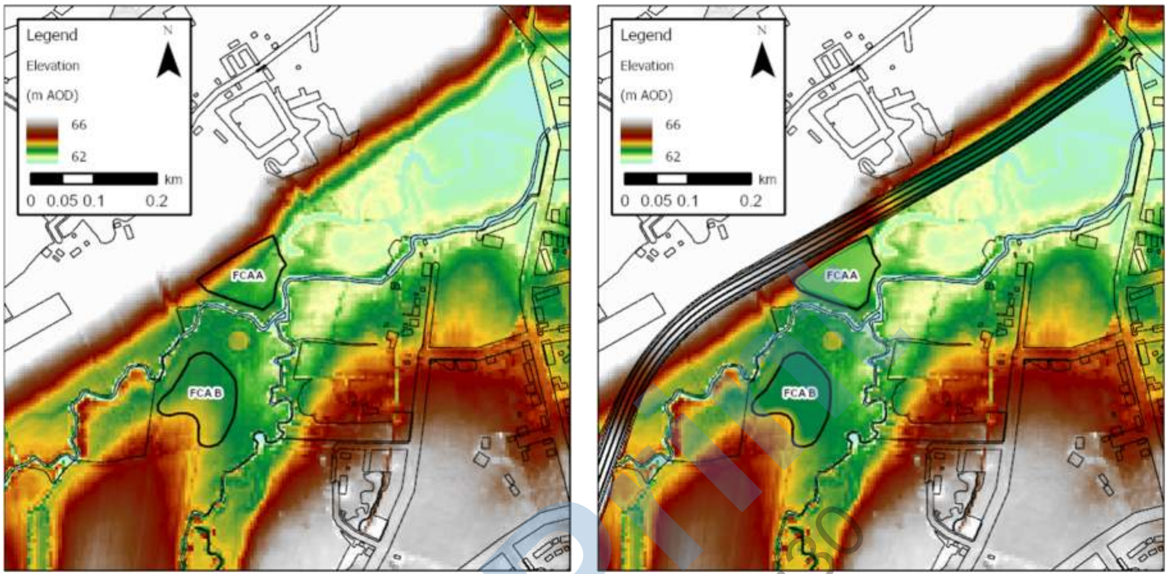


Figure 4-3: FCA locations in baseline topography (Left) and the two FCA’s topography (Right)

Table 4.4: FCA statistics, area and volume removed

FCA	Area (m2)	Volume removed (m3)
A	9,136	2,865
B	10,954	1,402
Total	20,090	4,267

4.3.6 Key design considerations for any FCA are how water would enter and leave the storage area and the duration of time that water would be present following a flood. A particular constraint would be ensuring compliance with Gatwick Airport’s requirements for limiting the potential for bird strike. Areas of open water could attract birds large enough to endanger planes, therefore drawdown is necessary within 48 hours of an FCA beginning to fill with floodwater. Such a strategy would prevent the creation of additional habitats for birds. To fulfil this requirement, the FCAs were designed within the hydraulic model with a very gentle slope to prevent the accumulation of standing water.

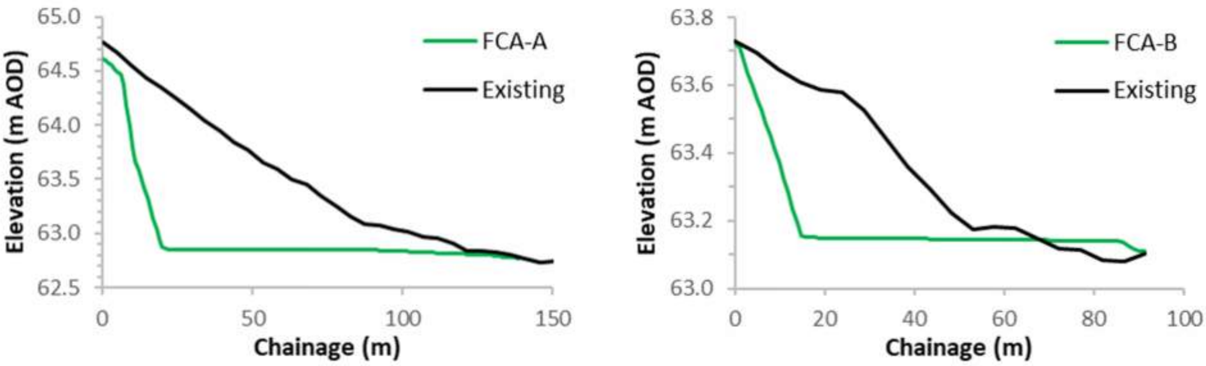


Figure 4-4: FCA locations in baseline topography (Left) and the two FCA topography (Right)

4.3.7 Figure 4-5 show the FCAs elevations for areas A and B.

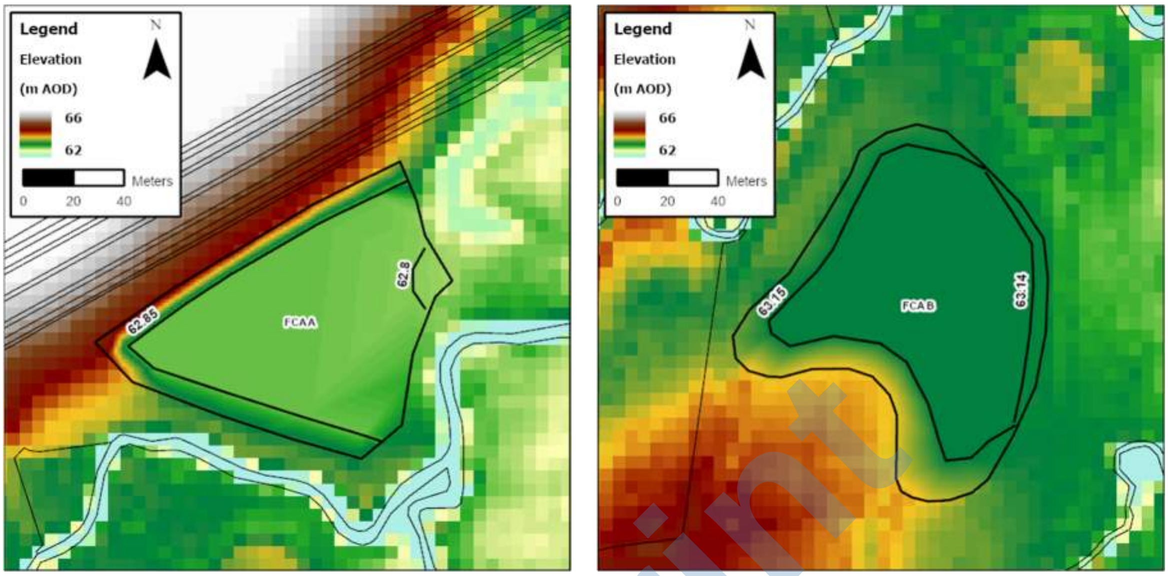


Figure 4-5: FCA A (Left) and B (Right)

4.3.8 West of Ifield Scheme model roughness

4.3.9 Figure 4-6 shows the roughness mapping for the Baseline and Development scenarios. The key difference is the proposed CWRR layout.

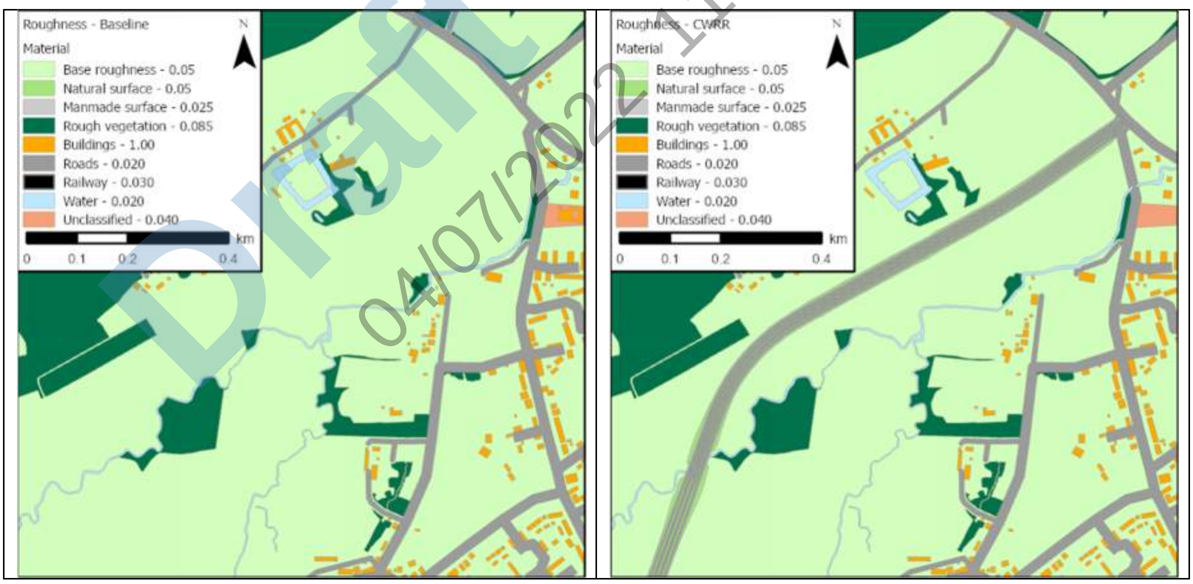


Figure 4-6: Hydraulic roughness mapping for the Baseline (Left) and Development (Right) scenarios

5. MODEL PROVING

5.1 Run performance and Verification

5.1.1 Table 5.1 summarises the mass balance error for the 2D TUFLOW model domain. The accepted tolerance range recommended by the software manual is +/-1%[5]. The overall cumulative mass balance error is less between -0.14% to 0.02% for all four simulations. The peak cumulative mass balance error, which occurs at the very start of the simulation is less than 0.61%. This is within the acceptable error range for such models.

Table 5.1: Mass balance errors

Model		**Baseline**		
	Mass balance error	**5yr3hr**	**100yr6hr**	**100yrCC 2080Upper6hr**
2D TUFLOW	**Peak Cumulative Mass Error**	0.53%	0.57%	0.61%
	Final Cumulative Mass Error	0.02%	-0.12%	-0.14%
	Volume Error	0.02	-0.12%	0.14%

5.1.2 Figure 5-1, Figure 5-2 and Figure 5-3 illustrate the 1D model run performance for the baseline scenario for the 5yr3hr, 100yr6hr and 100yrCC2080Upper6hr event respectively. The plots show that the model convergence criteria are achieved for the simulation period, with only occasional instances of short sharp periods of non-convergence, indicated by the red lines in the 'Model Convergence' charts. This is acceptable for a model of this size and complexity.

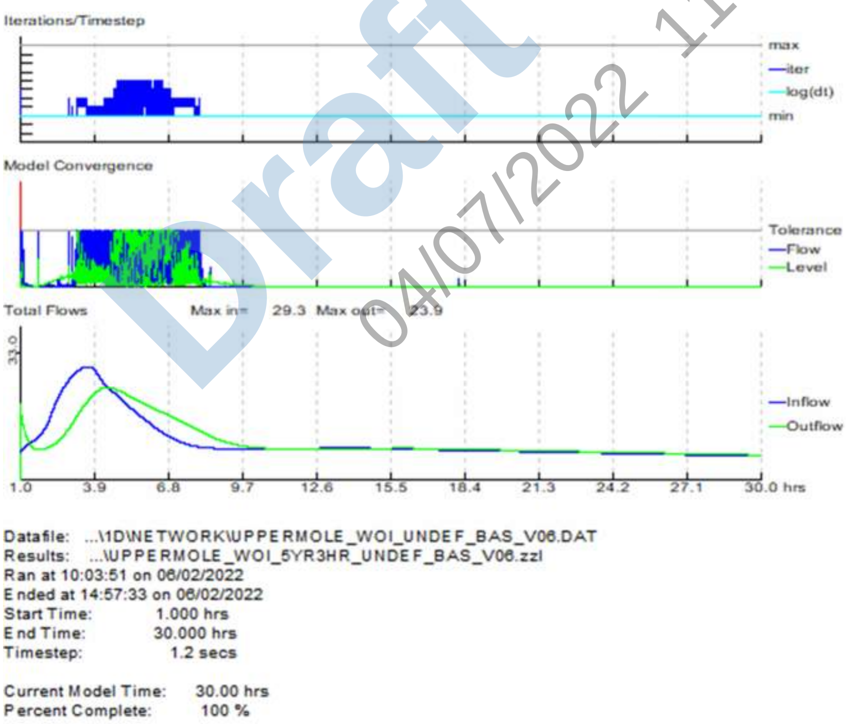


Figure 5-1: Model run performance - Baseline scenario 5yr3hr event

[5] BMT TUFLOW 1D/2D Fixed Grid Hydraulic Modelling – TUFLOW Classic/HPC User Manual Build 2018-03-AD

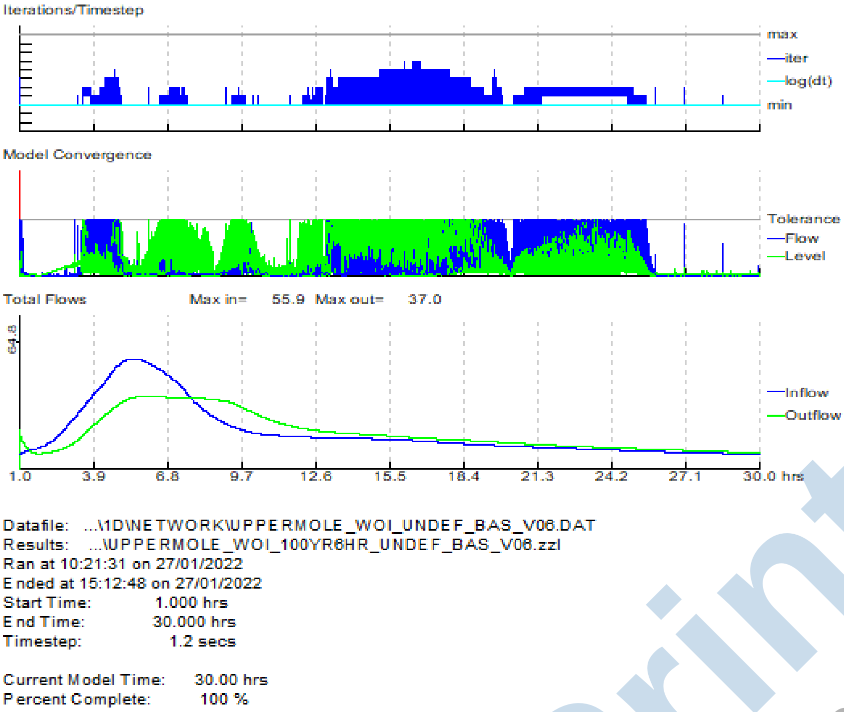


Figure 5-2: Model run performance - Baseline scenario 100yr6hr event

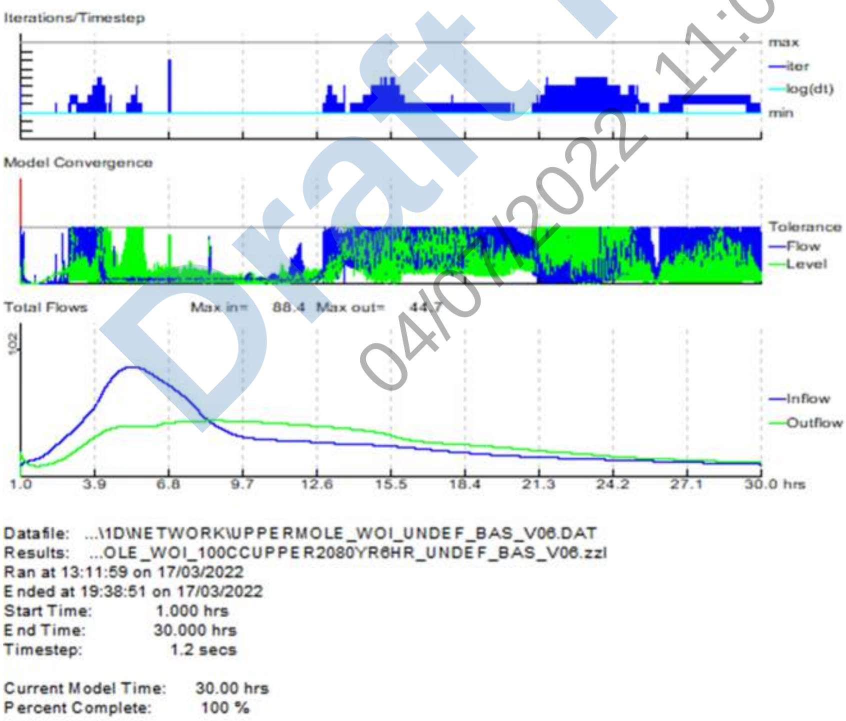


Figure 5-3: Model run performance - Baseline scenario 100yrCC2080Upper6hr event

5.2 Sensitivity analysis

5.2.1 Sensitivity analysis was carried out to understand the hydraulic model's uncertainty and result reliability. Sensitivity testing was carried out under the 100yr6hr event for the following parameters.

- Model inflows +/-20%
- Downstream boundary +/-20%
- 1D Channel Manning's n Roughness +/-20%
- 2D Floodplain Manning's n Roughness +/-20%
- Bridge width/area -20%

Model inflows

5.2.2 Sensitivity analysis was carried out on all model inflows by increasing and decreasing inflows by 20%. Figure 5-4 shows the flood depth difference compared to the baseline result. Increasing model inflows by 20% increases the flood depth by between 0.01m to 0.1m for most of the model area. A more significant increase was simulated in the Gatwick Area, with flood depth increases simulated to be greater than 0.2m. Decreasing model inflows by 20% decreases the flood depth by between 0.01m to 0.1m for most of the model area. A more significant decrease was simulated further downstream in the Gatwick Area, with flood depth decreases simulated to be greater than 0.2m.

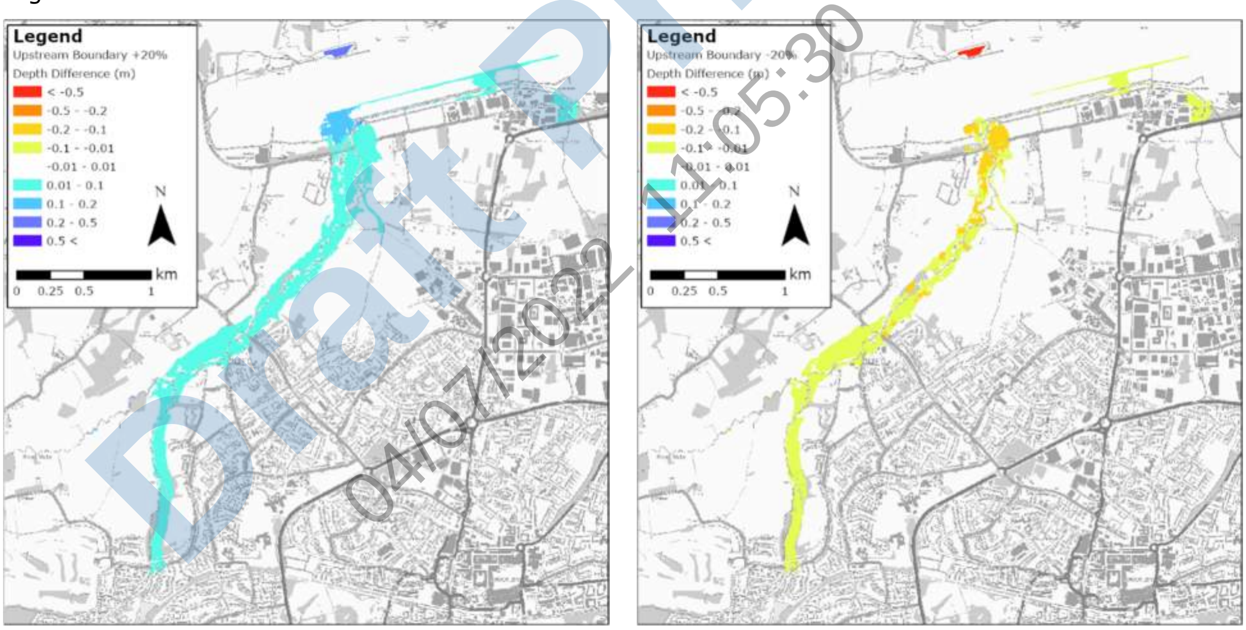


Figure 5-4: Sensitivity difference - Upstream Boundary increased by 20% (Left) and downstream by 20% (Right)

5.2.3 Figure 5-5 show the flood outline difference in the West of Ifield site area. Figure 5-5 shows that changes in model inflows did not generate significant changes in flood extents in the West of Ifield site area upstream of Ifield Green Road, simulating small increases and decreases in flood extents in line with increases and decreases in upstream inflows.

