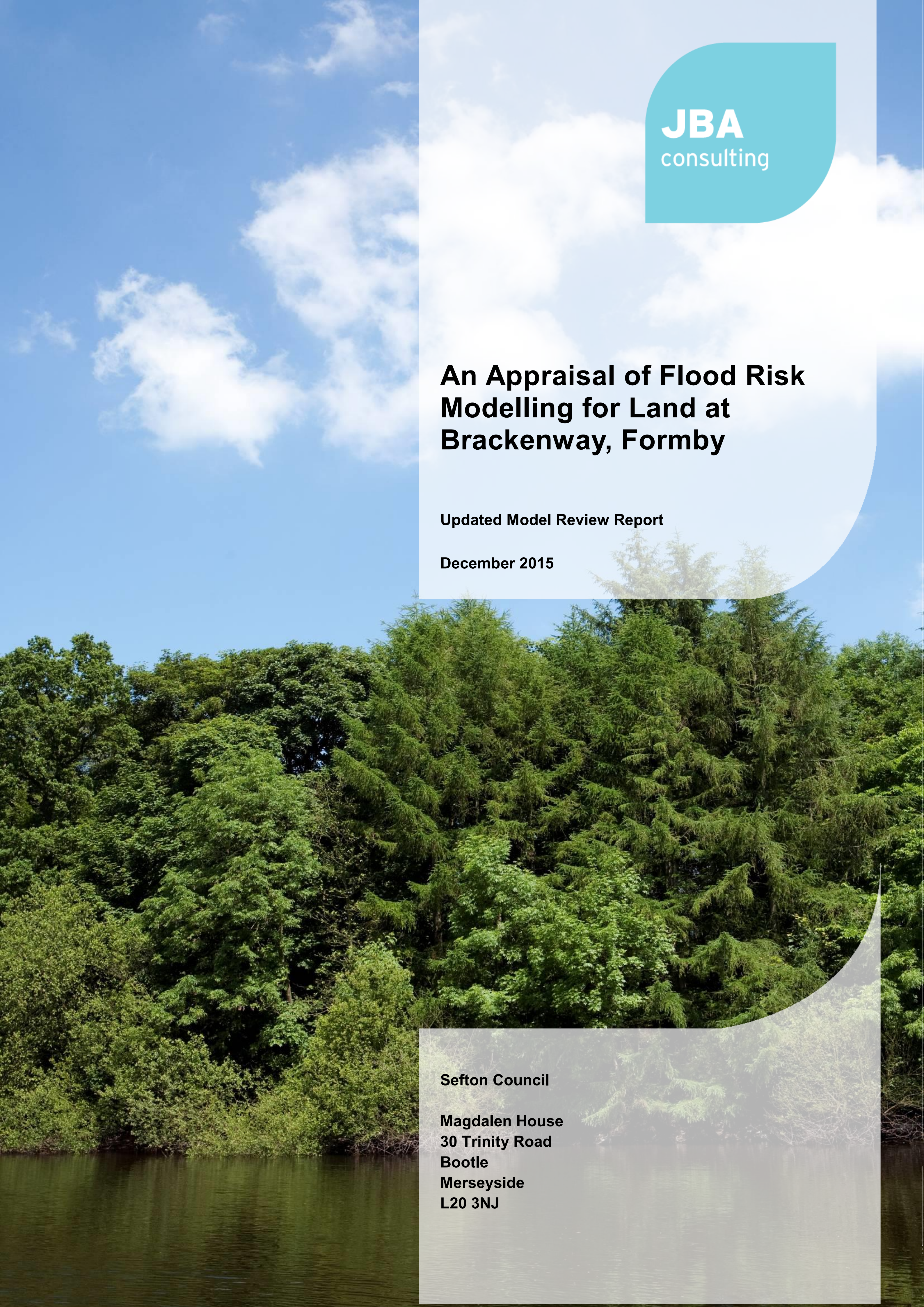

JBA consulting

An Appraisal of Flood Risk Modelling for Land at Brackenway, Formby

Updated Model Review Report

December 2015

Sefton Council

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
Draft Summary Report		Tom Hatfield Sefton Council
Updated Summary Report	Update to Section 3 to include additional modelling undertaken in response to the Draft Summary Report. Revision to conclusions (now documented in Section 4).	Tom Hatfield Sefton Council

Contract

This report describes work commissioned by Stuart Bate, on behalf of Sefton Council, by a letter dated 01 June 2015. Sefton Council's representative for the contract was Tom Hatfield. Ed Blackburn, Kevin Frodsham and Krista Keating of JBA Consulting carried out this work.

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Purpose

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1 Introduction

1.1 Introduction

Sefton Council have appointed JBA Consulting to undertake an appraisal of the flood risk modelling relating to the land at Brackenway, Formby. This modelling was submitted to the Council on behalf of Taylor Wimpey in support of a proposed housing allocation in the draft local plan.

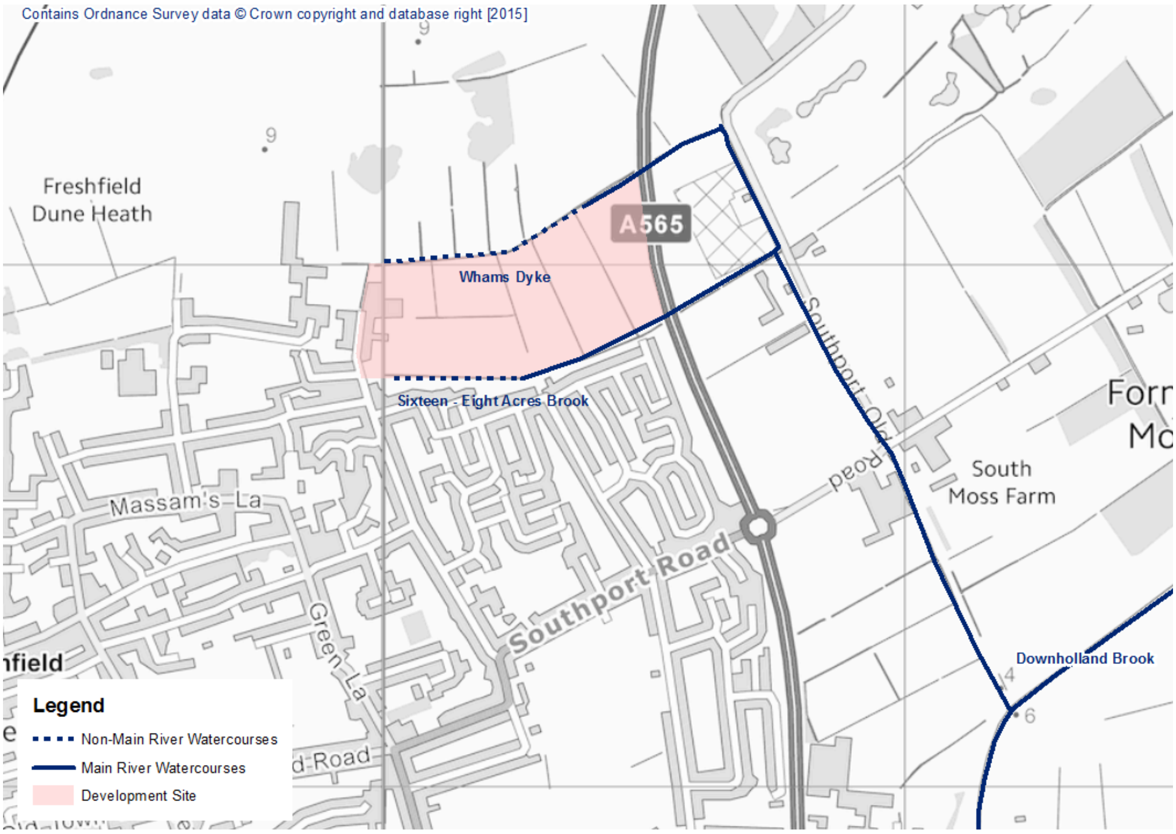
This report documents the outcome from the modelling review and is structured in the following way;

1. Project and site introduction
2. Key findings from the original model review completed in August 2015
3. Review of the additional modelling undertaken to address review comments and recommendations
4. Conclusions.