5.2.4 Figure 5-6 and Figure 5-7 show that changes in model inflows have a more significant impact in the Gatwick Area on the flood extents. Gatwick Airport is outside the area of interest of our study however, it is important to understand hydraulic model sensitivity. The model was truncated to improve model run times and remove the issues of model instability in locations not relevant to the West of Ifield study. The fluvial boundary for Crawter's Brook was re-located significantly closer to Gatwick Airport. Changes to the inflow boundary. This relocation may factor in the heightened model sensitivity to changes in model inflows at Gatwick Airport.

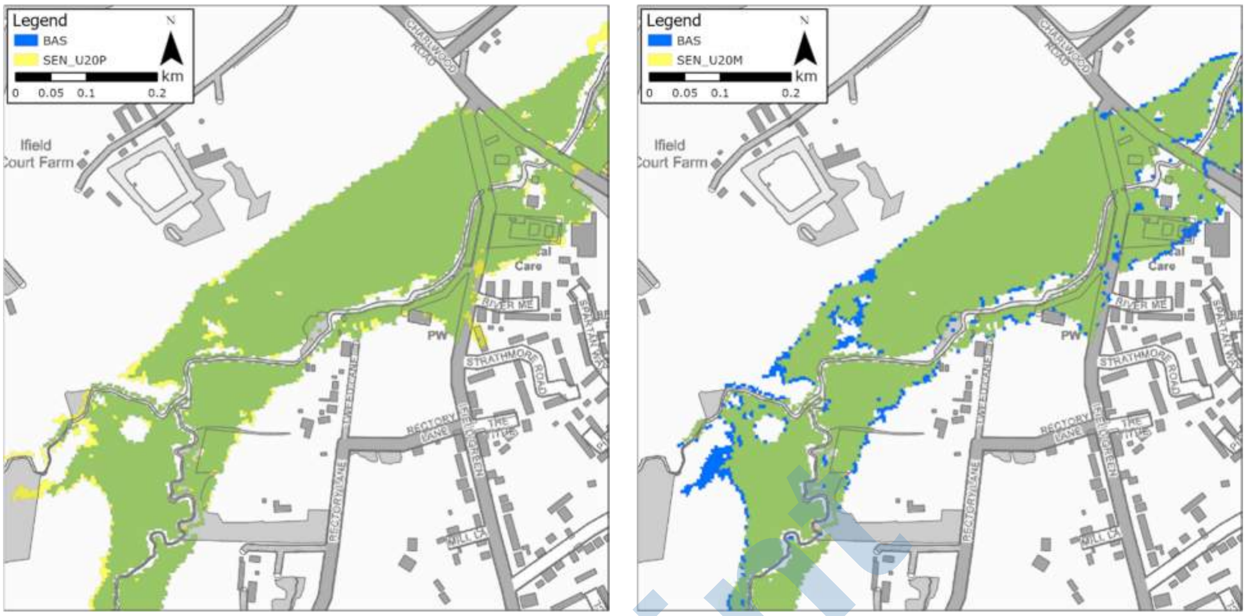


Figure 5-5: Sensitivity difference - Upstream Boundary increased 20% (Left) and decrease 20% (Right) - upstream of Ifield Green road bridge

Figure 5-6: Sensitivity difference - Upstream boundary increased by 20% - Gatwick Airport

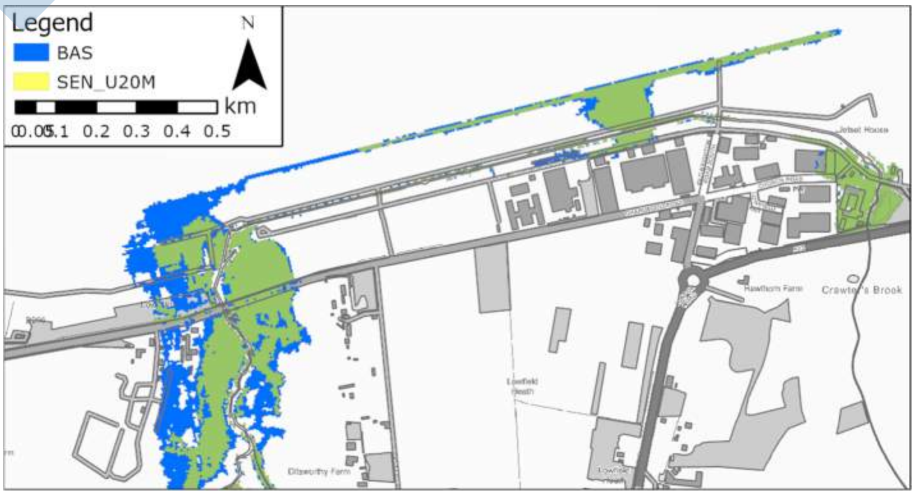


Figure 5-7: Sensitivity difference - Upstream boundary decreased by 20% - Gatwick Airport

Downstream boundary

5.2.5 A Normal Depth boundary has been applied to represent the downstream boundary of the model. Sensitivity testing of the downstream boundary was carried out by altering the channel gradient applied to calculate the Normal Depth boundary by +/-20%. The sensitivity testing setup id shown in Table 5.2.

Table 5.2: Downstream Boundary Sensitivity Testing Setup

Scenario	Test	Boundary Type	Slope Value	Gradient
BAS		Normal Depth	0.000580	1724.14
SEN_D20P	+20%	Normal Depth	0.000483	2068.97
SEN_D20M	-20%	Normal Depth	0.000725	1379.31

5.2.6 Figure 5-8 shows the flood depth difference compared to the baseline result for the downstream boundary sensitivity testing, increasing and decreasing the boundary by 20% respectively. The impact is restricted to downstream of the Gatwick culvert, at the pond to the north of the runway. The sensitive test simulated a difference of approximately +0.2m and -0.2m flood depth when increasing and decreasing the downstream boundary by 20% respectively. This indicates the hydraulic model is not significantly sensitive to changes in the downstream boundary setup, particularly in the area of interest to this study.

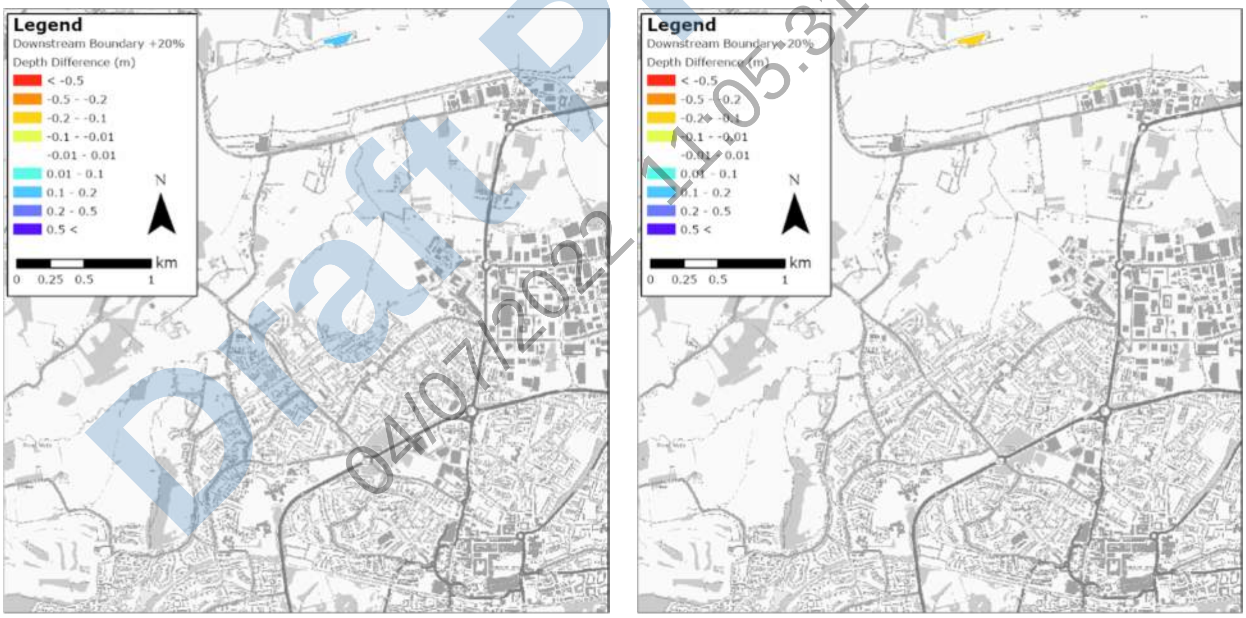


Figure 5-8: Sensitivity difference - Downstream Boundary increased 20% (Left) and decreased 20% (Right)

Channel roughness

5.2.7 Sensitivity testing was carried out on the 1D channel roughness, by increasing and decreasing the manning's n roughness parameter by 20%. Figure 5-9 shows the flood depth difference compared to the baseline result.

5.2.8 Increasing channel roughness by 20% increases the flood depth by between 0.01m to 0.1m for most of the model area. A greater increase was simulated around Gatwick Airport, reaching increasing by between 0.1 and 0.2m.

5.2.9 Decreasing channel roughness by 20% decreases floodplain flood depth by 0.01m to 0.2m. An area at Gatwick Airport, upstream of the culvert running under the Gatwick Airport runway, is simulated to have an increased flood depth of between 0.01m and 0.02m. Interrogation of this area found the increased depths were of the scale of approximately +0.015m. This increase, albeit small, is likely the impact of the culvert running under the Gatwick Airport runway.

5.2.10 The reduction in channel roughness allows flow to pass downstream with less energy, thus requiring a lower head of water and the resulting the reduction water levels in water levels observed for most of the model area. The hydrograph peak passes downstream faster than during the baseline run however, the culvert running under Gatwick Airport runway acts as a point of constriction. Although flow may reach the culvert entrance more quickly, only a certain amount of flow is able to pass through, thus resulting in a greater volume of water initially accumulating upstream of the culvert than was simulated compared to the baseline.

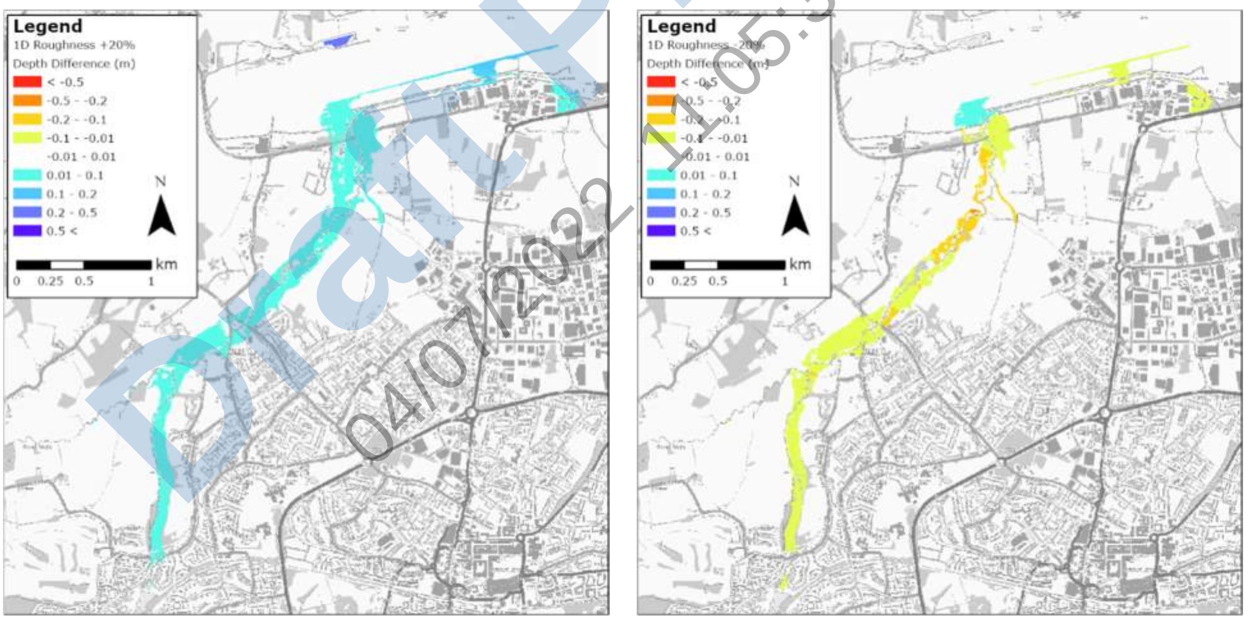


Figure 5-9: Sensitivity difference – Channel Roughness increased 20% (left) and decreased 20% (right)

5.2.11 Figure 5-10, Figure 5-11 and Figure 5-12 show the flood outline difference in the West of Ifield site area and at Gatwick. Figure 5-10 shows that changes in channel roughness did not show significant changes in flood extents in the West of Ifield site area upstream of Ifield Green Road, simulating small increases and decreases in flood extents in line with increases and decreases in upstream inflows.

5.2.12 Figure 5-11 and Figure 5-12 show that changes in channel roughness have a slightly more significant impact in the Gatwick Area on the flood extents. Gatwick Airport is outside the area of interest of our study.

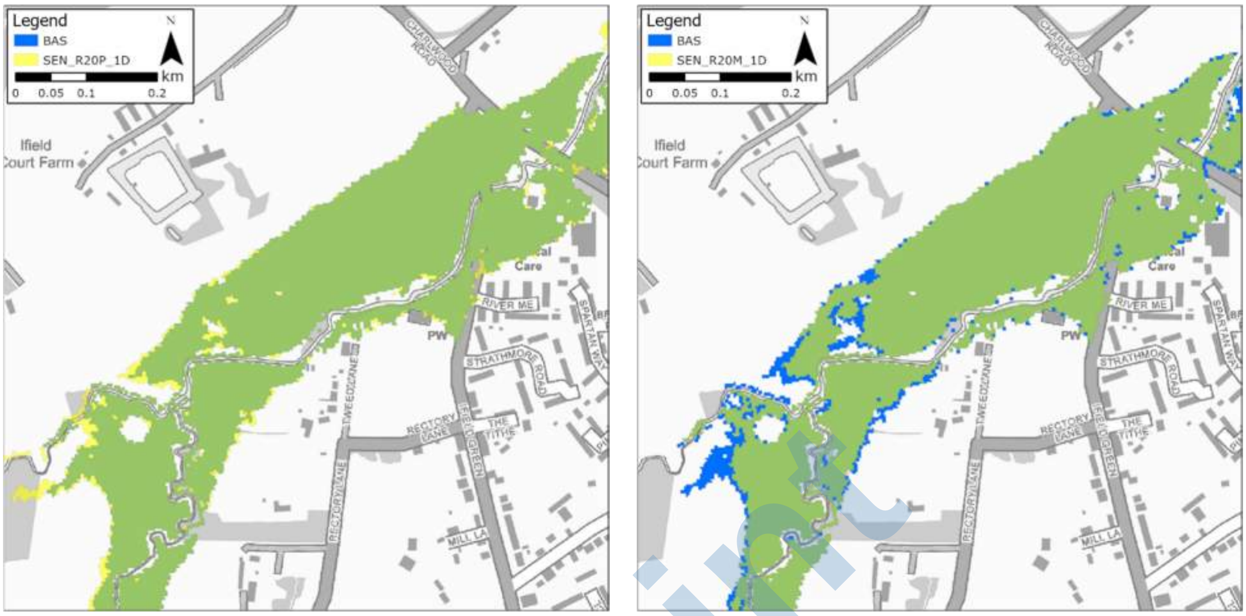


Figure 5-10: Sensitivity difference – Channel roughness increased 20% (Left) and decrease 20% (Right) - upstream of Ifield Green road bridge

Figure 5-11: Sensitivity difference - Channel roughness increased by 20% - Gatwick Airport

Figure 5-12: Sensitivity difference - Channel roughness decreased by 20% - Gatwick Airport

Floodplain Roughness

5.2.13 Sensitivity testing was carried out on the 2D Floodplain roughness, by increasing and decreasing the manning's n roughness parameter by 20%. Figure 5-13 show the flood depth difference compared to the baseline result.

5.2.14 Increasing floodplain roughness by 20% increases the flood depth by between 0.01m to 0.1m in the upstream areas and decreases flood depths downstream. Decreasing channel roughness by 20% decreases floodplain flood depth by 0.01m to 0.1m in the upstream areas and increases flood depths downstream. This inverse relationship is likely due to the impact of the culvert running under the Gatwick Airport runway. As detailed in 5.2.9 the culvert acts as a constriction point to all flows passing downstream under the runway.

5.2.15 Increases in floodplain roughness as resulted in the hydrograph peak passing more slowly downstream compared to the baseline. The slower hydrograph means there is more time for the water to pass through the culvert under the Gatwick Airport runway, reducing the volume of water accumulating upstream. The reverse is true for the decrease in floodplain roughness.

5.2.16 Gatwick Airport is outside the area of interest of our study. However, these sensitivity runs indicate the culvert under the Gatwick Airport runway is a key factor in the flood mechanisms operating around Gatwick Airport.

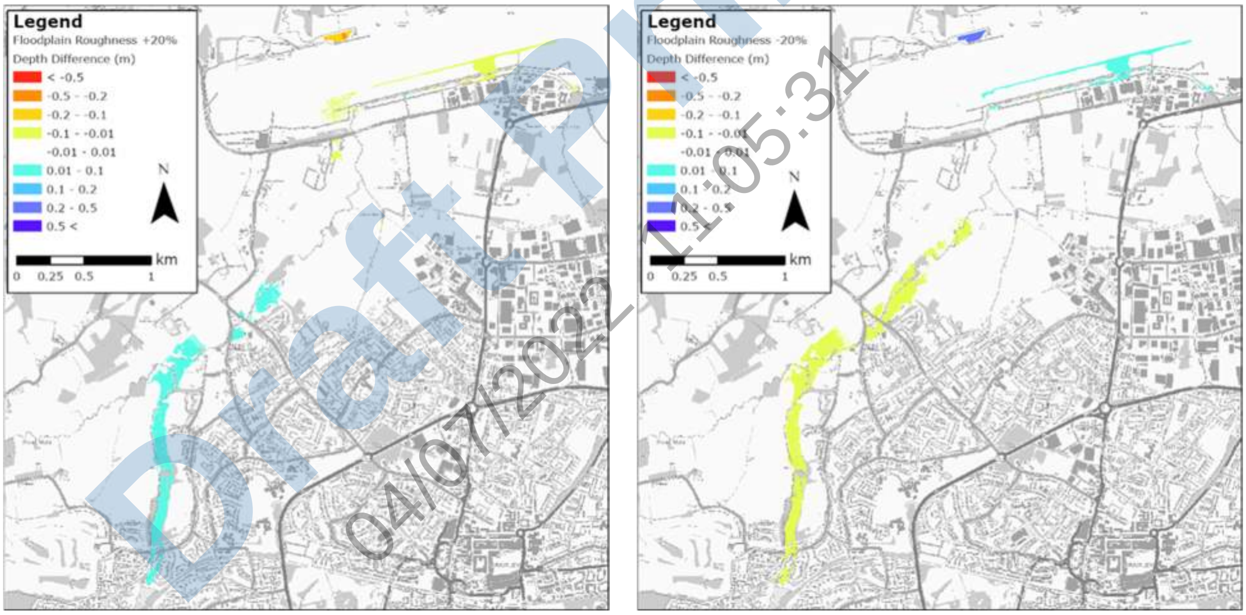


Figure 5-13: Sensitivity difference – Floodplain Roughness increased 20% (left) and decreased 20% (right)

Model Sensitivity Summary

5.2.17 The sensitivity results indicate that overall, the model sensitivity to changes to inflows was between 0.01m to 0.10m flood depth for much of the model area. The results indicate the model was more sensitivity to changes to inflows around Gatwick Airport, with flood depth differences simulated to be over 0.20m. Gatwick Airport is outside the area of interest of our study however, it is important to understand hydraulic model sensitivity. It is considered likely that this is related to the relocation of the Crawter's Brook inflow boundary closer to Gatwick Airport during model truncation, resulting in a more immediate influence on flows to the local area.

5.2.18 The sensitivity results indicate the model is not sensitive to changes in the downstream boundary, with any impact restricted to downstream of the Gatwick Airport culvert, at the pond to the north of the runway.

5.2.19 The sensitivity results indicate that overall, the model sensitivity to changes in channel (1D) roughness was between 0.01m to 0.10m flood depth for much of the model area. The sensitivity results indicated the model was more sensitive to changes in channel (1D) roughness around Gatwick Airport, reaching between 0.10 to 0.20m. The channel (1D) roughness sensitivity testing also highlighted that the culvert running under the Gatwick Airport runway was likely a key structure controlling flood risk mechanisms operating around Gatwick Airport. The culvert acts as a point of constriction, controlling the flow passing downstream.

5.2.20 Sensitivity testing of the floodplain (2D) roughness showed changes of between 0.01m and 0.1m in flood depth. This testing again highlighted the influence on flood risk of the culvert running under the Gatwick Airport runway. The sensitivity results showed when floodplain (2D) roughness was increased by 20%, the flood depths in the upstream area increased but decreased in the downstream area around Gatwick Airport. The reverse was true when floodplain (2D) roughness was decreased by 20%. This inverse relationship was related to the culvert, acting as a constriction point to all flows passing downstream under the runway. To summarise, increases in floodplain roughness slowed passage of the hydrograph peak allowing more time for the water to pass through the culvert under the Gatwick Airport runway and reducing the volume of water accumulating upstream. The reverse is true for the decrease in floodplain roughness.

5.3 Validation

5.3.1 The aim of this study is to investigate a range of fluvial flood mitigation options for the West of Ifield development which would be acceptable to key stakeholders and the EA. For this, the model was truncated to the area of interest to improve model run times and results file size. To understand how truncating the model has impacted the model results, hydrographs from the West of Ifield model and the EA model at cross-sections were compared at a range of cross-sections and events.

5.3.2 Figure 5-14, Figure 5-15, Figure 5-16 and Figure 5-17 show the hydrograph comparisons for the 20yr12hr, 100yr6hr and 1000yr24hr event at cross sections 11_1523, 19_4466, 19_2974 and 19_1019. The figures show that the truncated model is replicating the EA's model hydrograph's form and peak.

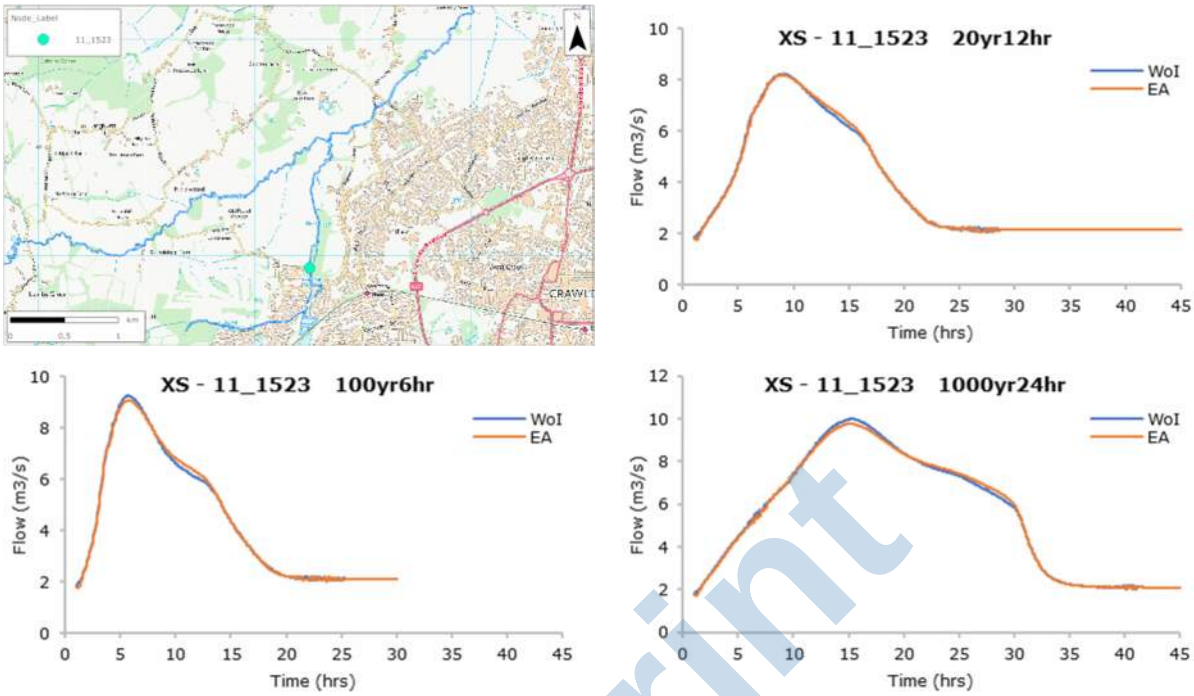


Figure 5-14: Comparison between West of Ifield and the EA model flows at cross section 11_1523, for the 20yr12hr, 100yr6hr and 1000yr24hr events

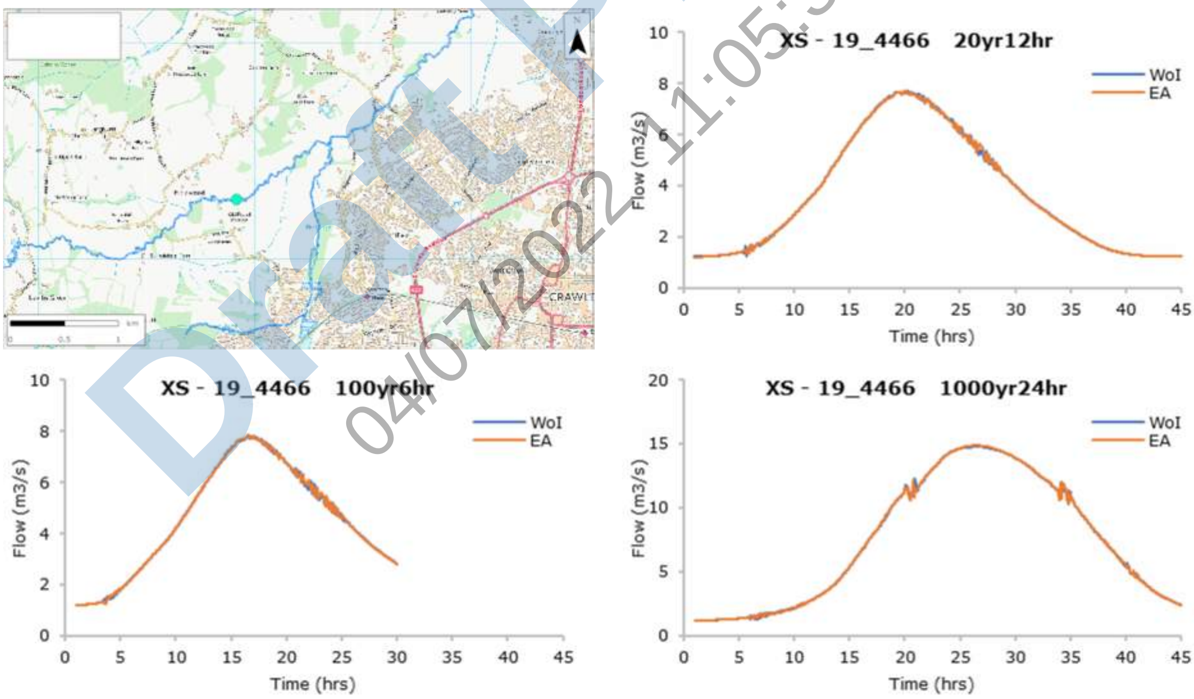


Figure 5-15: Comparison between West of Ifield and the EA model flows at cross section 19_4466, for the 20yr12hr, 100yr6hr and 1000yr24hr events

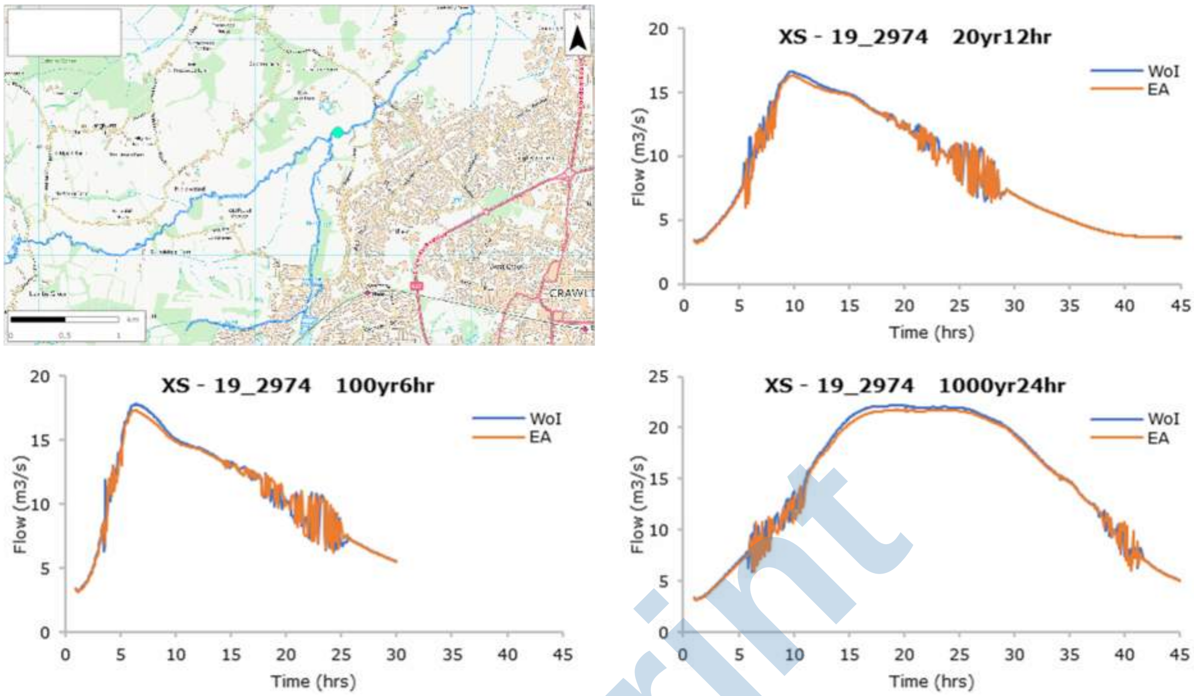


Figure 5-16: Comparison between West of Ifield and the EA model flows at cross section 19_2974, for the 20yr12hr, 100yr6hr and 1000yr24hr events

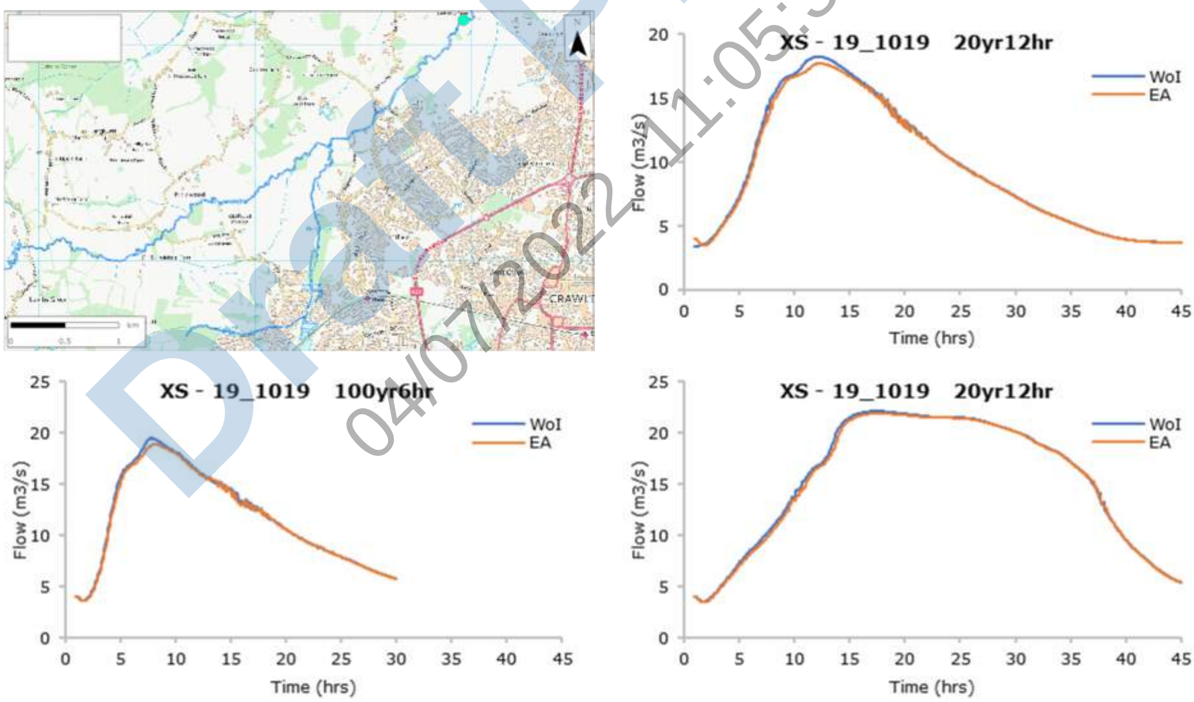


Figure 5-17: Comparison between West of Ifield and the EA model flows at cross section 19_1019, for the 20yr12hr, 100yr6hr and 1000yr24hr events

6. RESULTS

6.1 Simulations

6.1.1 The aim of the hydraulic modelling was to investigate a range of fluvial flood mitigation options for the West of Ifield development which would be acceptable to key stakeholders and the EA. Four Development scenarios were simulated for the 20-year, 100-year, 1000-year and 100-year Climate Change (Upper 2080) return period events.

- CWRR
- CWRR and FCA-A
- CWRR and FCA-B
- CWRR and FCA-A and FCA-B.

6.1.2 Figure 6-1 shows the proposed CWRR in relation to the existing EA Flood Zones 2 and 3 within the site boundary. The CWRR embankment will cut across an active floodplain as it passes over the River Mole and encroach along the northern boundary of the floodplain as it approaches Charlwood Road.

6.1.3 It is anticipated that the CWRR embankment crossing the active floodplain will act to hold back floodplain flow from west to east, alleviating the flood risk to the East. Considering the topography of the area upstream of the CWRR crossing, it is anticipated that any consequential increase in flood levels to the West of the crossing would be limited to the floodplain immediately upstream and within the West of Ifield development site boundary.

6.1.4 Figure 6-1 shows the two flood compensations areas proposed to mitigate the impact of the CWRR embankment's encroachment along the northern edge of the floodplain.

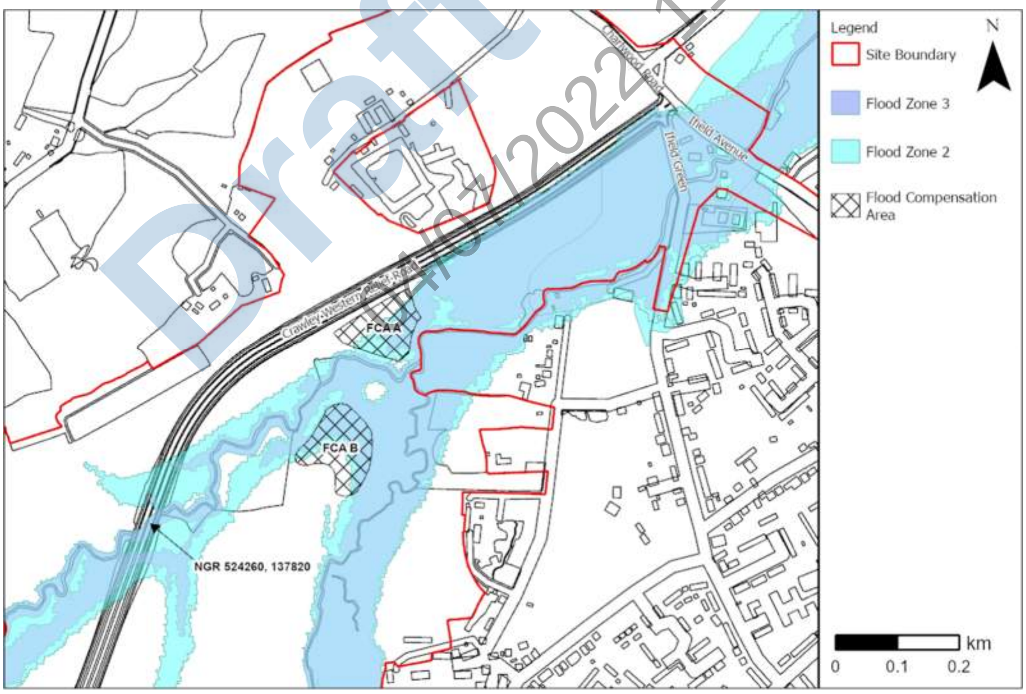


Figure 6-1: Proposed CWRR and FCA's in relation to existing EA Flood Zones

6.1.5 The model results indicate the impact to flood risk, in terms of flood depths, hazard and extent, of the CWRR scenario and the three FCA scenarios is limited to within the site boundary and downstream of the site. The model simulated a negligible impact to the flood risk upstream of the development site boundary.

6.2 Flood Extents

6.2.1 Figure 6-2 shows the change to flood extents resulting from CWRR scenario compared to the Baseline scenario for the 20-year, 100-year, 1000-year, and the 100-year with Climate Change (Upper 2080) events. The yellow areas represent where the Baseline and CWRR scenario extents are identical, the green areas represent the areas that flood during the Baseline scenario but not during the CWRR scenario and the blue areas represent the areas that flood during the CWRR scenario but not during the Baseline scenario.