1.2 Site Description

The site at Brackenway is located in the Lower Alt catchment, to the north east of Formby. The site is located immediately upstream of the Formby Bypass (A565) and is bounded by existing residential properties to the south (Hawkesworth Drive) and to the west, as shown in Figure 1-1.

Figure 1-1 Location of the Site at Brackenway, Formby



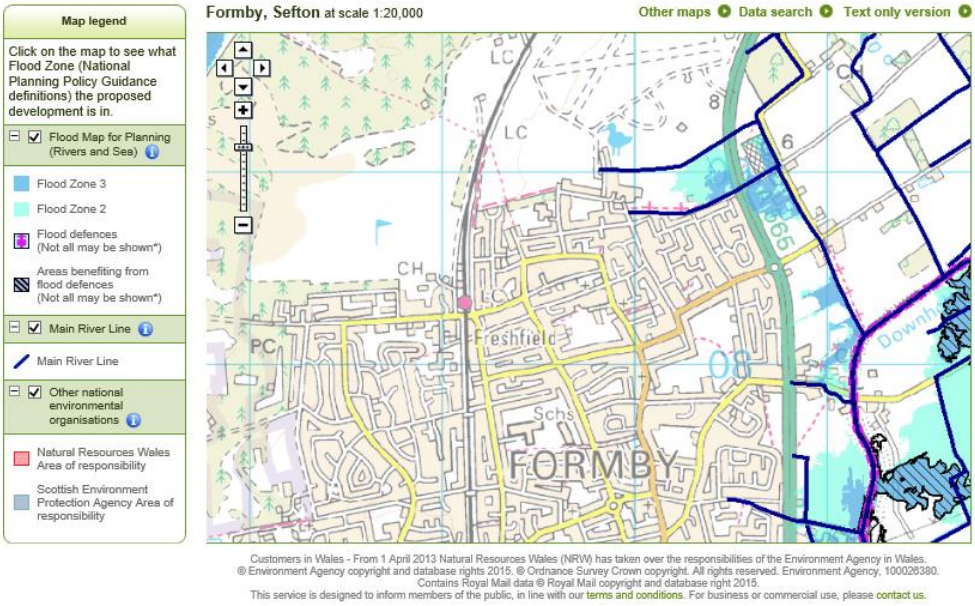
As indicated in Figure 1-1, Whams Dyke watercourse and Sixteen/Eight Acre watercourse bound the development site. These designated Main River watercourses drain parts of the site and flow in north easterly direction, joining a short distance downstream (~200m) of Formby Bypass. Whams Dyke then flows into Downholland Brook, a key tributary of the River Alt. This outfall is flapped to prevent backflow up the system when water levels in Downholland Brook are high. Water levels in Downholland Brook are influenced by the pumping regime at Altmouth Pumping Station some distance downstream.

1.3 Flood History

Flooding to Hawkesworth Drive and to parts of the development site are known to have occurred on several occasions, most recently in 2012. This provides valuable information that can be used to verify the outputs from the flood modelling by allowing checks and comparisons on predicted flooding frequency, mechanisms, pathways and depths to be made.

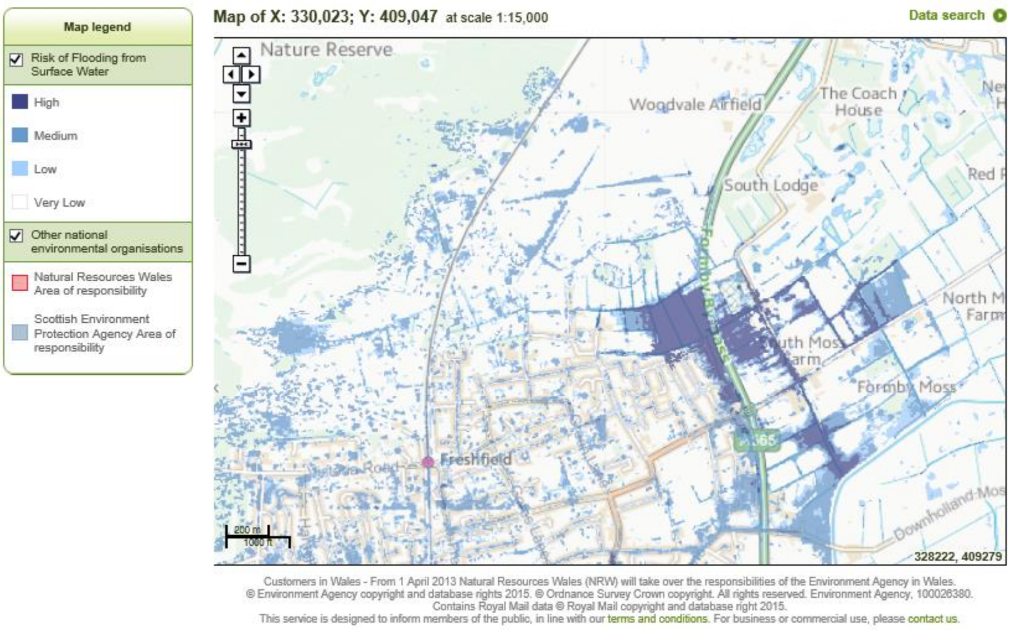
The Environment Agency's Fluvial Flood Map indicates that parts of the site are currently within Flood Zones 3 and 2, as shown in Figure 1-2. This also indicates that the embankment that exists on the right hand bank of Eight Acre watercourse (in front of properties along Hawkesworth Drive) is not an Environment Agency designated and maintained flood defence.

Figure 1-2 Environment Agency Flood Map (taken from Environment Agency website)



The Environment Agency's Updated Flood Map for Surface Water (UFMfSW) is shown in Figure 1-3 below.

Figure 1-3 Environment Agency's UFMfSW (taken from Environment Agency website)



1.4 Key Datasets

The key datasets that have been used and referenced as part of the model review are summarised in Table 1-1 below.

Table 1-1 Key Datasets

File	Description
ORIGINAL REVIEW - Documented in Section 2 of Report	
FORMBY Flood Risk Assessment Report_Final.pdf including Hydraulic Modelling Report contained within Appendix D	Final FRA report, dated June 2015 produced by the consultant on behalf of Taylor Wimpey
The Acres Formby SW Calculations - Development Area_v2.xls	Spreadsheet outlining surface water calculations undertaken for the site
Complete Model	Modelling Files supplied by K Hemmings to JBA via secure file download originally dated 23/07/2015 but with updated results supplied on 11/08/15
ADDITIONAL REVIEW - Documented in Section 3 of Report	
Node_flood_level_All_nodes_1hr_6hr_from_csv_export_20.xlsx, Node_flood_volume_All_nodes_1hr_6hr_from_csv_export_20.xlsx	Final water level and flood volume outputs from the surface water assessment.
Sensitivity testing outputs as documented in e-mail from K Hemmings 29/10/15 & 03/12/15	Tabulated water levels from the sensitivity testing undertaken.
Sensitivity Testing_CSD.xlsx	Predicted water level outputs from the critical storm duration assessment.

1.5 Modelling Overview

The modelling consultants have developed a Flood Risk Assessment (FRA) for the site. To support this, a 1D-2D hydraulic model has been developed. This draws on two earlier existing modelling studies;

- Environment Agency's Lower Alt ISIS-TUFLOW model. This was developed by JBA Consulting 2009-10 as part of the Lower Alt with Crossens Pumped Land Drainage Strategic Plan. Note - this study developed a catchment wide fluvial model of the Lower Alt system and did not model the full extent of Whams Dyke and Eight Acre watercourse alongside the development site.
- Sefton SWMP M2 TUFLOW (ESTRY) model, developed for the Surface Water Management Plan (SWMP) to understand surface water flood risk.

The development of the model is documented in Section 4 (Model Development) of Appendix D (Hydraulic Modelling Report) in the FRA. In summary, the ISIS-TUFLOW model has been extended to include a 2D TUFLOW domain across the site and represent the full extent of Whams Dyke and Sixteen/Eight Acres watercourse that have been modelled using 1D ESTRY sections. Within this extended model, direct rainfall profiles configured for the SWMP study have been applied.

1.6 Original Scope of the Review

This review has examined the configuration, performance and predictions of the flood modelling to determine whether the model is fit for the purpose of informing the site-specific flood risk assessment. The review has also considered whether the model configuration and predictions are reliably reported in the FRA (and accompanying Hydraulic Modelling Appendix) that was submitted to Sefton Council.

Given the large extent of the model, that covers the whole of the Lower Alt catchment, the review has concentrated on the model configuration and predictions in the vicinity of the development site.

2 Flood Modelling Review

2.1 Introduction

This section of the report summarises the outcomes from the review of the flood risk model developed for the site, completed in August 2015. The additional assessment completed following the review to address recommendations made is documented in Section 3 of the report.

As advised in the project brief prepared by Sefton Council, the robustness of the fluvial and surface water modelling completed to support future development at the site has been reviewed with potential weaknesses or inconsistencies in the modelling highlighted.

2.2 Model Schematisation

The model has been schematised to represent Whams Dyke and Sixteen/Eight Acres watercourses that run alongside the development site, modelled using 1D ESTRY sections to represent the channels and a 2D TUFLOW domain to represent the local floodplain and local overland surface water flow routes (by applying direct rainfall). The model does not directly include or represent the local surface water drainage system that connects into the local fluvial system. This omission is important given the connections present, interaction between fluvial and surface water risk sources and the intention that future development will reduce the existing surface water risk to Hawkesworth Drive. The existing model schematisation does not allow the surface water benefits to Hawkesworth Drive to be directly quantified.

2.3 1D-2D Model Construction

The technical review has highlighted several aspects of the model construction where inconsistencies and uncertainties arise. These are related to the 1D ESTRY model and are summarised in Table 2-1 together with foreseen actions.

Table 2-1 Review Comments Relating to Model Construction

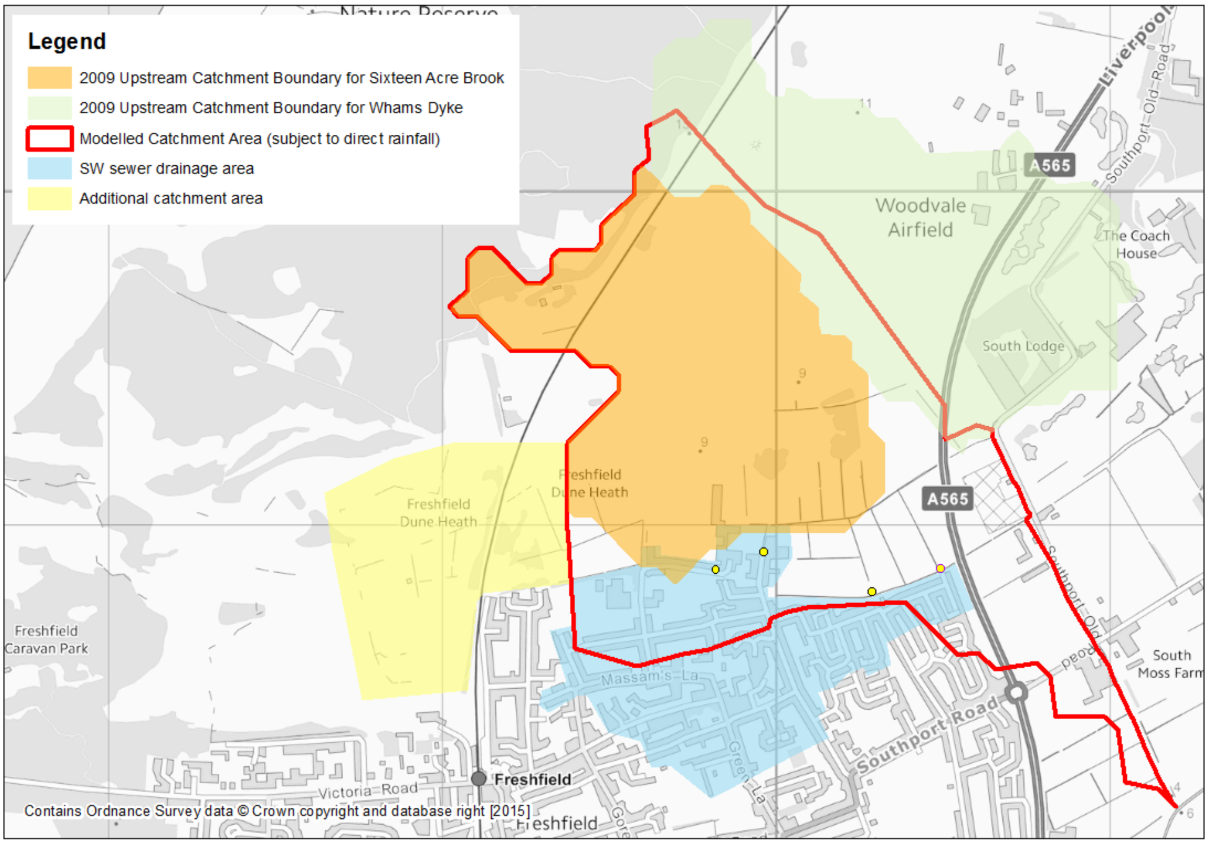
Review Comment	Rationale	Action Required
Baseline 1D ESTRY MODEL		
A2. Clarify whether hard bed or soft bed was used to model the ESTRY channels.	Could affect the modelled channel capacity of Whams Dyke and Sixteen/Eight Acres watercourses and resultant predicted water levels. It is commonplace to represent surveyed soft bed information within hydraulic models developed for the Environment Agency. This would be consistent with the original Lower Alt modelling.	Consultant to confirm what information has been used. If hard bed information has been used, sensitivity testing at a minimum should be undertaken to understand the impacts of this on predicted water levels for key design events.
A3. Justify the discrepancy in 1D and 2D channel widths along the ESTRY reaches.	There should be no overlap between the modelled 1D and 2D domains, as this can lead to double counting.	JBA accept that this is unlikely to have a significant impact on model predictions. However, at a minimum, sensitivity testing should be undertaken for key design events to confirm this is the case.
A4. Justify the 1D roughness pattern in the ESTRY reaches.	The allocation of Manning's n roughness values is subjective and should be justified. This is particularly relevant in the local context given the presence of dense vegetation during the summer months.	Sensitivity testing should be undertaken to understand the varying impact of summer and winter vegetation on predicted water levels. Any variation should be factored into adopted freeboard allowance.
A5. Justification to support the non- standard coefficients used to represent 1D ESTRY structures	Representation of the 1D structures within the model could affect conveyance and predicted water levels therefore it is important that non-default settings are understood.	Consultant to provide additional supporting information to justify settings or evidence of additional sensitivity testing to understand impacts.