6.2.2 The model results did not show a significant increase or decrease in flood extents outside the site boundary for any of the fluvial events simulated for the CWRR scenario compared to the Baseline scenario, indicating the CWRR has a negligible impact on flood extents outside site boundary.

6.2.3 Figure 6-2 shows that within the site boundary, the flood extent during the CWRR scenario is reduced compared to the Baseline scenario. The CWRR embankment is preventing the spread of flood waters across the floodplain, most noticeably at the point the CWRR crosses the River Mole, resulting in a significantly reduced flood extent during the 1000-year and 100-year plus climate change (Upper 2080).

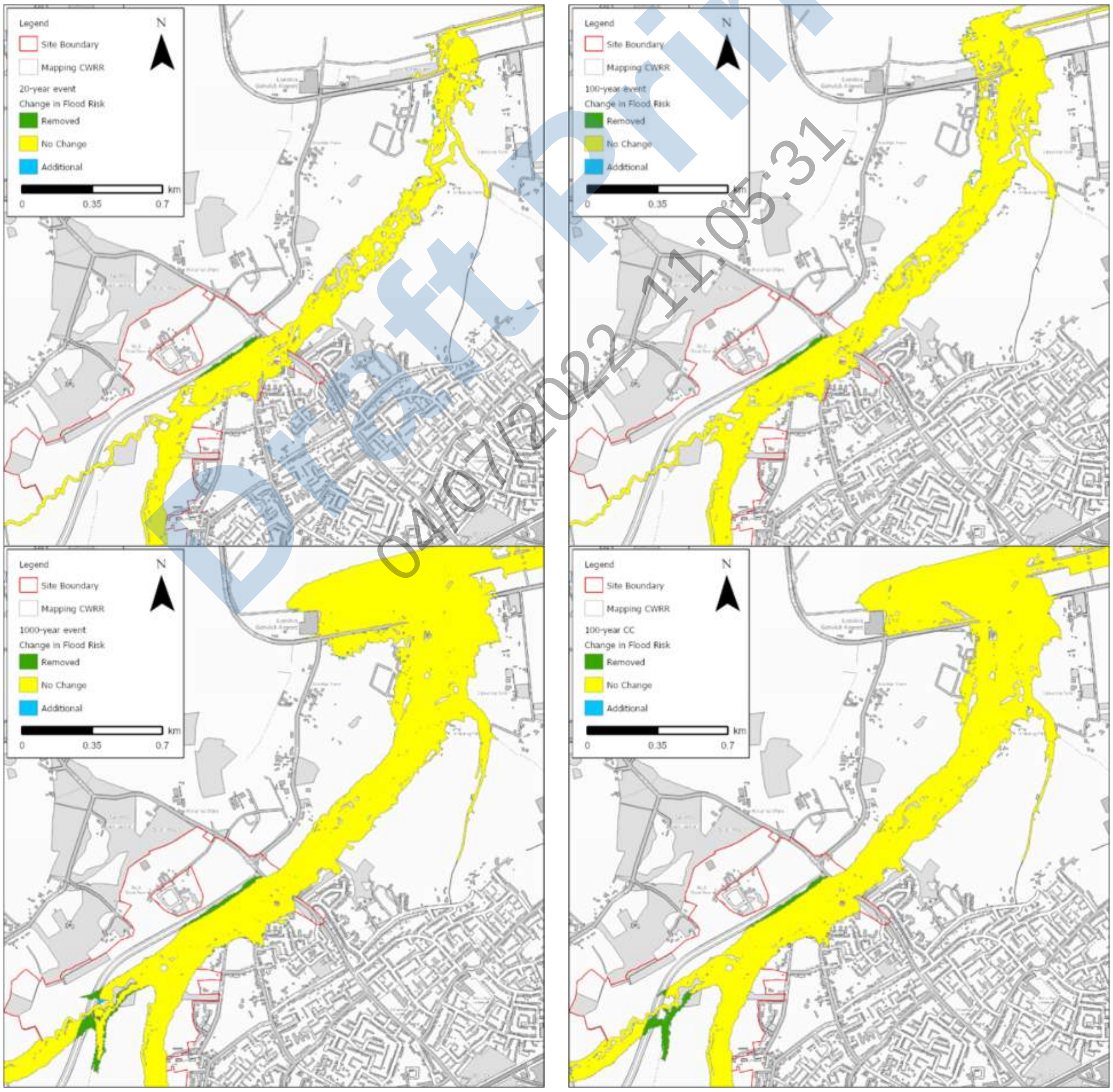


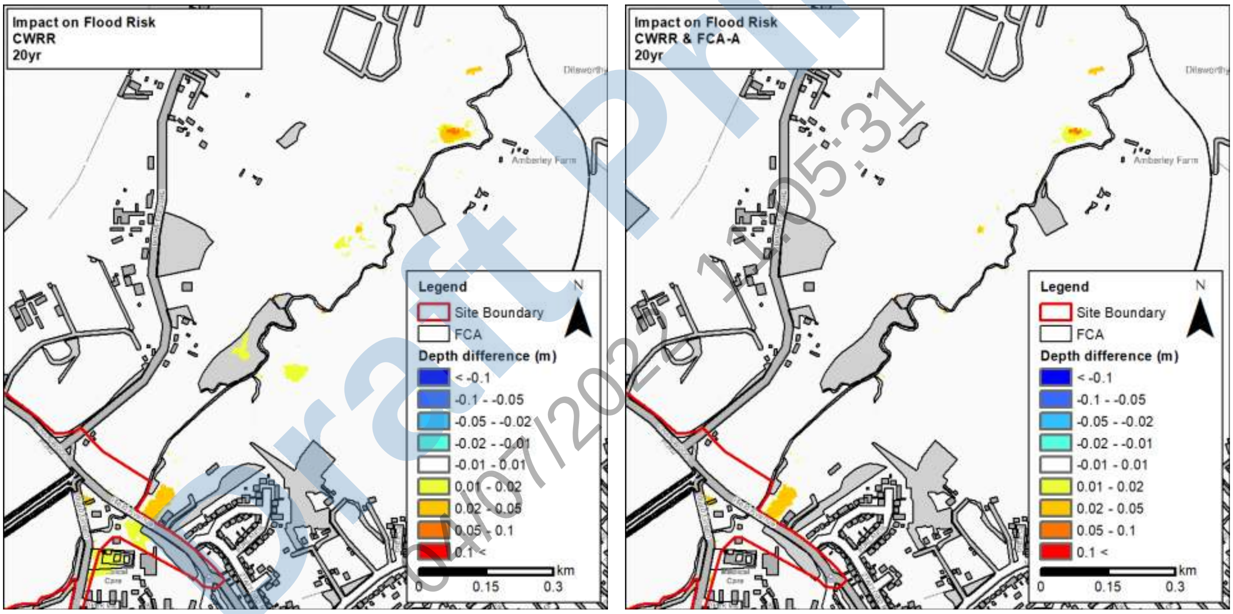
Figure 6-2: Flood Extent comparison between the Baseline and the West of Ifield development scenario with the CWRR for the 20-year (top left), 100-year (top right), 1000-year (bottom left) and 100-year with Climate Change (Upper 2080) events (bottom right).

6.3 Downstream Impact on Flood Risk

1 in 20-year event

6.3.1 Figure 6-3 shows the flood depth difference compared to the Baseline scenario of the CWRR scenario, and the three FCA scenarios simulated for the 1 in 20-year event. It is noted that all depth differences referenced for this area are less than +/- 0.10m.

6.3.2 The CWRR scenario simulated increased flood depths to the land and property between Ifield Green and Ifield Avenue, and at isolated several areas along the River Mole floodplain up to 1.3km downstream of Ifield Avenue. The FCA scenarios showed the FCAs acted to remove the increased flood risk to the land and property between Ifield Green and Ifield Avenue caused by the CWRR and alleviated the increased flood risk simulated to the isolated areas of the floodplain downstream of Ifield Avenue. FCA-B is simulated to mitigate the increased flood risk more significantly than FCA-A. The CWRR FCA-A and FCA-B simulation alleviated the increased flood risk caused by the CWRR embankment most significantly, with the flood depth difference compared to the Baseline scenario simulated to be between 0.01m to 0.02m.



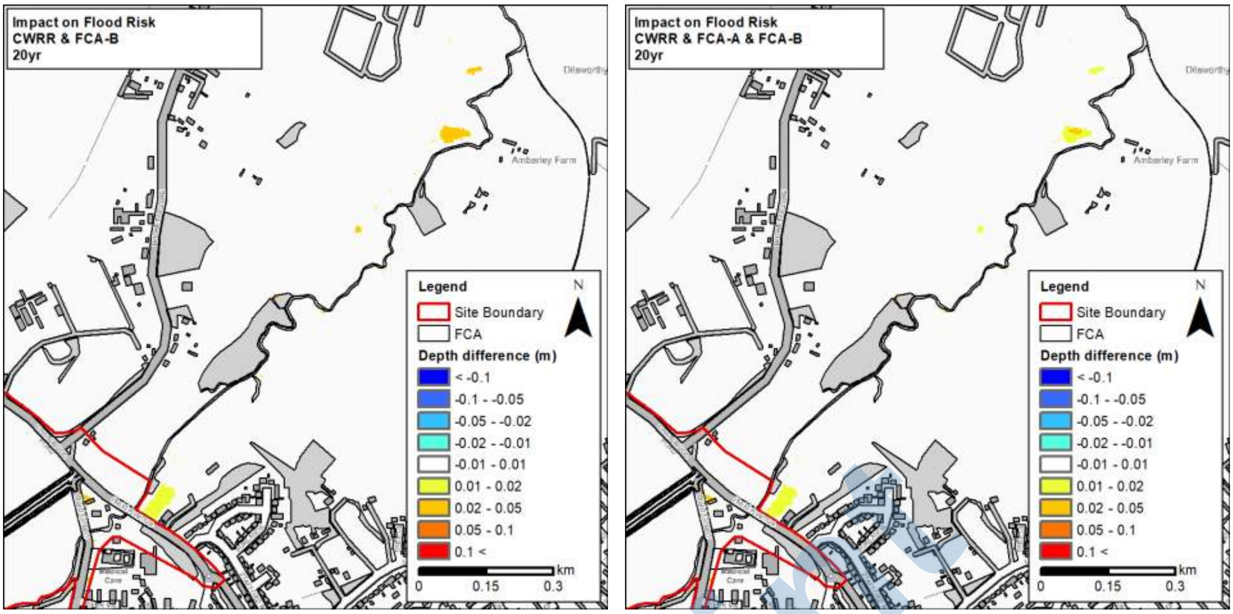


Figure 6-3: Downstream impact on flood risk of the West of Ifield development scenarios for the 1 in 20-year event

6.3.3 To contextualise the impact to flood risk shown in Figure 6-3, Figure 6-4 shows the 1 in 20-year flood depth results for Baseline and CWRR scenario. The change in flood risk to the floodplain immediately north of Ifield Avenue is between 0.02m to 0.05m, while the simulated flood depth is between 0.40m to 0.60m. The increase is comparatively small compared to the existing depth.

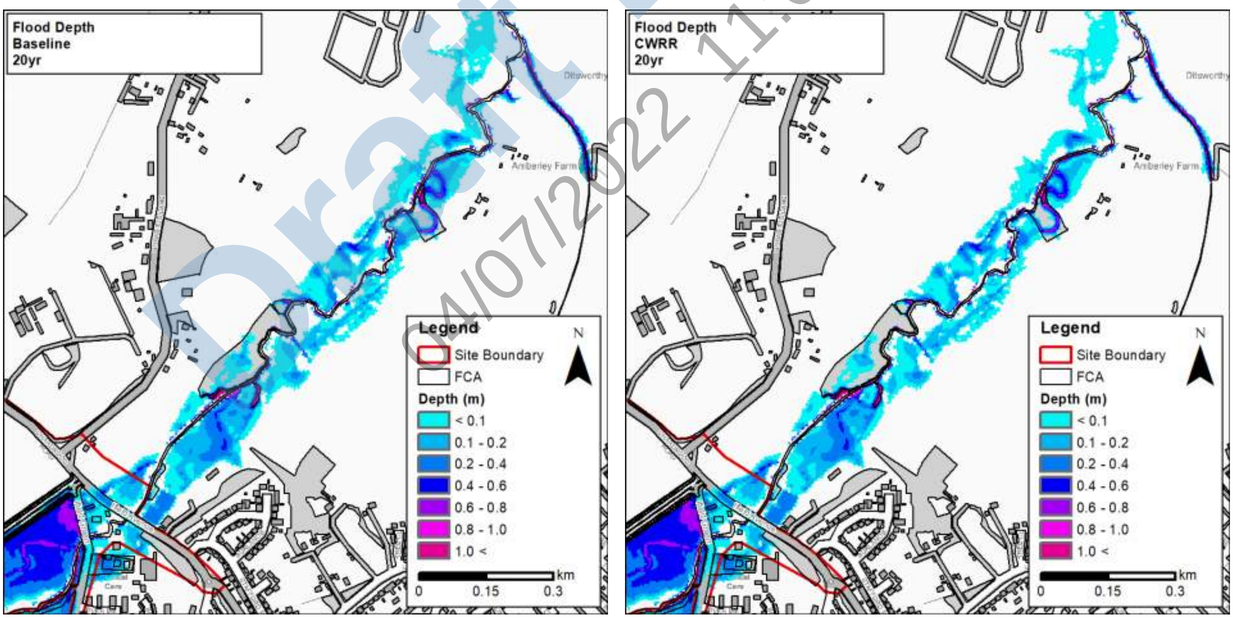


Figure 6-4: 1 in 20-year Flood Depth for the Baseline and CWRR scenario

1 in 100-year event

6.3.4 The flood depth difference during the 1 in 100-year event downstream of the site boundary is simulated around London Gatwick Airport and along the River Mole floodplain (Figure 6-5).

6.3.5 The CWRR scenario simulated increased flood depths at the pond north of the runway at London Gatwick Airport, the grass area to the south of the runway, and at areas of the River Mole floodplain upstream of London Gatwick Airport.

6.3.6 The FCAs are simulated to alleviate the increase in flood risk caused by the CWRR embankment. FCA-B is simulated to have a greater alleviating power compared to FCA-A. FCA-B simulated no increased risk to the pond north of the runway compared with FCA-A, where a 0.01m to 0.02m increase in flood depths is simulated.

6.3.7 The CWRR FCA-A and FCA-B scenario simulated no increase in flood risk downstream of the site boundary compared to the Baseline scenario.

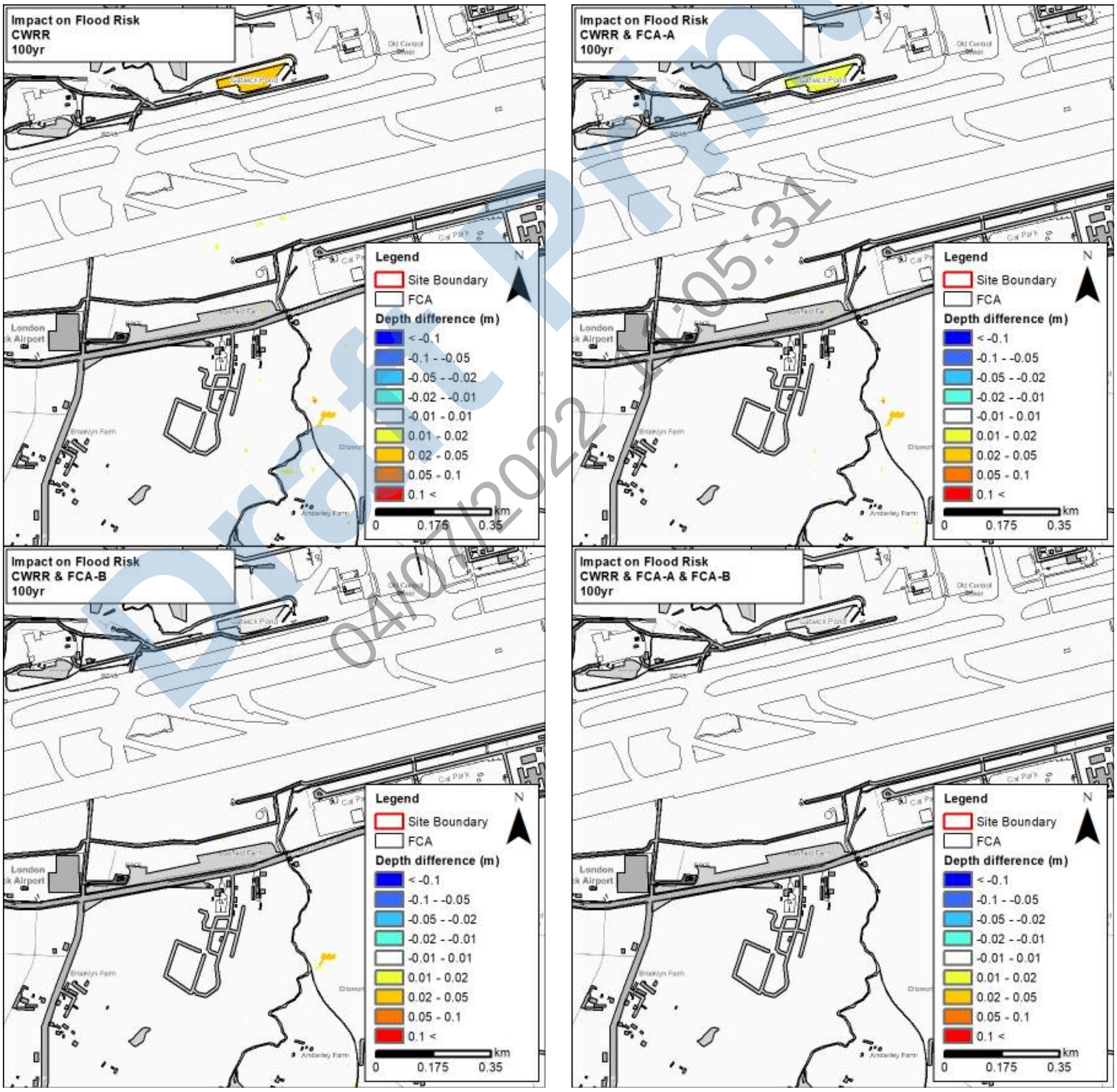


Figure 6-5: Downstream impact on flood risk of the West of Ifield development scenarios for the 1 in 100-year event

6.3.8 To contextualise the impact to flood risk shown Figure 6-5, Figure 6-6 shows the 1 in 100-year flood depth results for Baseline and CWRR scenario. The change in flood risk to the pond North of the runway is between 0.02m to 0.05m, while the simulated flood depth is over 1.00m. The increase is comparatively small compared to the existing depth and is highly unlikely to result in a change in material flood risks.