2.4 Model Inflows and Hydrology

The modelled catchment area that is subject to direct rainfall modelling, has been compared against other key datasets such as the original model inflow boundaries configured for the EA's ISIS-TUFLOW model and the underlying sewer network. These datasets are compared in Figure 2-1. Appendix D of the FRA (Section 4.2.2) states that flows between models (development model and the EA's ISIS-TUFLOW model) were found to be similar, although this is not directly quantified. We would expect this statement to be backed up by evidence by, for example, a tabulated summary or a comparative hydrograph plot.

Figure 2-1 shows that whilst the modelled catchment area corresponds well to the original upstream catchment boundary derived for Sixteen/Eight Acre Brook, there is some deviation with the upstream catchment boundary previously delineated for Whams Dyke. Assessment of the underlying sewer network has found that a significant proportion of the sewer network drainage area is not included within the catchment polygon delineated and there may be some additional catchment area draining towards to the site from west.

Figure 2-1 Modelled Inflow Boundary Comparison



The comparison indicates that the modelled catchment inflow area draining towards the site may be underestimated and this may affect overland flow pathways, flows and resultant predicted water levels. JBA understand that this catchment boundary was taken from the earlier SWMP study but recommend that this is reviewed further and verified against available datasets (including UU sewer network and LiDAR data) to provide greater evidence that the modelled catchment area is correct and not underestimated. Additional sensitivity testing could be undertaken to assess the impact of a larger catchment inflow area on predicted peak water levels within the site.

2.5 Representation of Development Proposals

The review has highlighted several inconsistencies with the way the proposed development has been incorporated into the model. These are noted in Table 2-2 below.

Table 2-2 Review Comments Relating to the Representation of Development Proposals

Review Comment	Rationale	Action Required
DEVELOPMENT PROPOSALS		
A6. Clarify whether it is the developer's intention to use 16, 250mm diameter culverts (or similar capacity) beneath the new access road.	Each of the 4 1d_nwke lines drawn represents 4 separate identically shaped culverts. It is currently unclear whether this is a mistake as the capacity of the culvert system is not discussed in the FRA. Sixteen culverts seems a lot.	Consultant to confirm whether number of culverts under access road correctly represented. Model should be updated if the current representation of the model is found to be incorrect.
A7. Raised development platforms have been modelled by increasing existing ground levels by a fixed amount rather than raising site levels up to minimum levels reported within the FRA.	Existing ground levels will show local variation and hence will not represent the potentially flat surface created by the development. This is important as the post-development site topography will determine overland flow routes, which using the current version of the model currently will simply mirror existing flow routes. May also affect fluvial flood risk.	Model should be updated to reflect proposed site topography (by raising site levels up to design levels). This will better represent site topography and allow the impacts of a potentially flatter post-development footprint (or detailed proposed site levels if available) on surface water overland flow routes and fluvial flood risk to be understood.
A9. No change to roughness values or infiltration parameters set between pre and post development models.	Given the change from open farmland, we would expect to see roughness and infiltration parameters updated to reflect proposed hard standing areas.	Consider additional sensitivity testing to understand the impact changes may have on the speed and volumes of overland runoff.
A10. Design levels adopted within the FRA are only appropriate to the eastern part of the site and do not reflect the variation in predicted peak water levels along and between Sixteen/Eight Acre watercourse and Whams Dyke.	Design levels across other parts of the site may not meet the design criteria and may be underestimated.	Design levels across the development should be reviewed and updated to reflect the predicted water level variations or should adopt a conservative level across the site.

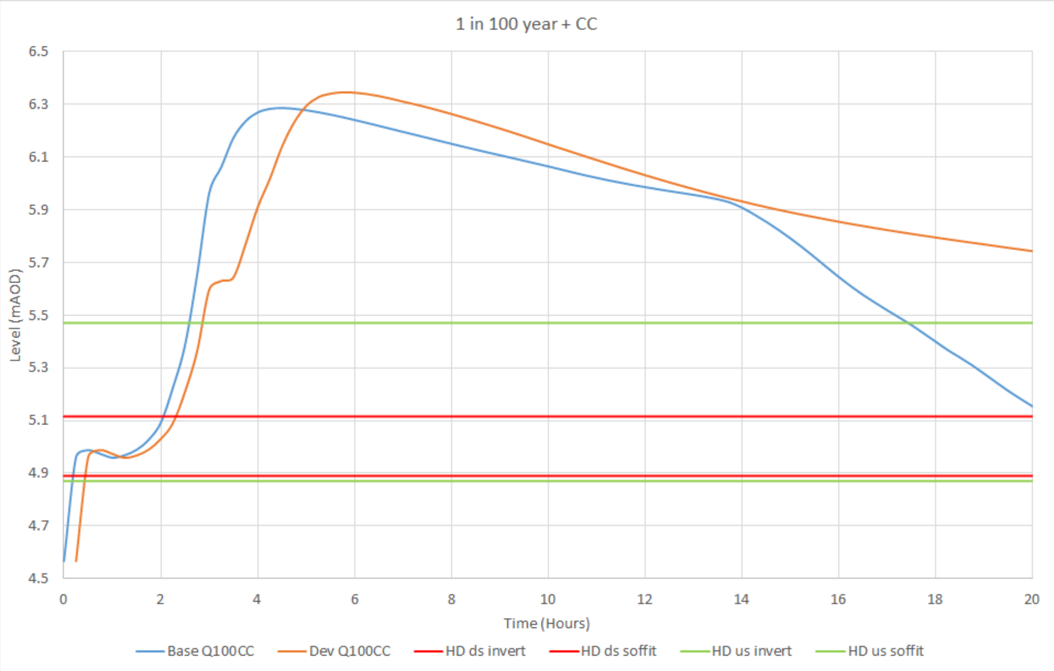
The review has checked the greenfield runoff calculations undertaken for the development. These were found to be appropriate for outline planning.

2.6 Surface Water Impacts

Surface water runoff calculations have been checked as part of the model review. Given that surveyors (Storm Geomatics) have collected local topographic survey at the site to inform the FRA, the fact that outfall levels have not been surveyed is a key omission. In the absence of surveyed outfall levels, these levels have been assumed from the nearest pipe invert levels recorded in the UU sewer network. Note - actual levels are expected to be lower and this may overestimate the level of locking and underestimate the duration of locking.

As documented in Section 2.2, the local surface water network has not been modelled and hence the impacts on the surface water system cannot be directly assessed. Instead probable impacts have been reported in a qualitative way. As part of this review, predicted pre and post development water levels at cross section ACR0198.2 (the cross section nearest to Hawkesworth Drive) have been compared to help understand the likely impacts. These comparisons illustrate that for the 1 in 5 year design event, the hydrograph peak and the duration of surface water outfall locking are reduced in the post development scenario. However, for the 1 in 10, 1 in 25, 1 in 50, 1 in 75 and 1 in 100 year events, although the hydrograph peak is reduced in the post development scenario, the duration of outfall locking is shown to be greater. The 1 in 100 year plus climate change and 1 in 1000 year events indicate both a higher peak water levels and a longer duration of outfall locking in the post development scenario. The analysis undertaken indicates that there is unlikely to be any improvement to the surface water flood risk at Hawkesworth Drive as a result of the proposed development, and that local flood risk may in fact increase because of the increased duration of locking of the system. If development at the site is to be progressed, JBA recommend that further more detailed representation / modelling of the local surface water system is undertaken and integrated into the existing model to fully understand the impacts of the development. This should be informed by a new survey of local drainage network (A11).

Figure 2-2 1 in 100 year plus climate change modelled water levels and outfall levels at the surface water outfall at Hawkesworth Drive (HD)



2.7 FRA Reporting

Comments associated with the FRA are outlined in Table 2-3.

Table 2-3 FRA Comments

Review Comment	Rationale	Action Required
FRA REPORTING		
In several places, the FRA reports changes in flood risk (between pre and post development scenarios) in a qualitative manner.	Changes should be directly quantified using predicted water level and flow differences across the site.	Additional detail should be added to report.
Section 3.2.2 conflicting information presented with regards to flood risk - presence within Flood Zones		Update report to address.
Figure 5.1 – how can water level (red line) be different on left and right banks?		Update figure or provide better explanation in the report to document what this figure shows.
Section 5.4 – FRM and Mitigation 'Sign up to flood warning'	Not a realistic statement as site not in an existing FWA. No suitable gauge to provide FW. Unlikely that sufficient lead time can be provided due to rapid response and small size of the catchment.	Update report accordingly. Also relevant to Section 5.6.2 and 7.1.4.
Section 5.7.3 The report states 'With consideration of the proposed flood risk management measures described, there are no remaining residual' risks'.	Not true - residual risks from blockage, defence failure, surface water will remain. These should be acknowledged and an appropriate allowance factored into the site freeboard.	Further investigation / sensitivity testing to understand the impacts of remaining residual risks on predicted flood levels and extents.
Section 5.4.4 Inconsistency between reported levels and model outputs that are only valid for the south-eastern part of the site.	Where a variation of levels is observed either the highest levels should be used to represent or a conservative scenario or a range of levels should be presented at	Update report and design levels accordingly.

	different locations should be presented.	
Reported benefit to Hawkesworth Drive (as a result of additional flood storage and flapped outfalls on SW system) not directly quantified.	Not directly modelled or quantified. Attenuation of outflow from the site could extend the duration that SW outfalls are locked. The peak fluvial (in-channel) levels are higher in the post development scenario for the 1%CC AEP event.	Ideally a representation of the local SW system would have to be incorporated into the model to allow the impacts on the proposed flapped outfalls and increased defence height to be directly understood.
Section 6.4.9 – 'Proposed surface water drainage strategy could provide sufficient storage'. (3750 m3 in pond, 2000 m3 via permeable paving and underground storage, 500m3 in drainage pipes).		Outline calculations to be reviewed at detailed design.

3 Review of Updated Modelling

3.1 Introduction

This section of the report documents the modelling work that was completed to address the comments and recommendations that were identified in the original model review (documented in Section 2). This work was completed between October and December 2015 and this section of the report is structured to follow a similar format to Section 2.

3.2 1D-2D Model Construction

The original model review highlighted a number of concerns relating to the construction of the 1D-2D model, and suggested that, at a minimum, further sensitivity tests should be undertaken to more fully understand the impact of any model updates on model predictions.

In response to these comments, a number of sensitivity tests were undertaken by the consultant for the climate change enhanced 1% AEP (5hr critical storm duration). The outputs from these runs are described in the sub-sections below. Predicted peak water levels are summarised in Table 3-1.

A2. Surveyed Channel Information

Following the original model review the consultant confirmed that hard bed information from the survey had been used to define channel sections within the 1D ESTRY model. To understand the impact of using the surveyed soft bed information, which would reduce the available channel capacity, an additional sensitivity test has been undertaken. The outputs from this model run showed that the nature of the bed had a negligible impact on peak water levels during a large flood event (i.e. this could be viewed as a neutral impact if water levels are rounded to 2 decimal places). This confirms that design levels for the development, as predicted by the model, are not sensitive to the decision to use the surveyed hard bed information to define the channel geometry.

A4. Roughness

The model review highlighted that Eight Acre Brook and Whams Dyke watercourses have been modelled with a constant bed roughness of 0.04 and a constant bank roughness of 0.06. To understand the sensitivity of the model to the chosen roughness parameters, Manning's 'n' values within both 1D and 2D parts of the model have been changed by ±20%. These tests will assess some of the uncertainty in the allocation of channel and floodplain roughness values that is inherent in all hydraulic models and should include for the seasonal variations in roughness values (due to the vegetation) that could occur in the Eight Acre Brook and Whams Dyke catchments.

Table 3-1 indicates that peak water levels in Eight Acre Brook and Whams Dyke are shown to increase by up to 0.04m if roughness is increased by 20%. Similarly, peak water levels are shown to fall by up to 0.05m if roughness is reduced by 20%. In both cases, Whams Dyke is shown to be less sensitive than Eight Acre Brook. Predicted peak water level variations of this magnitude are to be expected and demonstrate that the model is behaving realistically to the changes made.

A5. Non-Standard ESTRY Coefficients at Structures

The original model review identified several places where non-standard coefficients had been used to represent 1D (ESTRY) structures, including the Formby Bypass Culvert. As no justification had been provided to support any non-standard coefficients, JBA recommended that an additional sensitivity test based on default settings be carried out to understand the impact of the previously modelled coefficients on peak water levels. Reported peak water levels provided by the consultant are shown to remain unchanged (when rounded up to 2 decimal places) as a result of this test, confirming that the modelled inlet and outlet losses at the structures tested are not sensitive to the non-standard coefficients.

Table 3-1 Summary of the Change in Predicted Peak Water Levels in the 1%CC AEP Event as a Result of the Additional Sensitivity Testing Completed

	Eight Acre Brook Node – ACR0506.1	Whams Dyke Node – WHAM0570.1
Baseline Result for Comparison	6.48 (0)	6.55
Hard/Soft Bed	6.48 (0)	6.55 (0)
Loss coefficient on culverts	6.48 (0)	6.55 (0)
Manning's +20%	6.52 (0.04)	6.57 (0.02)
Manning's -20%	6.43 (-0.05)	6.54 (-0.01)

Conclusions

The testing has shown that the model behaves realistically to changes in model parameters with modelled water levels found to vary by up to ±0.05m. From this it can be concluded that comments A2, A3, A4 and A5 made in the original model review, are unlikely to have a significant impact on the design levels for the development and the conclusions made about its viability.

Going forward, to ensure that the model is as accurate as it can be and to ensure that there are no cumulative impacts produced, any further more detailed modelling should consider incorporating these changes into the baseline model.

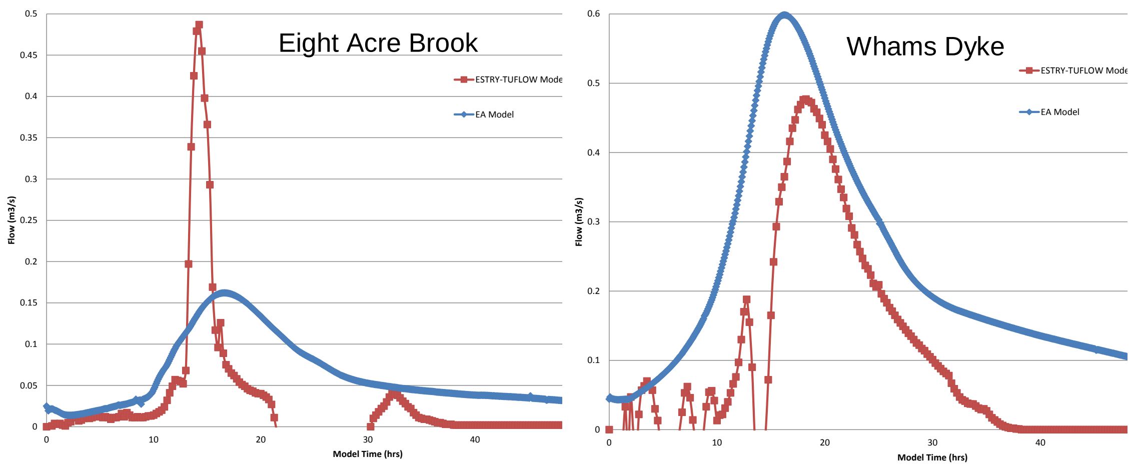
3.3 Model Inflows & Hydrology

Further dialogue has been provided by the consultant to justify the catchment boundaries used within the assessment. The additional hydrology related checks undertaken are described below.