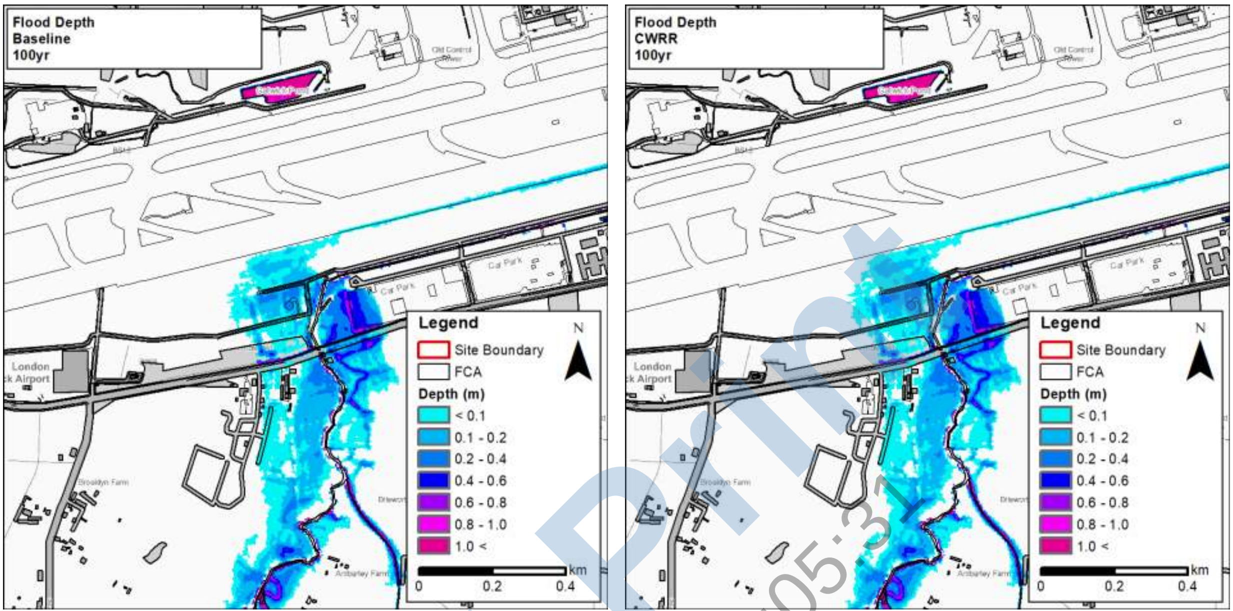
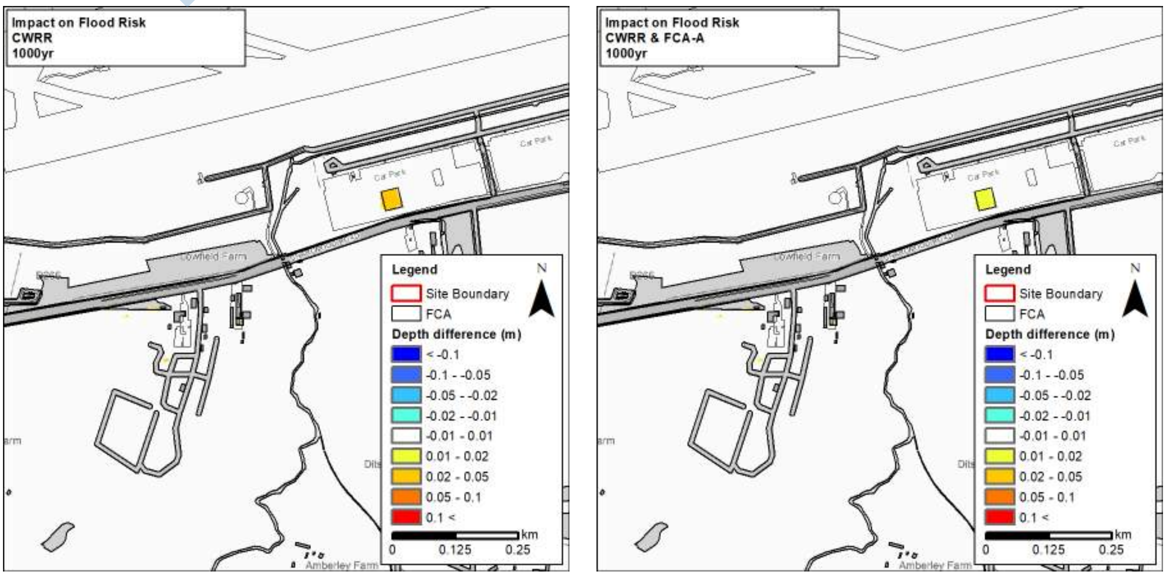


Figure 6-6: 1 in 100-year Flood Depth for the Baseline and CWRR scenario

1 in 1000-year event

6.3.9 The flood depth difference during the 1 in 1000-year event downstream of the site boundary is solely at the vegetated area of the Car Park to the south of the runway (Figure 6-7). The CWRR scenario simulated an increased flood depth of between 0.02m and 0.05m. The FCA's are simulated to alleviate the increase in flood risk, the FCA-A scenario, and the FCA-B scenario both simulated a 0.01m to 0.02m increase. The CWRR FCA-A and FCA-B scenario simulated no increase in flood risk compared to the Baseline scenario.



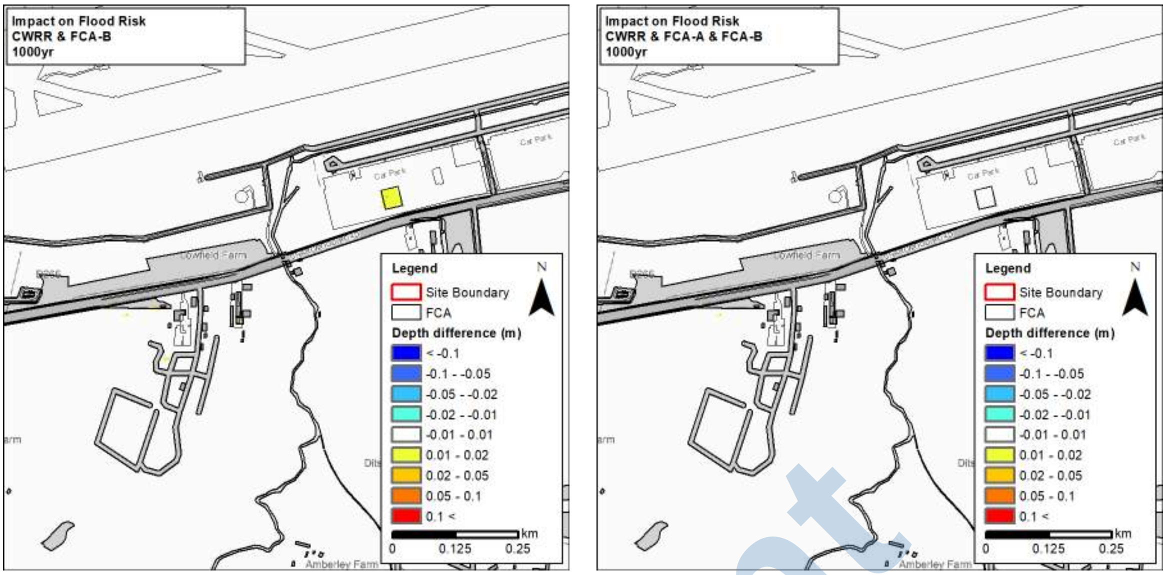


Figure 6-7: Downstream impact on flood risk of the West of Ifield development scenarios for the 1 in 1000-year event

6.3.10 To contextualise the impact to flood risk shown Figure 6-7, Figure 6-8 shows the 1 in 1000-year flood depth results for Baseline and CWRR scenario. The change in flood risk to the vegetated area in the Car Park is between 0.02m to 0.05m, while the simulated flood depth is between 0.80m and 1.00m. The increase is comparatively small compared to the existing depth.

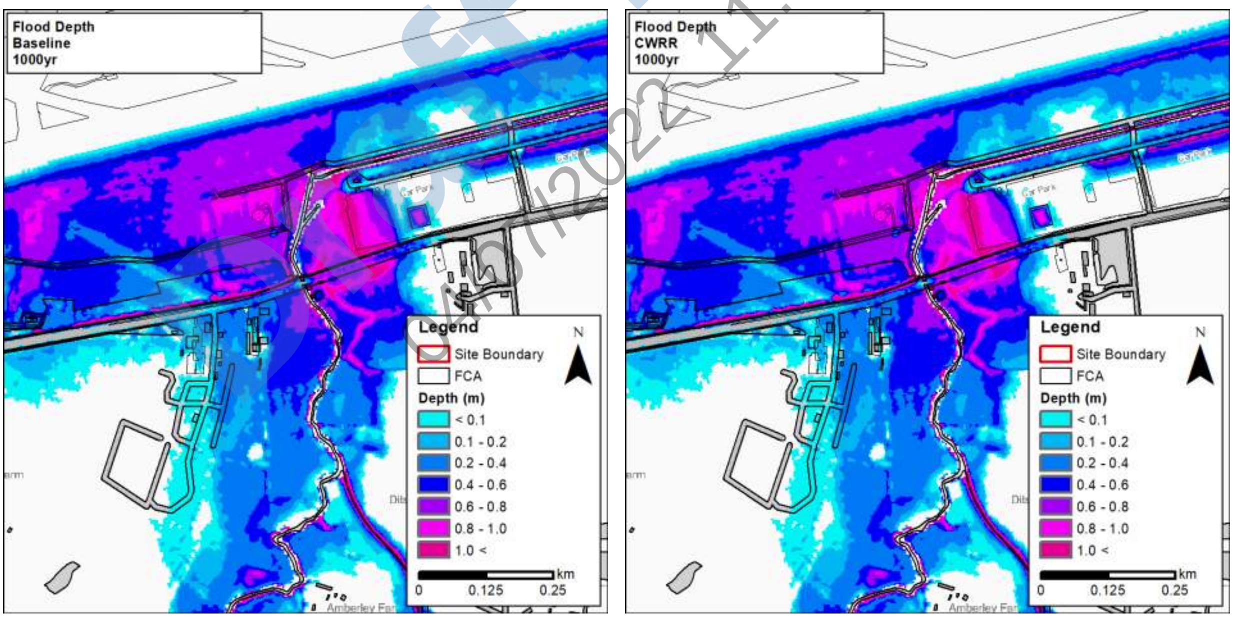


Figure 6-8: 1 in 1000-year Flood Depth for the Baseline and CWRR scenario

1 in 100-year with Climate Change (Upper 2080)

6.3.11 The only location simulated to have a flood depth difference compared to the baseline during the 1 in 100-year with Climate Change (Upper 2080) event downstream of the site boundary is the Car Park to the south of the runway and the grass area south of the runway (Figure 6-9).

6.3.12 The CWRR scenario simulated increased flood depths across the two Car Parks of between 0.01m to 0.05m, and a small area of increased flood depth, between 0.010m and 0.020mm, at the grass area south of the runway. The FCAs are simulated to reduce this increase in flood risk. The FCA-A scenario and the FCA-B scenario both simulating a 0.01m to 0.02m increase while the FCA-A and FCA-B scenario simulated no increase in flood risk.

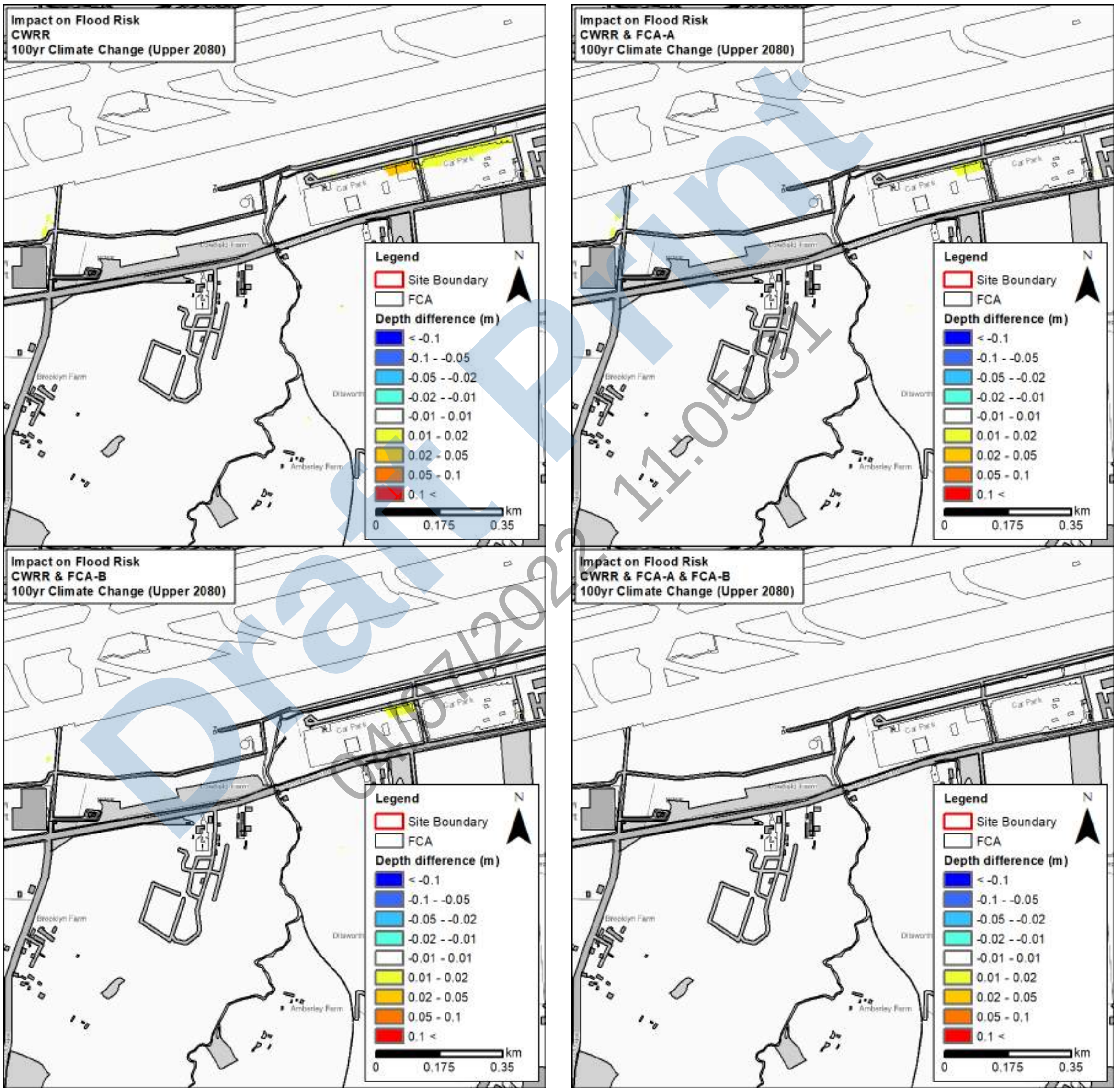


Figure 6-9: Downstream impact on flood risk of the West of Ifield development scenarios for the 1 in 100-year event plus Climate Change (Upper 2080)

6.3.13 To contextualise the impact to flood risk shown Figure 6-9, Figure 6-10shows the 1 in 100-year with Climate Change (Upper 2080) flood depth results for Baseline and CWRR scenario. The change in flood risk to the Car Park is between 0.0m to 0.05m, while the simulated flood depth is up to 1.00m. The increase is comparatively small compared to the existing depth.

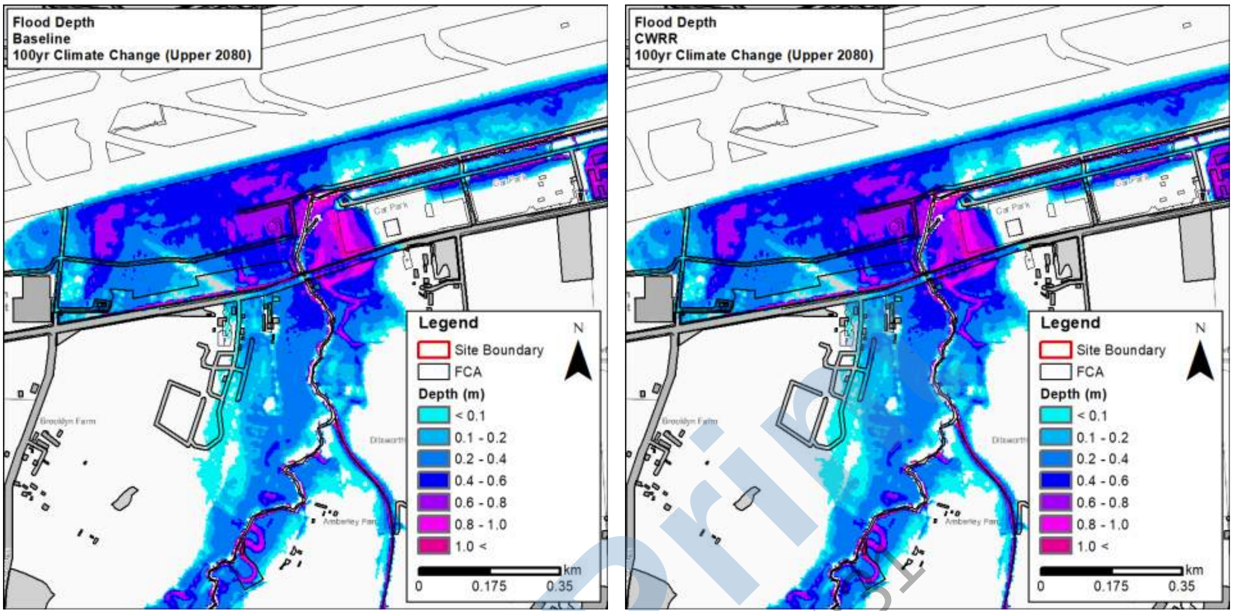


Figure 6-10: 1 in 100-year event plus Climate Change (Upper 2080) Flood Depth for the Baseline and CWRR scenario

6.3.14 The figures indicate the impact on downstream flood risk is small, with all increases simulated to be isolated, small areas of less than 0.10m differences.

6.3.15 The largest increases were simulated for the CWRR scenario, where no FCAs were present. The FCA-B was simulated to be more effective at alleviating the increases in flood risk caused by the CWRR embankment than FCA-A for the 20-year and 100-year event. The most effective solution was using both FCA-A and FCA-B, which simulated no increased flood risk downstream for the 100-year, 1000-year, or 100-year with Climate Change (Upper 2080). A small increase of between 0.01m-0.02m was observed for the 20-year event, limited to the floodplain downstream of Ifield Avenue however, when compared to the simulated flood depths, of between 0.40m to 0.60m, these increases in flood depths are negligible.

Summary of Downstream impact on Flood Risk

6.3.16 The FCA's were simulated to mitigate the increased flood risk downstream of the development site caused by the CWRR embankment. FCA-B was simulated to alleviate the flood risk more effectively than FCA-A. When both FCA-A and FCA-B were operating in combination, the model simulated no increase in flood risk compared to the baseline downstream of the development site for the 1 in 100-year (Flood Zone 3), 1 in 1000-year (Flood Zone 2) or the 1 in 100-year with climate change (Upper 2080). The 1 in 20-year event simulated increases in flood depths of between 0.01m to 0.02m at isolated areas of the River Mole floodplain between Ifield Avenue and approximately 1.3 km downstream. These increases are close to negligible when considering the flood depths in these locations are between 0.40m to 0.60m, and thus amount to between 1.7% and 5% increase in flood depths.

6.4 Impact on Flood Risk within Site Boundary

6.4.1 Figure 6-11 shows the flood depth model results within the Site Boundary for the 1 in 20-year event for the Baseline and CWRR scenario.

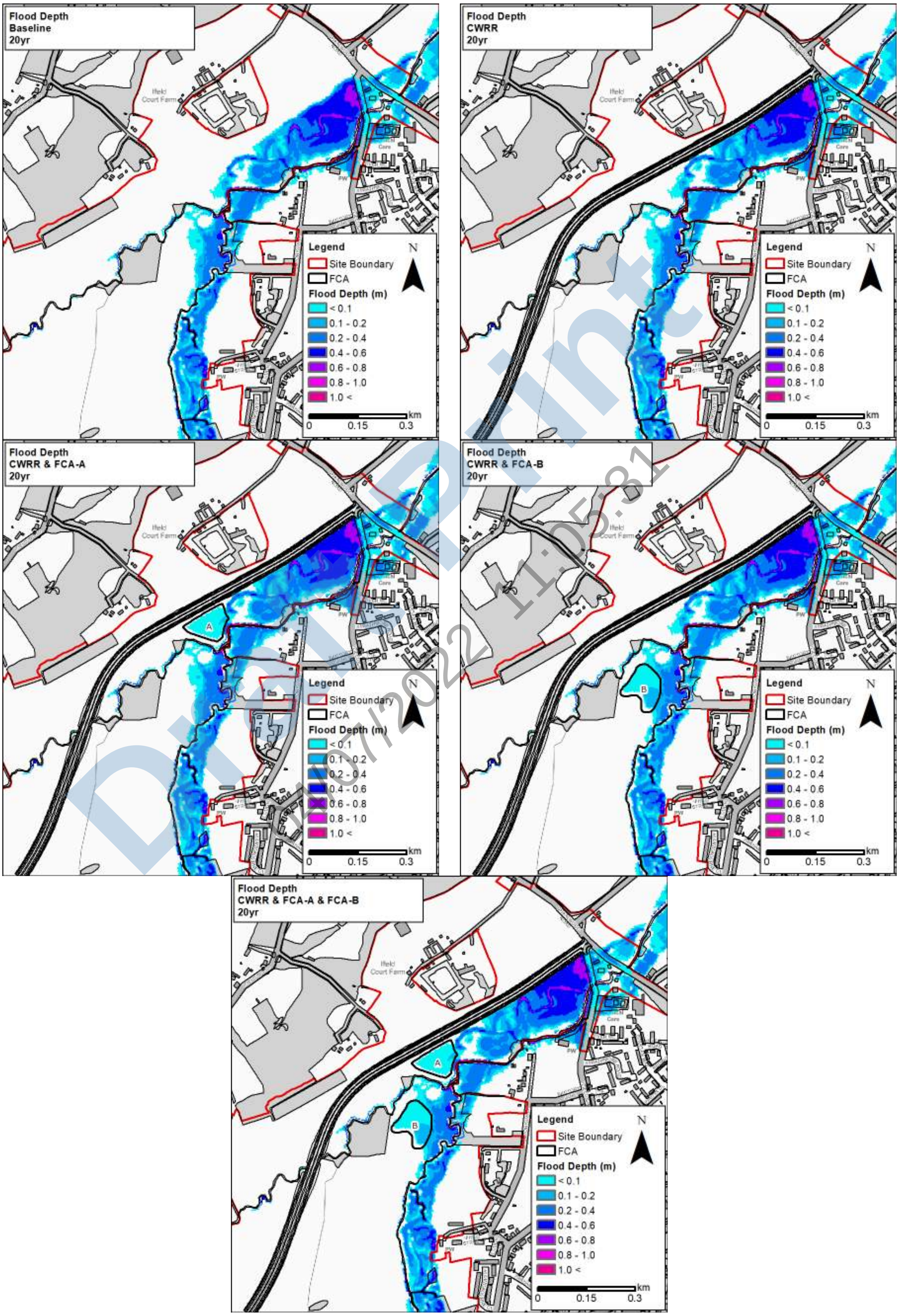


Figure 6-11: Flood depth for the 1 in 20-year event for the baseline and the four CWRR scenario

6.4.2 The CWRR embankment crossing is not simulated to affect flood risk during the 1 in 20-year event because modelling of the River Mole floodplain shows the floodplain upstream of Ifield Brook is largely flood-free. The impact on flood risk simulated during the 1 in 20-year event (Figure 6-12), is a result of the CWRR embankment encroaching into the floodplain prior to the connection with Charlwood Road.

6.4.3 Figure 6-12 shows the CWRR is not simulated to impact flood risk within the site boundary, but to the land and property around Ifield Avenue and Ifield Green. The FCAs act to mitigate the increased risk to the land and property around Ifield Avenue and Ifield Green.

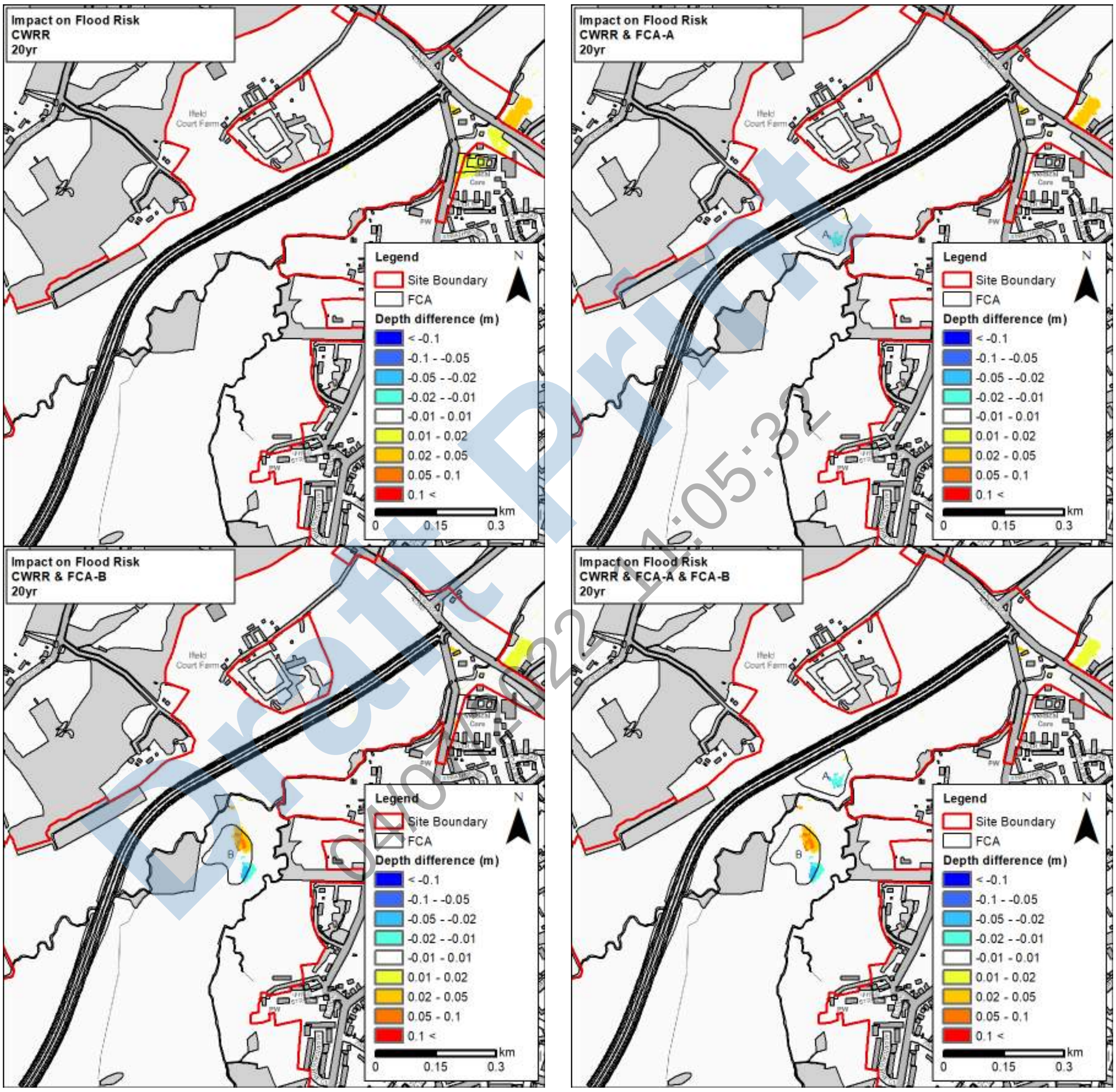


Figure 6-12: Impact on flood depths at the West of Ifield development for the 1 in 20-year event for the baseline and four development scenarios

6.4.4 Figure 6-13 shows the flood depth model results within the Site Boundary for the 1 in 100-year event for the Baseline and CWRR scenario.

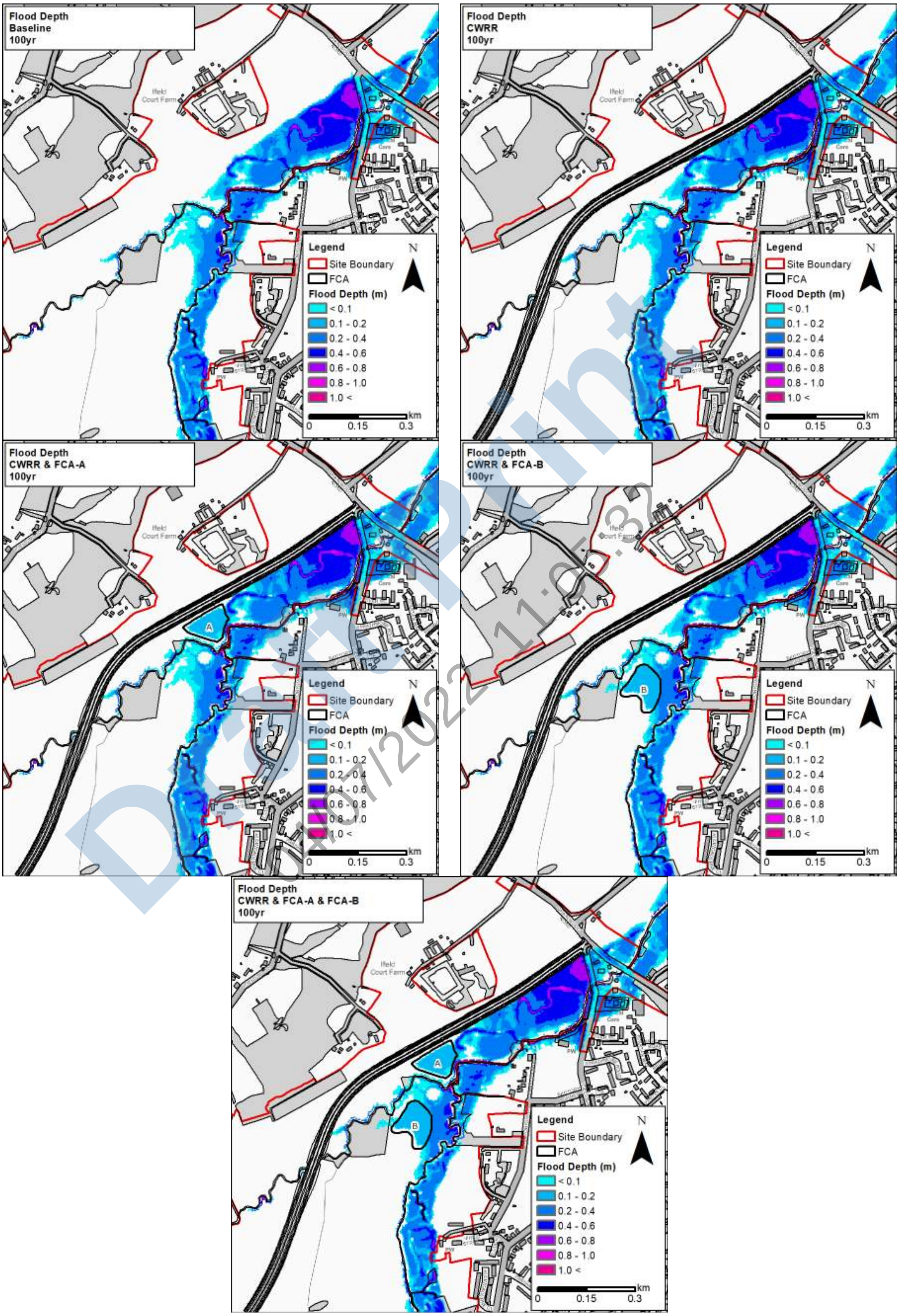


Figure 6-13: Flood depth for the 1 in 100-year event for the baseline and the four CWRR scenario

6.4.5 As with the 20 year event, the CWRR embankment crossing the river does not appear to affect flood risk during the 1 in 100-year event because the River Mole floodplain is not simulated to flood upstream of the confluence with Ifield Brook. The CWRR embankment encroaching into the floodplain prior to the connection with Charlwood Road is not simulated to impact flood depths within the site boundary (Figure 6-14). Section 6.3 details how the impact of the CWRR embankment during the 1 in 100-year event is simulated downstream, around Gatwick Airport.

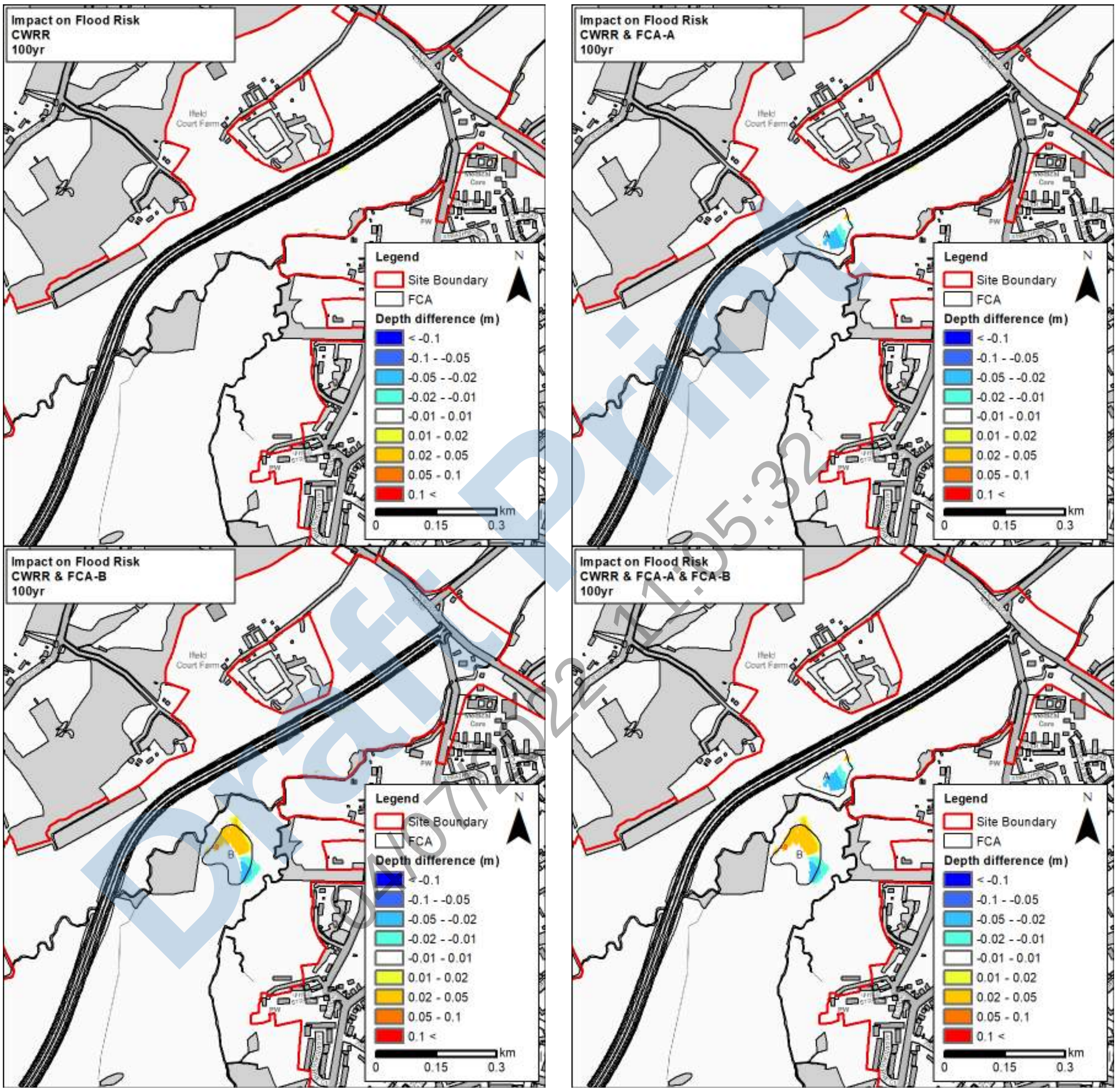


Figure 6-14: Impact on flood depths at the West of Ifield development for the 1 in 100-year event for the baseline and four development scenarios

6.4.6 Figure 6-15 shows the flood depth model results within the Site Boundary for the 1000-year event for the Baseline and CWRR scenarios.

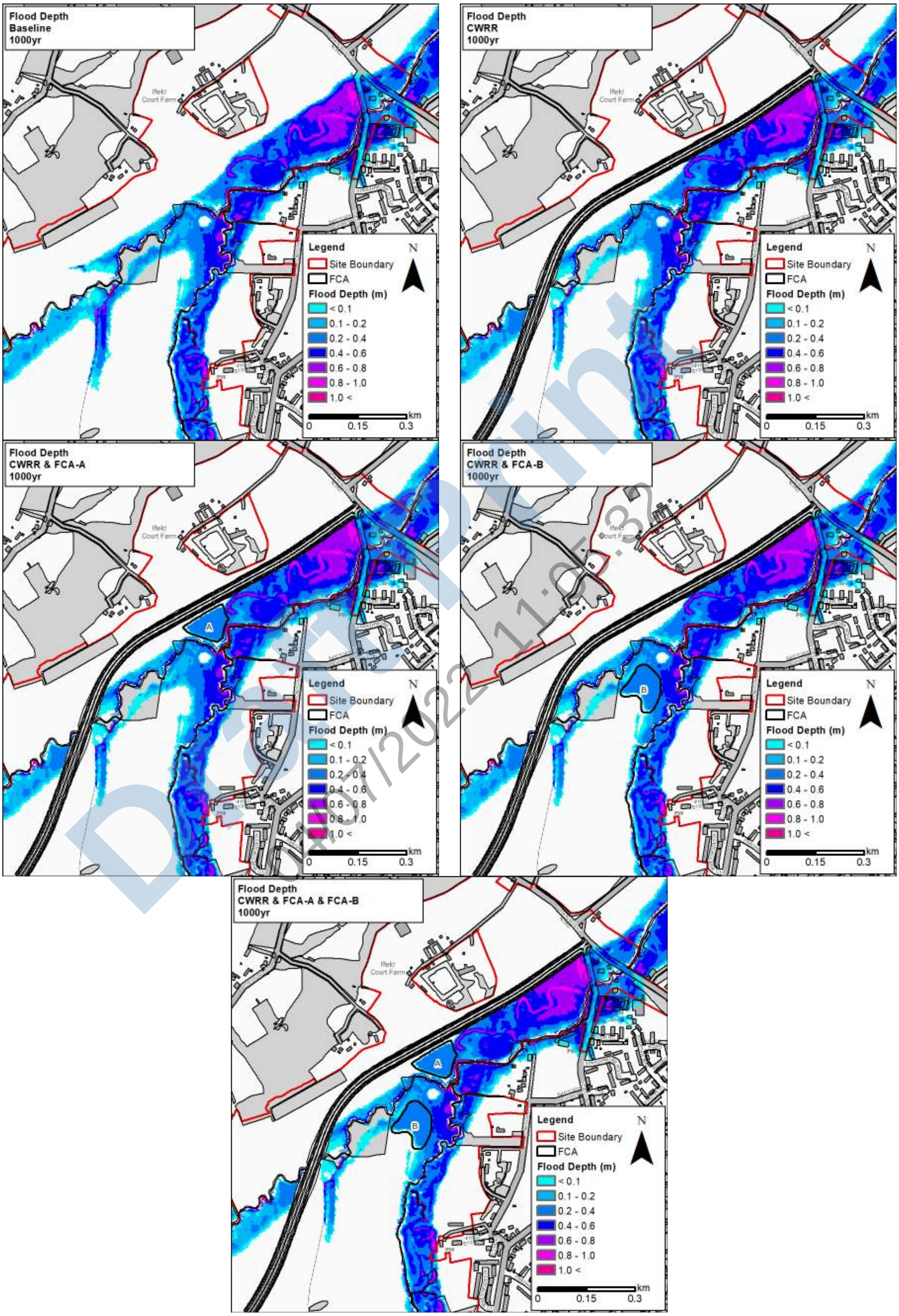


Figure 6-15: Flood depth for the 1 in 1000-year event for the baseline and the four CWRR scenario

6.4.7 The CWRR embankment crossing forms a barrier to floodplain flow during the 1 in 1000-year event. Figure 6-16 shows increased flood levels within the floodplain to the west (upstream) of the CWRR crossing. However, this results in reduced flood risk downstream to the east.