Consistency in Flows with the Environment Agency's Lower Alt Model

Using the outputs from the critical storm duration test for the 24hr storm duration, a check for consistency was made against the outputs of the Environment Agency's Lower Alt model; also run with a 24hr storm duration. A comparison of the predicted hydrographs on Eight Acre Brook and Whams Dyke for the 1% AEP event at the culverts under Formby bypass are shown in Figure 3-1. These plots highlight some difference in peak flow between models which is inevitable because of the varying hydrological methods used by the models. The Environment Agency model uses a point based inflow hydrograph from a scaled version of ReFH, compared to the direct rainfall applied and the predicted flow routing within the ESTRY-TUFLOW model of the Brackenway site.

Figure 3-1 Predicted Flow Hydrographs at the Formby Bypass Culvert on Eight Acre Brook & Whams Dyke



Critical Storm Duration

The impact of a range of storm durations have been tested by the consultant. This assessment considered storm durations ranging from 1 to 6 hours in the Whams Dyke and Eight Acre Brook catchments. In addition, the impact of a longer, 24 hour, storm (consistent with the storm duration applied within the Environment Agency's Lower Alt model) has also been tested. When testing the storm duration for the Whams Dyke and Eight Acre Brook catchments, it is understood that the storm duration for the other inflows into the wider Lower Alt model have remained unchanged from the 24 hour duration applied across the Lower Alt catchment. The testing has been completed for the 1% AEP design event.

The outputs provided from these model runs are shown graphically in Figures 3-2 and Figure 3-3 and are summarised in Table 3-2. This evidence supports the adoption of the 5 hour storm as the critical duration for the fluvial system.

Figure 3-2 Predicted 1%CC AEP Event Water Levels at Node WHAM0181.1 on Whams Dyke

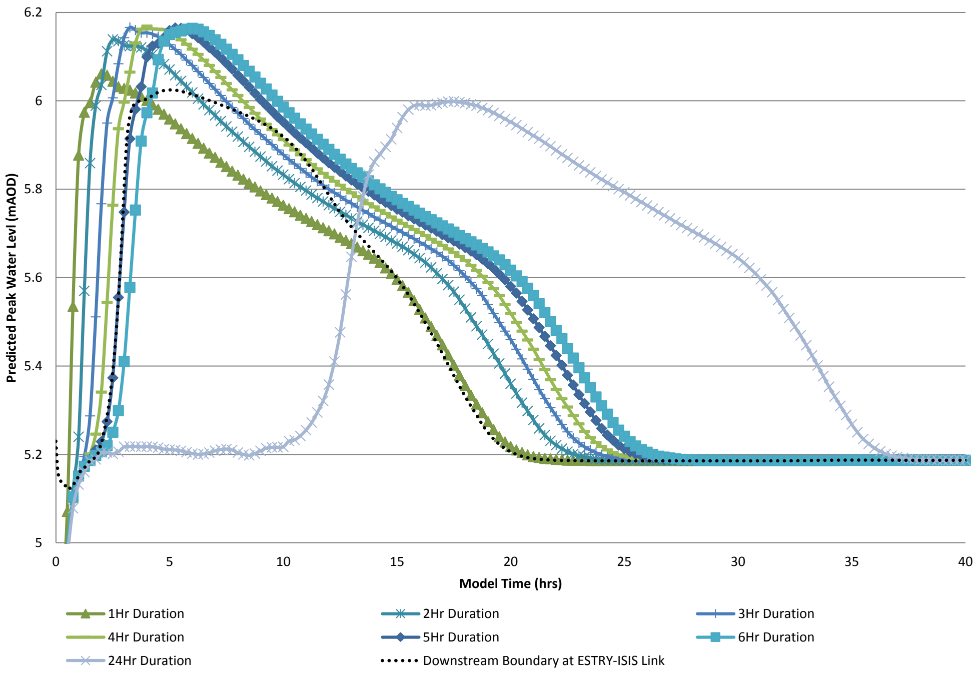


Figure 3-3 Predicted 1%CC AEP Event Water Levels at Node ACR0198.1 on Eight Acre Brook

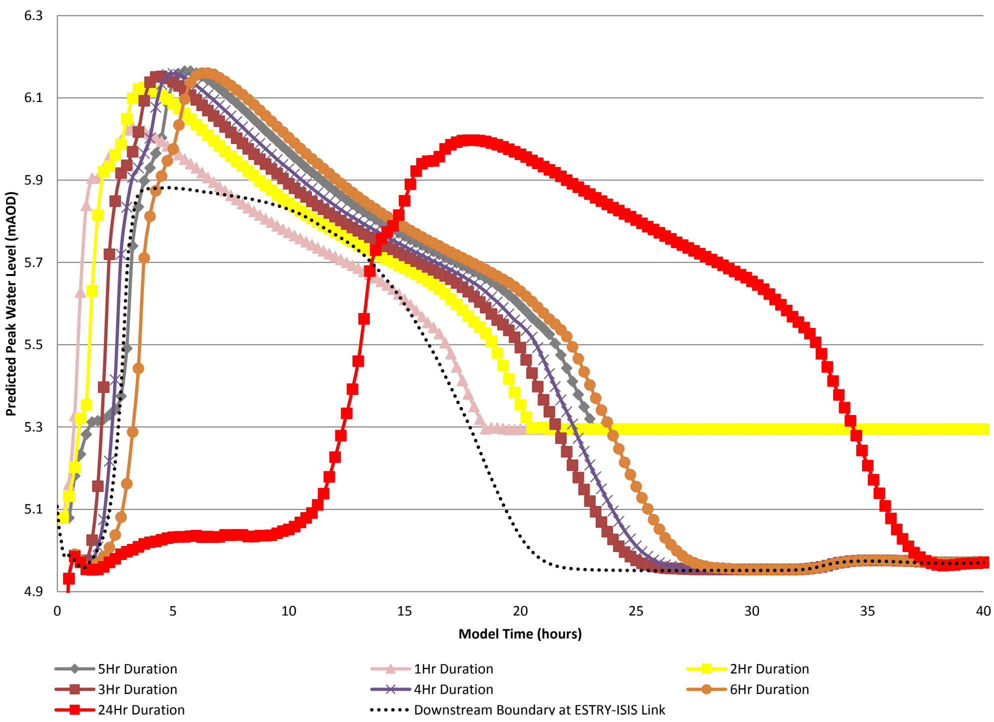


Table 3-2 Summary of the Change in Predicted Peak Water Levels in the 1% AEP Event as a Result of Critical Storm Duration Testing

	Eight Acre Brook Node – ACR0312.1	Whams Dyke Node – WHAM0181.1
1hr storm	6.03	6.06
2hr storm	6.13	6.11
3hr storm	6.15	6.17
4 hr storm	6.16	6.15
5hr storm	6.17	6.17
6hr storm	6.16	6.16
24hr storm	6.00	6.00

3.4 Representation of Development Proposals

The consultants' response to the original mode review comments A6, A7, A9, and A10 is that a sufficiently detailed development layout is not yet available in order to accurately represent the detailed impact of the proposed development within the model. Hence, JBA recommend that more detailed modelling is undertaken at the planning application stage to inform the final FRA. This detailed modelling should consider;