6.4.8 Approximately 200m downstream of the CWRR embankment crossing, the model simulates a 0.01m to 0.02m increased flood level on the northern (left in the direction of flow) bank, where the CWRR embankment is encroaching into the floodplain and preventing the free spread of water across the floodplain.

6.4.9 The CWRR embankment encroaching into the floodplain prior to its connection with Charlwood Road causes a 0.01m to 0.05m increase in flood level within the floodplain to the west of Ifield Green.

6.4.10 Figure 6-16 shows the FCA's are not simulated to have a significant impact on the change in flood risk within the site boundary resulting from the CWRR embankment during the 1 in 1000-year event. Section 6.3 details that the impact of the FCAs is downstream at London Gatwick Airport.

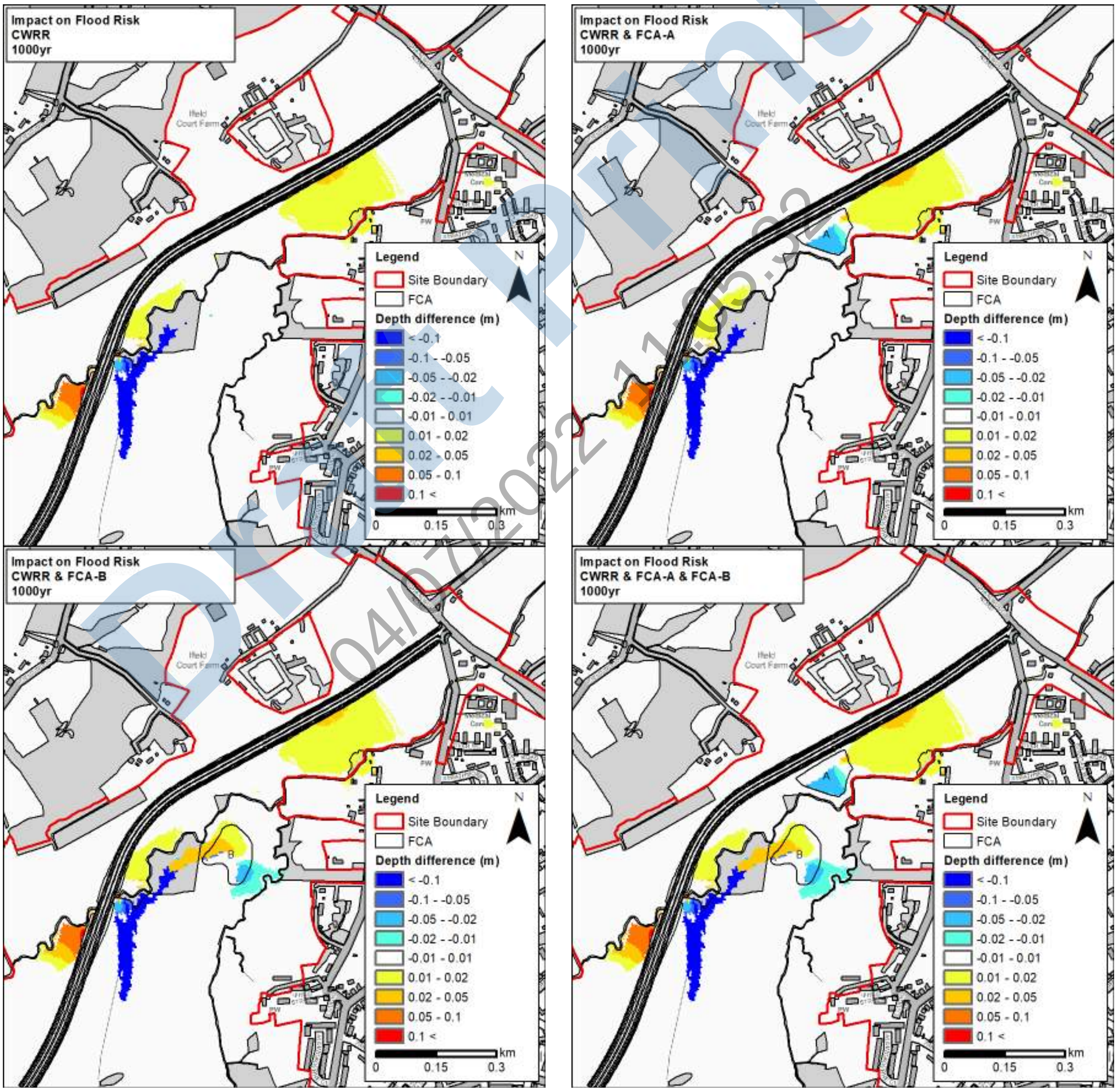


Figure 6-16: Impact on flood depths at the West of Ifield development for the 1 in 1000-year event for the baseline and four development scenarios

6.4.11 Figure 6-17 shows the flood depth model results within the Site Boundary for the 100-year with Climate Change (Upper 2080) event for the Baseline and CWRR scenarios.

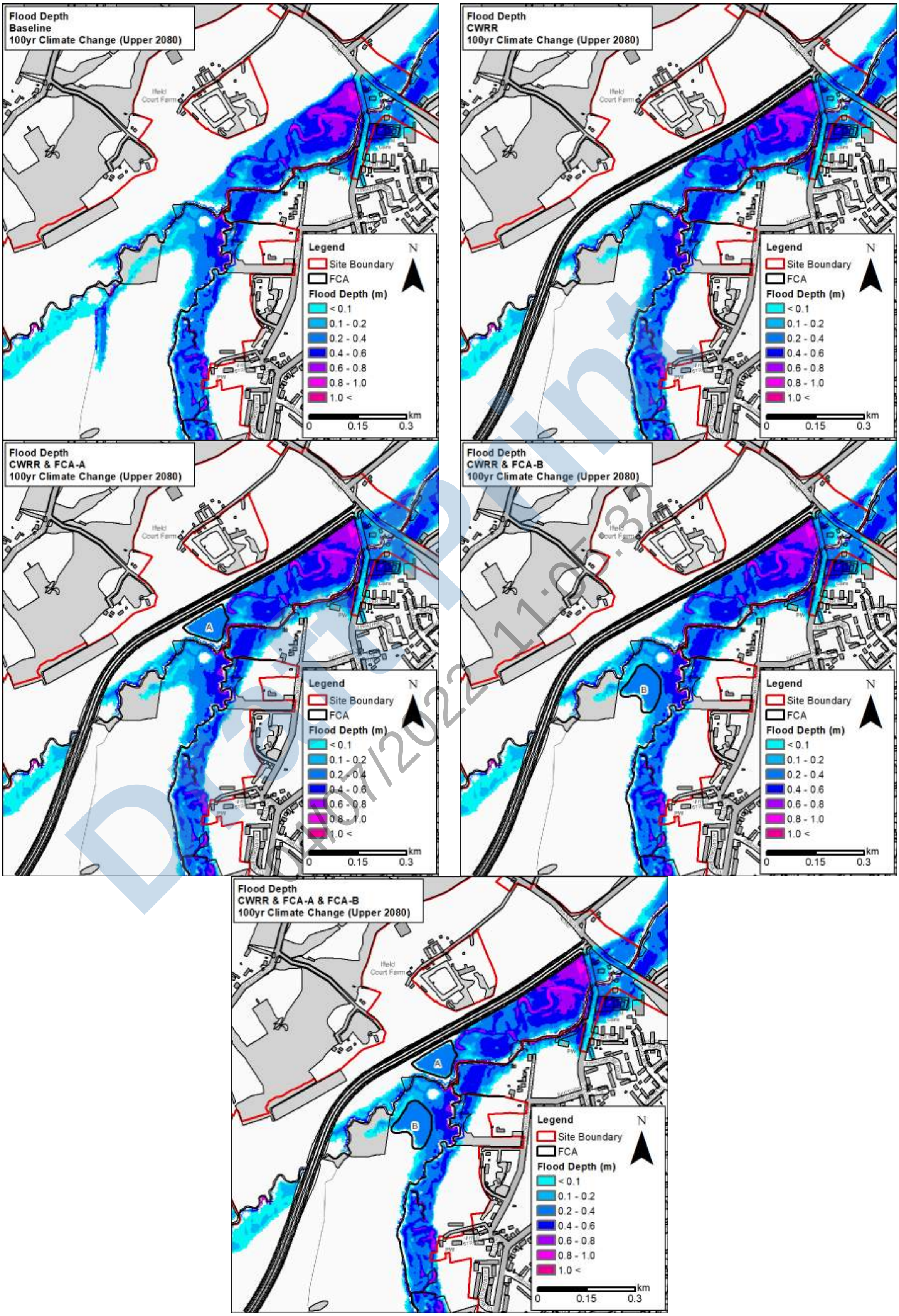


Figure 6-17: Flood depth for the 1 in 100-year with Climate Change (Upper 2080) event for the baseline and the four CWRR scenario

6.4.12 Figure 6-17 demonstrates that the CWRR embankment crossing acts to significantly reduce the flood risk simulated east of the CWRR embankment crossing during the 1 in 100-year with Climate Change (Upper 2080) event but increases flood levels to the west. Figure 6-18 shows the flood risk increases by up to 0.10m however, this increase is limited to the floodplain immediately west of the CWRR embankment crossing, and is well within the development site boundary.

6.4.13 The CWRR embankment encroaching into the floodplain prior to the connection with Charlwood Road is also simulated to cause a 0.01m to 0.02m increase in flood risk at to the floodplain west of Ifield Green.

6.4.14 Figure 6-16 shows the FCAs are not simulated to have a significant impact on the change in flood risk within the site boundary resulting from the CWRR embankment during the 1 in 100-year with Climate Change (Upper 2080) event. Section 6.3 details that the impact of the FCAs is downstream at London Gatwick Airport.

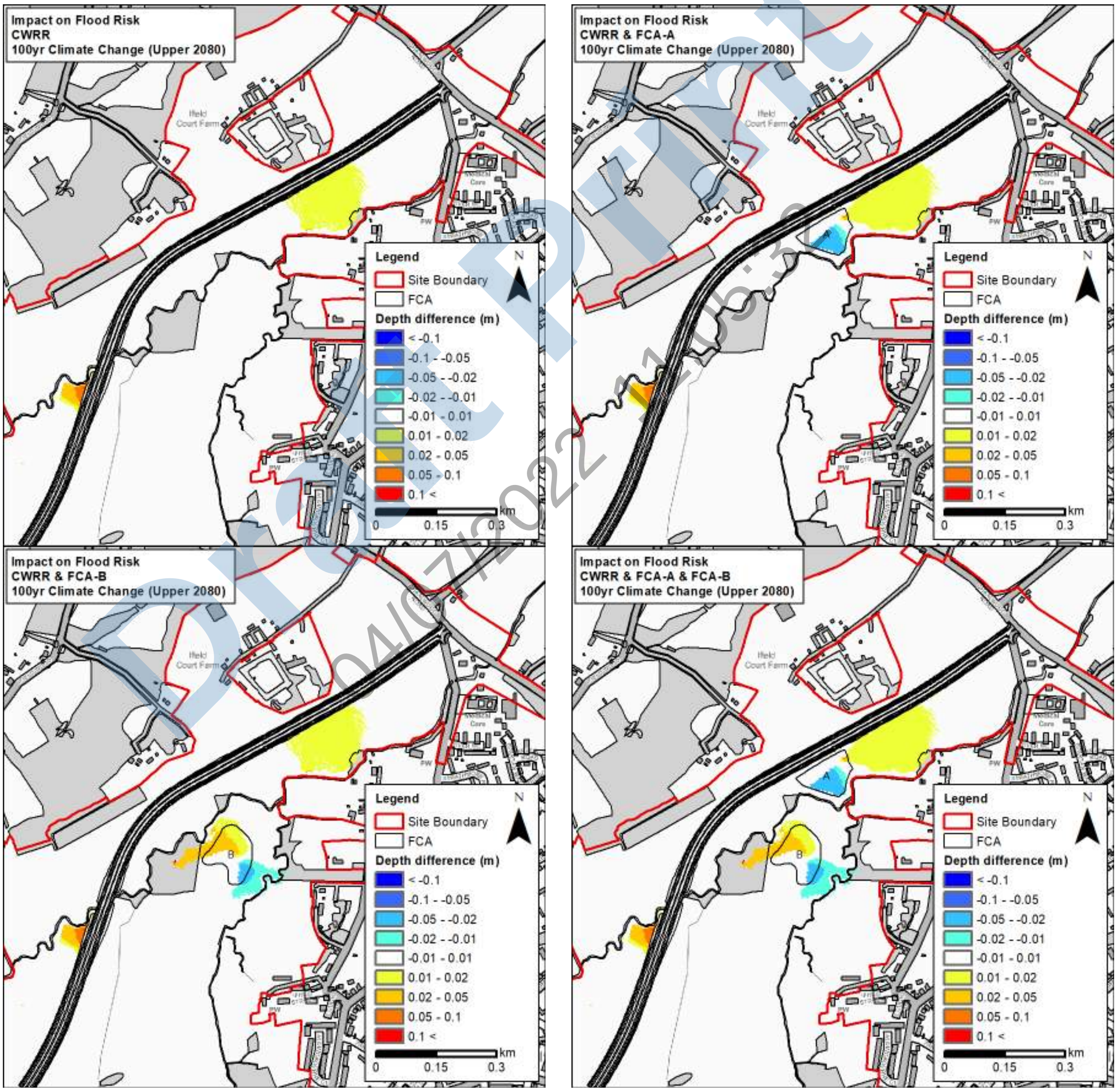


Figure 6-18: Impact on flood depths at the West of Ifield development for the 1 in 100-year plus climate change (2080 Upper) event for the baseline and four development scenarios

6.5 Hazard Rating

6.5.1 Peak flood hazard was configured to record the UK Hazard Rating as proposed in the flood risks to people guidance (FD2321) using the formula D*(V+0.5)+DF, where D = depth, V = velocity and DF = debris factor. Table 6.1 details the Flood Hazard Rating following Current Guidance[6].

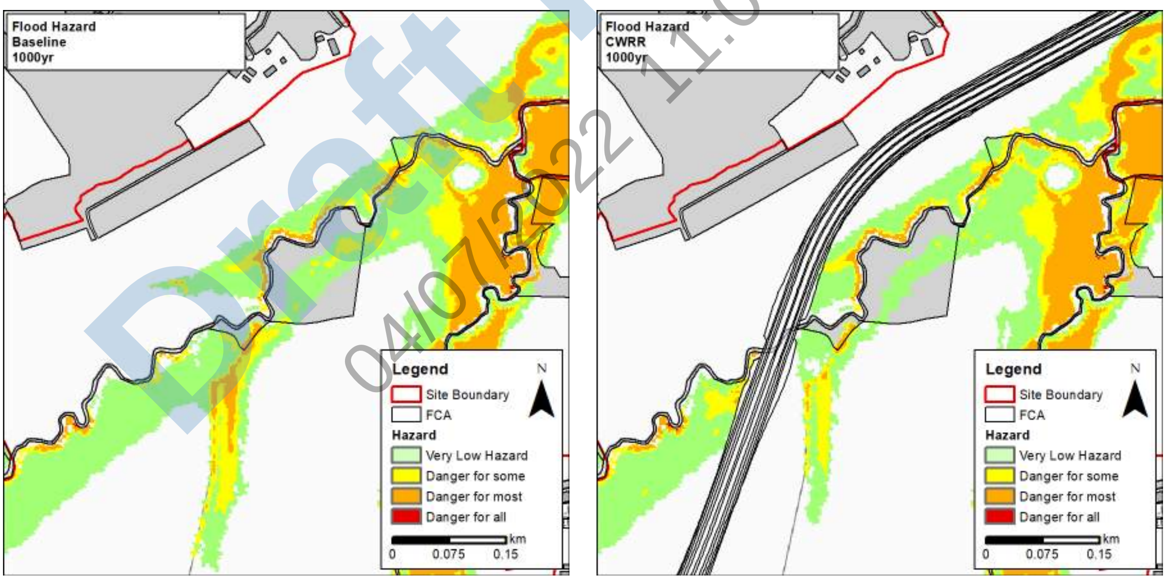
Table 6.1: Flood Hazard Rating

Flood Hazard Rating	Classification	Hazard to People
< 0.75	Very Low Hazard	Caution
0.75 – 1.25	Danger for some	Includes children, the elderly and the infirm
1.25 – 2.0	Danger for most	Includes the general public
2.0 <	Danger for all	Includes the emergency services

6.5.2 The key areas of significant increase in flood risk resulting from the CWRR embankment are within the site boundary, at the CWRR embankment crossing and the FCA's during the 1000-year event and the 100-year with Climate Change (Upper 2080).

6.5.3 Figure 6-19 shows the Flood Hazard rating for the 1000-year event for the Baseline scenario, CWRR scenario and the three FCA scenarios. The CWRR embankment increase the hazard rating of the flooding at the floodplain immediately west of the CWRR embankment crossing of the River Mole from "Very Low Hazard" to "Danger for Some". The hazard rating of the flooding to the east of the CWRR embankment crossing is reduced from "Danger for Most" to "Danger for Some".

6.5.4 The FCA's have a flood hazard rating of "Danger for Some".



[6] SUPPLEMENTARY NOTE ON FLOOD HAZARD RATINGS AND THRESHOLDS FOR DEVELOPMENT PLANNING AND CONTROL PURPOSE – Clarification of the Table 13.1 of FD2320/TR2 and Figure 3.2 of FD2321/TR1

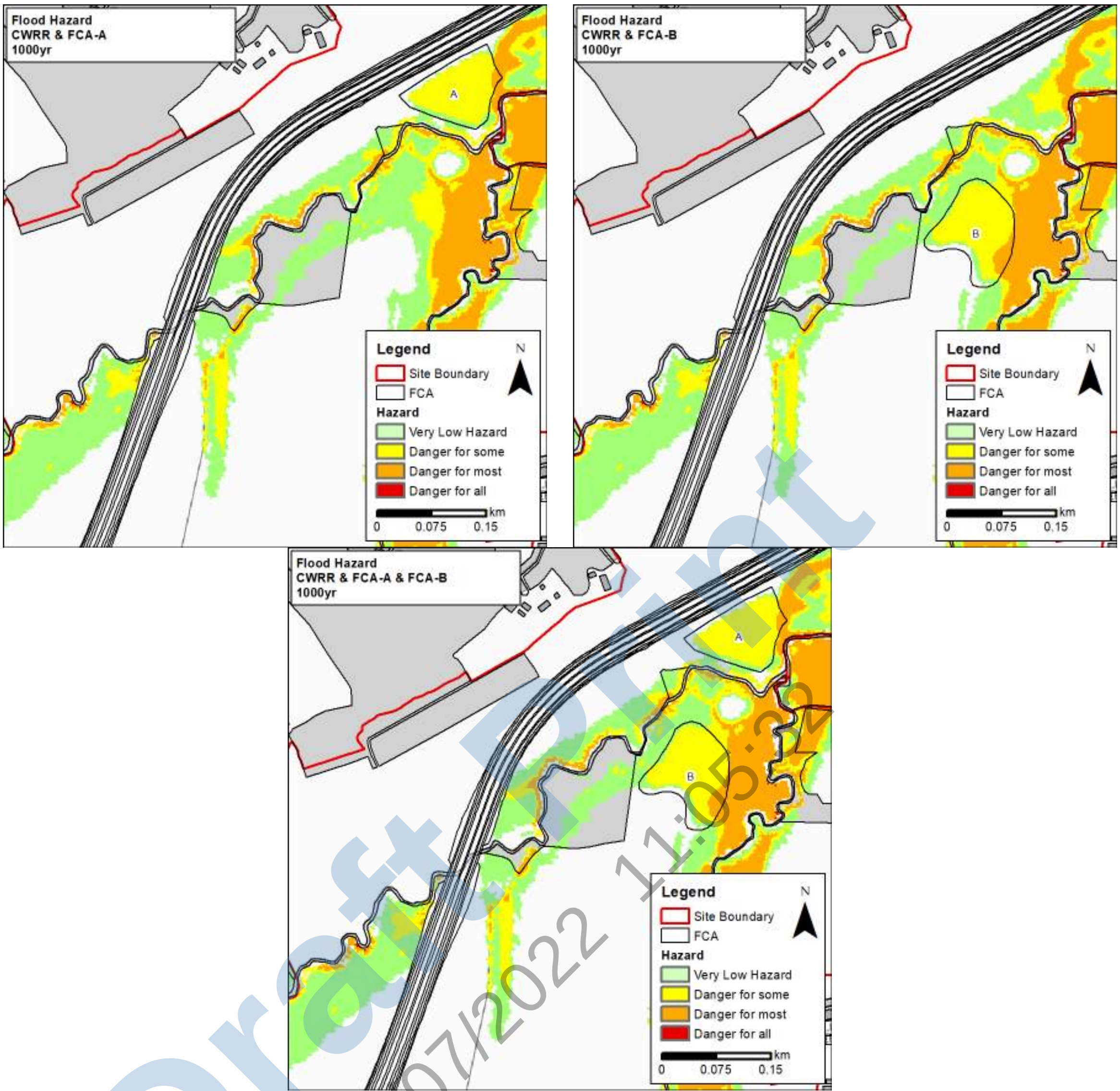


Figure 6-19: Hazard rating at the West of Ifield development for the 1 in 1000-year event for the baseline and four development scenarios

6.5.5 Figure 6-20 shows the flood hazard rating for the 1 in 100-year with Climate Change (Upper 2080) event for the Baseline scenario, the CWRR scenario and the three FCA scenarios. The CWRR embankment does not increase the hazard rating of the flooding the west of the CWRR embankment crossing, the hazard remaining “Very Low Hazard”.

6.5.6 The CWRR embankment has significantly reduced the flood risk to the east of the CWRR embankment crossing and therefore, has removed the associated flood hazard during the 1 in 100-year with Climate Change (Upper 2080) event.

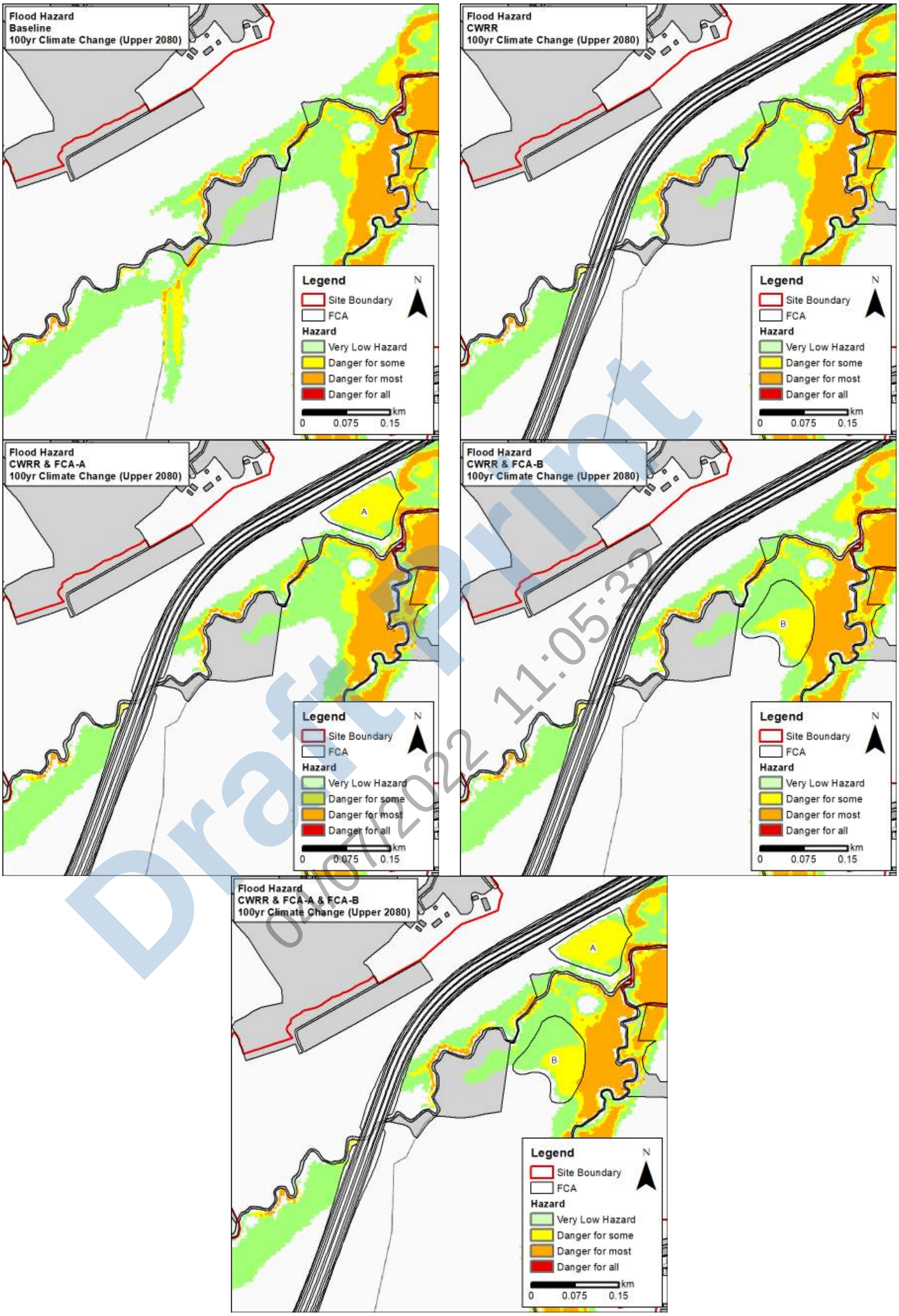


Figure 6-20: Hazard rating at the West of Ifield development for the 1 in 100-year plus climate change (2080 Upper) event for the baseline and four development scenarios

6.6 Flood Duration

6.6.1 One of the key constraints to the flood risk management strategy is to ensure surface water attenuation does not give rise to heightened bird strike risk to London Gatwick Airport. The agreed drawdown in strategic basins was a maximum of 48 hours so as not to provide additional habitats for birds in the local area.

6.6.2 Figure 6-21 shows the maximum flood duration for the 1 in 20-year, 1 in 100-year, 1 in 1000-year and 1 in 100-year with Climate Change (Upper 2080). The model results indicate that the FCA's are not simulated to flood for longer than the 48-hour limit.

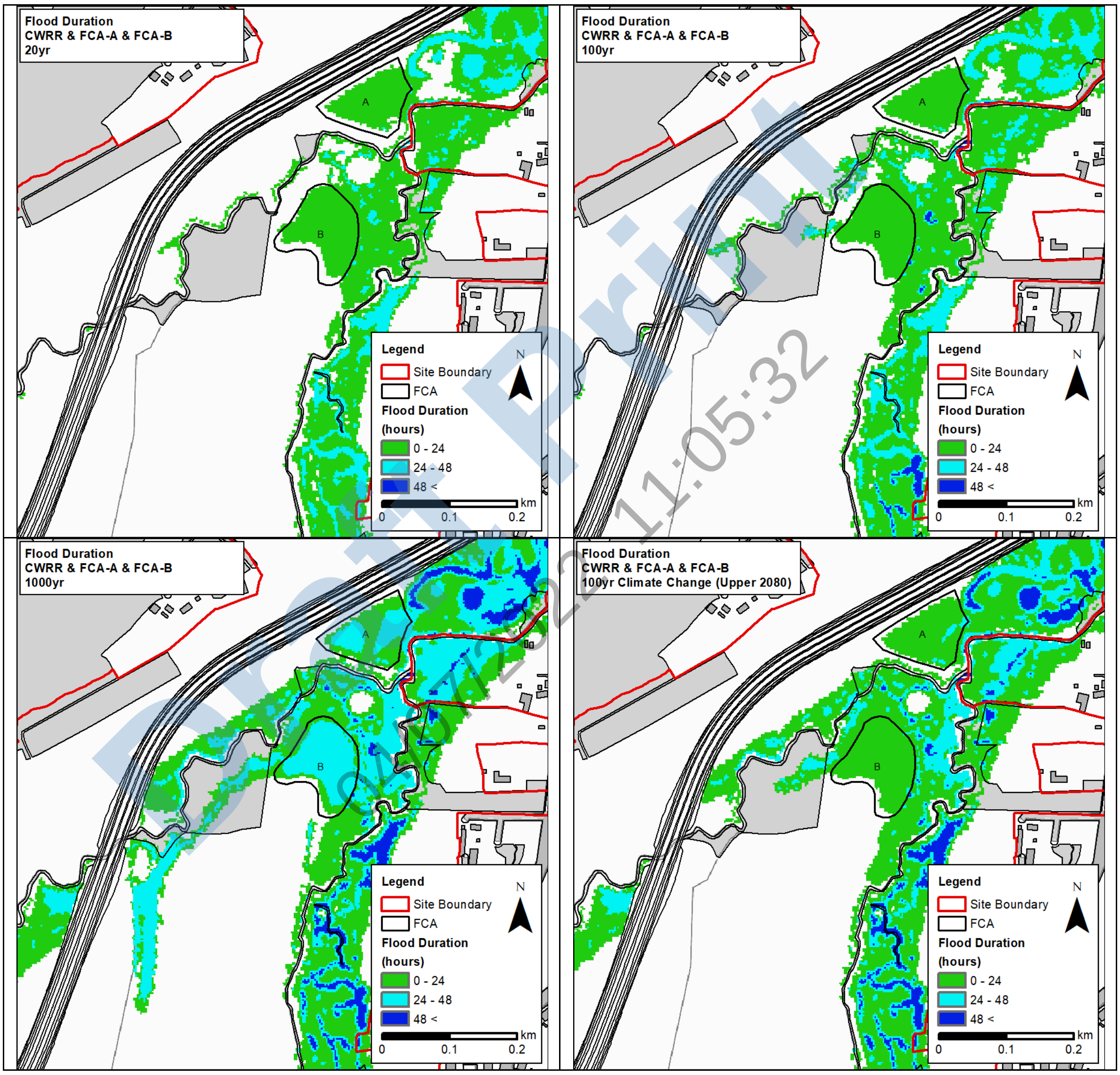


Figure 6-21: Maximum Flood Duration at the West of Ifield development for the 1 in 20-year, 1in 100-year, 1 in 1000-year and 1 in 100-year plus climate change (2080 Upper) event for the CWRR FCA-A and FCA-B scenario

7. LIMITATIONS

7.1.1 During any hydraulic modelling study, there will always be associated limitations, for example with uncertainty, data availability and so on. The representation of any complex system by a model requires several assumptions to be made. In the case of the hydraulic modelling prepared by Ramboll for this report, it has been assumed that:

- Cross sections accurately represent the shape and variation of the river.
- Model parameters have been determined appropriately.
- Design flows are an accurate representation of a given return period.
- The surveyed cross sections of hydraulic structures and units used to represent them in the model adequately represent the situation.
- LiDAR accurately reflects bank heights and that the filtered LIDAR has appropriately removed the influence of vegetation along the banks.

7.1.2 The accuracy of hydraulic models is heavily dependent on the accuracy of the hydrological and topographic data on which they are based.

7.1.3 While every effort has been made to accurately reflect the situation on the ground and estimate model parameters, these can never be completely certain. Therefore, assumptions are made as part of the modelling process. Sensitivity tests have been carried out to highlight the sensitivity of the model.

7.1.4 The model has been built for the purpose of flood risk mapping. It has been optimised for high flows and would need adapting to be suitable to be used for more low flows.

7.1.5 All minor watercourses are represented in 2D only based on LiDAR. Only River Mole, Ifield Brook, Hyde Hill Brook, Ifield Mill Stream and Crawter's Brook are represented in 1D using survey information. Channel conveyance within the 2D channels will therefore not be fully represented in the model, and in some places may be overestimated where the channel width is not known.

7.1.6 The model has been validated against the previous EA hydraulic model results, as the EA model had been formally calibrated and validated and is the parent model of the West of Ifield model.

7.1.7 The methodologies adopted were informed by best practice and use of available data. Whilst the modelling approaches are deemed suitable and acceptable, there will always be future improvements and updates that can be made.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Study overview

8.1.1 Homes England intends to redevelop approximately 201 ha of land located west of Ifield within the administrative area of HDC in West Sussex for a residential-led mixed use settlement. The West of Ifield development is out of the floodplain, located on the higher ground between the River Mole and Ifield Brook. The CWRR, part of the scheme, links the West of Ifield development to Charlwood Road, crossing the River Mole and overlaps the EA Flood Zones. As a result of building within the floodplain, it is acknowledging that flood compensation will be needed to manage risk.

8.1.2 Ramboll have been commissioned by Turner and Townsend project management limited working on behalf of Homes England to complete hydraulic modelling to understand the impact of potential flood alleviation strategies proposed as part of the scheme.

8.1.3 Ramboll utilised the EA's hydraulic model of the Upper Mole (Undefended scenario) to investigate a range of fluvial flood mitigation options. The model utilised the existing hydrology developed as part of the EA modelling study of the Upper Mole. The 1 in 100-year with Climate Change event was updated to follow the latest government guidance, utilising the Mole Management Catchment peak river flow Upper 2080 allowances of 40%. The model was truncated to cover the West of Ifield Area, to improve model run times and to remove the issues of inherited model instability in locations not relevant to the West of Ifield development.

8.1.4 Five FMP-TUFLOW 1D/2D model scenarios were simulated to assess the impact of a range of fluvial flood mitigation options for the West of Ifield development. One Baseline scenario and Four Development scenarios:

- CWRR – the CWRR embankment road
- CWRR and FCA-A – the CWRR embankment road and FCA-A
- CWRR and FCA-B – the CWRR embankment road and FCA-B
- CWRR and FCA-A and FCA-B – the CWRR embankment road and both FCA-A and B

8.2 Results

8.2.1 The downstream impacts of the CWRR embankment are small, with negligible changes to flood extents and flood depth increases simulated to be less than 0.10m.

8.2.2 The FCAs were simulated to mitigate the increased flood risk downstream of the development site caused by the CWRR embankment. FCA-B was simulated to alleviate the flood risk more effectively than FCA-A. When both FCA-A and FCA-B were operating in combination, the model simulated no increase in flood risk compared to the baseline downstream of the development site for the 1 in 100-year (Flood Zone 3), 1 in 1000-year (Flood Zone 2) or the 1 in 100-year with climate change (Upper 2080). The 1 in 20-year event simulated increases in flood depths of between 0.01m to 0.02m at isolated areas of the River Mole floodplain between Ifield Avenue and approximately 1.3 km downstream. These increases are close to negligible when considering the flood depths in these locations are between 0.40m to 0.60m, and thus amount to between 1.7% and 5% increase in flood depths.

8.2.3 The hydraulic modelling results show that the impact on flood risk of the CWRR embankment is most significant within the development site boundary. The CWRR embankment crossing of the River Mole acts as a barrier to floodplain flow during the higher return period events, resulting in increased flood risk to the west and decreased flood risk to the east. The increase in flood risk to the west was simulated to be less than 0.10m for all events and was limited to floodplain immediately west of the CWRR embankment crossing. The decrease in flood risk to the east was most significant, with flood depths and extents significantly reduced. This would provide a greater area for development.

8.2.4 The single significant increase in the flood hazard rating results were simulated at the floodplain west of the CWRR embankment during the 1 in 1000-year event, rising from "Very Low Hazard" to "Danger for Some". This increase is limited to the area immediately west of the CWRR embankment and is a result of the increases in flood depth. The flood hazard rating results elsewhere showed either negligible change or a reduction in hazard rating as a result of the CWRR embankment crossing. The reduction in the flood hazard rating category was most significant to the area east of the CWRR embankment crossing, reducing from "Danger for Most" to "Danger for Some". The FCAs themselves have a flood hazard rating of "Danger for Some".

8.2.5 The FCAs were designed within the hydraulic model with a very gentle slope to prevent the accumulation of standing water over time. This was to prevent the creation of additional habitats for birds so as to not give rise to heightened bird strike risk to London Gatwick Airport. The agreed drawdown in strategic basins was a maximum of 48 hours. The model results indicate that the FCAs are not simulated to flood for longer than this 48-hour limit.

8.3 Summary and Recommendations

8.3.1 The hydraulic model results show that the most effective flood alleviation method for the CWRR embankment is the use of both FCA-A and FCA-B, with the 1 in 100-year, 1 in 1000-year and 1 in 100-year with Climate Change (Upper 2080) showing negligible increases in flood risk downstream of the site boundary.

8.3.2 The CWRR embankment crossing reduces the flood risk to the east of the River Mole crossing location. This increases the area available for potential development.

8.3.3 The design of the CWRR embankment at the River Mole crossing location should factor in the 0.10m increase in flood risk at the floodplain to the west for the higher return periods.

8.3.4 At detailed design stage, the final design of the FCAs should be checked using the hydraulic model to ensure their respective effectiveness.

8.3.5 There is potential for further analysis of the FCAs in terms of size and model roughness changes relating to the ground cover that could be used to slow the flows. This could enhance the effectiveness of individual FCAs that could negate the requirement of two to achieve a negligible impact downstream.

8.3.6 Ground investigation of the locations for the proposed FCA should be completed to ensure that the locations are appropriate for use and construction of FCAs.

8.3.7 Review model output against future periods of raised flow/flooding, verifying the hydraulic model and its inputs, where possible.

Appendices not included in Draft print

APPENDIX A
EA UPPER MOLE FEH CALCULATION RECORD

APPENDIX B
EA/GAL UPPER MOLE FLUVIAL FLOOD MODELLING STUDY – FINAL REPORT – VERSION: 1.2 (SEPTEMBER 2018)

APPENDIX C
CRAWLEY WESTERN RELIEF ROAD DESIGN – RAMBOLL 2022

APPENDIX D
RAMBOLL MODEL REVIEW EA UPPER MOLE

APPENDIX E
EA CORRESPONDENCE