- The detailed design of the linking culverts under the proposed new access road. This should include information on the size, number and location of proposed culverts, noting that 16 250mm diameter culverts are currently represented. Future proposals should at least maintain the combined opening area of these culverts or test the impact of any revisions made on floodplain connectivity.
- The final proposed land raising and contouring plan should be modelled in detail across the site, to determine the impacts of the revised levels on runoff and flow routes since this could change the volume of floodwater that is predicted to flow into Sixteen/Eight Acre Brook and Whams Dyke. (Note that, in the absence of any site specific information, the post development scenario simply raises existing site levels by a fixed amount). Going forward, it is recommended that predicted flows into Sixteen/Eight Acre Brook and Whams Dyke are closely monitored. It may also be of benefit to contour site levels to create preferential flow routes towards Whams Dyke and reduce flows into Sixteen Acre Brook.
- Changes to proposed open and hard standing areas based on the proposed housing layout should be reflected within the roughness and infiltration parameters set across the 2D (TUFLOW) model.
- Design levels within any resulting FRA should be re-assessed and presented for a range of node points within the model to inform a variation in design levels across the development or, alternatively, a single conservative design level could be adopted across the whole development. The predicted fall in peak water levels along Sixteen/Eight Acre Brook of 0.85m from 6.80mAOD to 5.95mAOD for the 1% CC AEP event highlights the reasoning behind this issue.

3.5 Surface Water Impacts

The absence of surface water (network) modelling to quantify the impacts of the proposed development on the local surface water system, which discharges into Eight Acre Brook, was a key concern that was identified within the original model review, especially given that the reported surface water benefits of the scheme were not directly quantified.

To address this concern, the consultant has completed an assessment of the surface water impacts using United Utilities (UU) InfoWorks CS model of the network. This assessment assumes that the UU model is both fit for this intended use and sufficiently detailed to allow the relative changes in flood risk between the pre and post development scenarios to be established.

The following approach has been adopted;

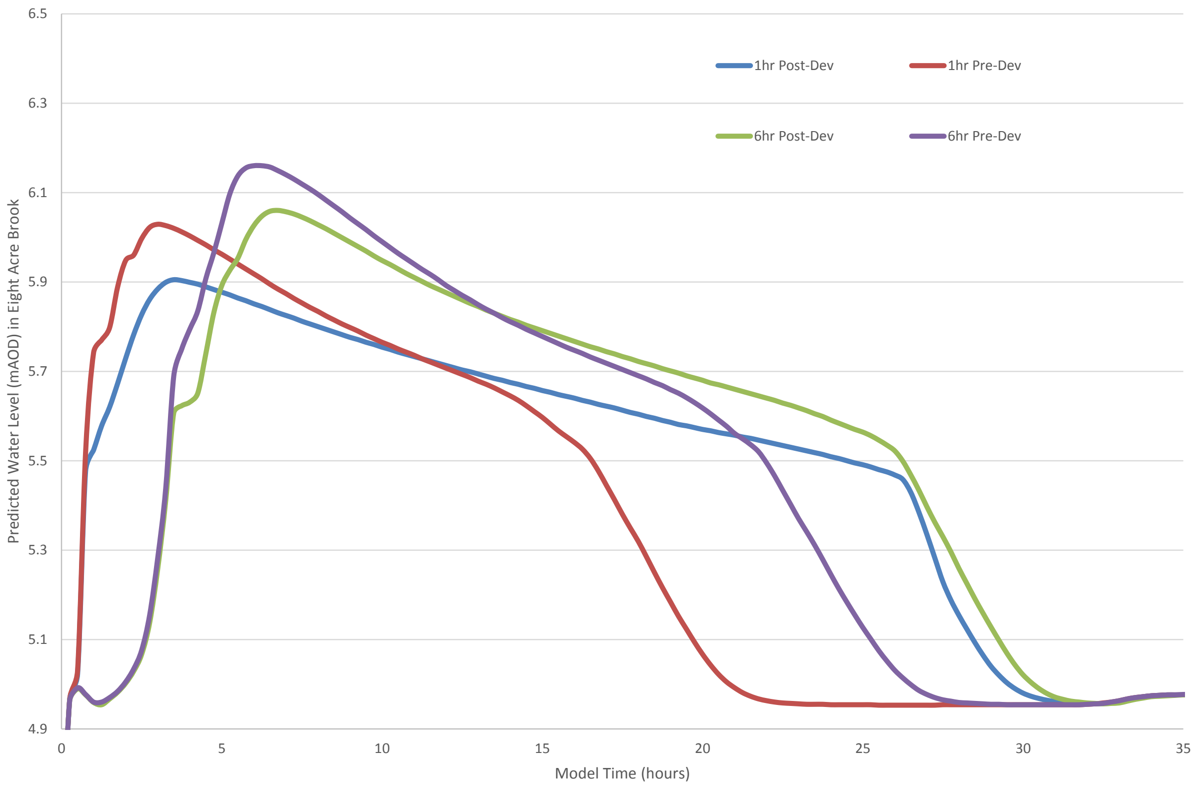
- The simplified representation of Eight Acre Brook has been removed from the model and replaced with a Head-Time (HT) boundary at the location of each surface water outfall.

Within the HT boundary, time varying river levels as predicted by the ESTRY-TUFLOW model, for specific events and storm durations have been applied for the pre and post development scenarios. The pre and post development boundary conditions used within the model are illustrated in Figure 3-4.

- In addition to the revised river levels predicted for the post development scenario, the post development model also includes the flap valves to be fitted at the two existing surface water outfalls into Eight Acre Brook.
- A range of storm durations ranging from 0.5hrs to 6hrs have been configured and run through the InfoWorks CS model to understand the critical storm duration for the surface water network. This was found to range from 0.5hrs to 1.5hrs and a duration of 1hr has been taken forward as the critical storm duration for the system. The 1hr storm has been considered in addition to the 5hr duration identified as critical for the fluvial system. It should be noted that this has been modelled with a 6 hour storm duration as 5hr duration inflow files were not supplied by UU and could not easily be generated by the consultant.
- Pre and post development models have been configured and run for 1% AEP event using the 1hr and 6hr storm profiles.

The impact of the development has been assessed by comparing the predicted overland flood volumes at manholes within the network since flood risk data in the form of predicted flood extents and depths were not readily available from the 1D model. The reported model outputs are from version 20 of the model.

Figure 3-4 Pre and Post Development Boundary Conditions used within the InfoWorks CS Model



3.5.1 Predicted Flood Volumes

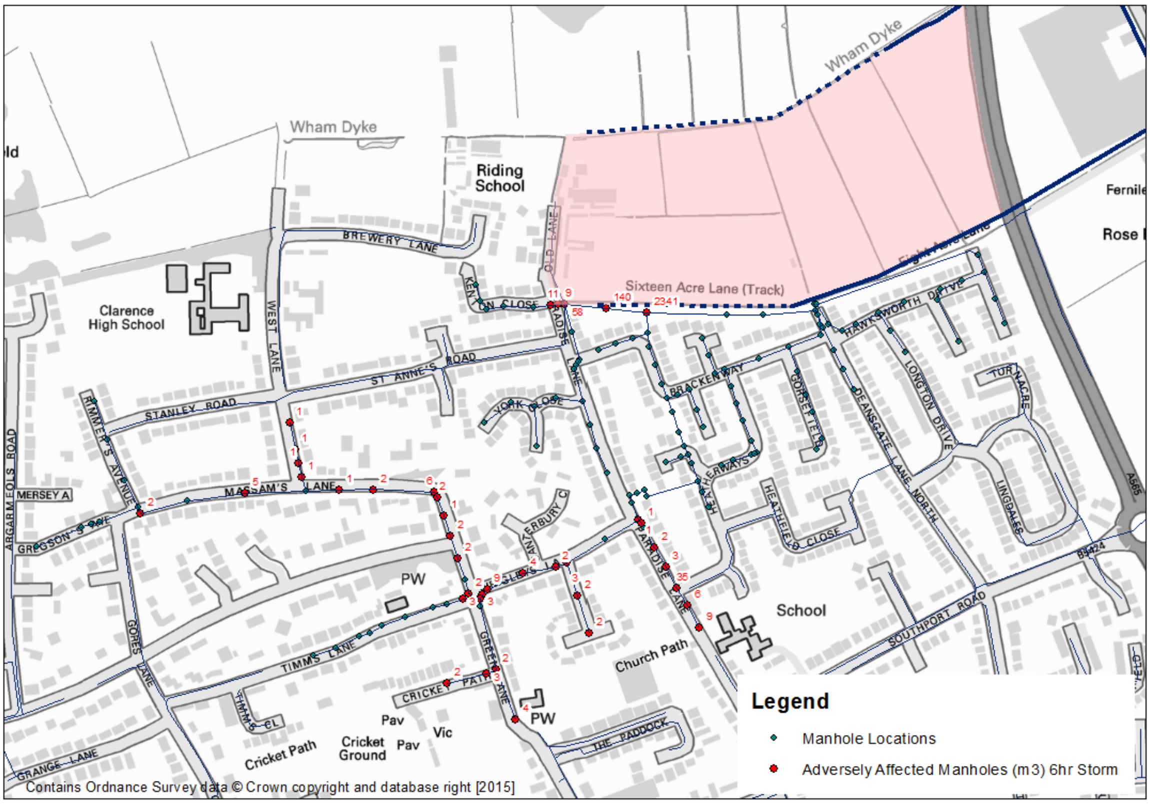
Predicted surplus flood volumes from the final post-development model (v20 that includes additional on-site storage across an area of 4900m^2) are changed in some parts of the network relative to the pre-development case. For this report, an adverse impact is assumed to have occurred where the predicted flood volumes at manholes are increased in the post-development case relative to the pre-development case. The predicted change in flood volumes at manholes that are adversely affected are summarised graphically in Figure 3-5 and Figure 3-6 for the 1hr and 6hr, 1% AEP, storm profiles respectively. These adverse impacts are caused by the change in predicted water levels in Eight Acre Brook as a result of the development.

For the 6 hour storm there are a total of 39 manholes where predicted total post-development flood volumes are shown to be greater than pre-development volumes, with a total increase in overall flood volume of 2684m³ predicted. The relative change in flood volume at most manholes has been screened and is generally shown to be small (<1m³ or <1% of overall flood volume) although there are a few specific locations where larger differences are predicted. These locations are summarised in Table 3-3. There are no 'above surface' flood benefits shown to be provided by the development (i.e. overland flood volumes are not reduced at any of the manholes), although 'below ground' flood volumes within the network are shown to be reduced at 21 manholes. This will increase the short-term available flood storage in the network at these locations, should a second rainfall event occur before the system has fully drained / discharged into Eight Acre Brook.

Table 3-3 Manholes with an Increase in Predicted Flood Volume Resulting from the Proposed Development - 6hr Storm

Node ID	Relative Increase in Predicted Flood Volume (m³)	Easting	Northing
SD30080709*	2341	330078	408774
SD30080711	140	330025	408780
SD29089706	58	329972	408786
SD29089709	11	329954	408784
SD29089714	9	329963	408785
SD29084505	2	329425	408516
*Manhole SD30080709 represents a localised low spot in the network			

Figure 3-3 Additional Flood Volume Predicted at Adversely Affected Manholes for the 1% AEP 6 Hour Storm Event



The same analysis has been completed for the 1 hour storm duration identified as the critical duration for the surface water system. The simulation completed for the 1% AEP event indicates that a total of 23 manholes are shown to be adversely affected, with flood volumes at all of these locations increased by >1m³ and accounting for >1% of the overall flood volume. These nodes are summarised in Table 3-4.

Figure 3-4 Additional Flood Volume Predicted at Adversely Affected Manholes for the 1% AEP 6 Hour Storm Event

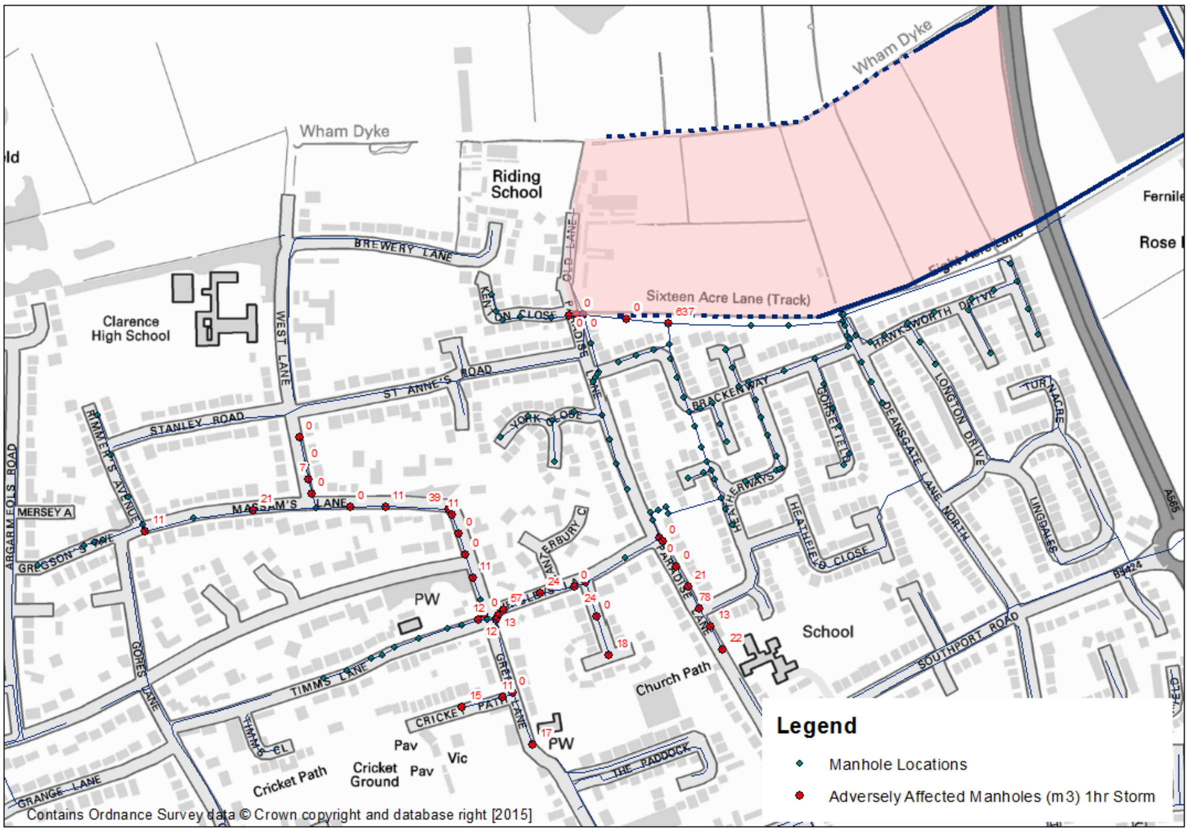


Figure 3-5 Manholes with a Predicted Reduction in Peak Water Level in the 1% AEP 6 Hour Storm Event

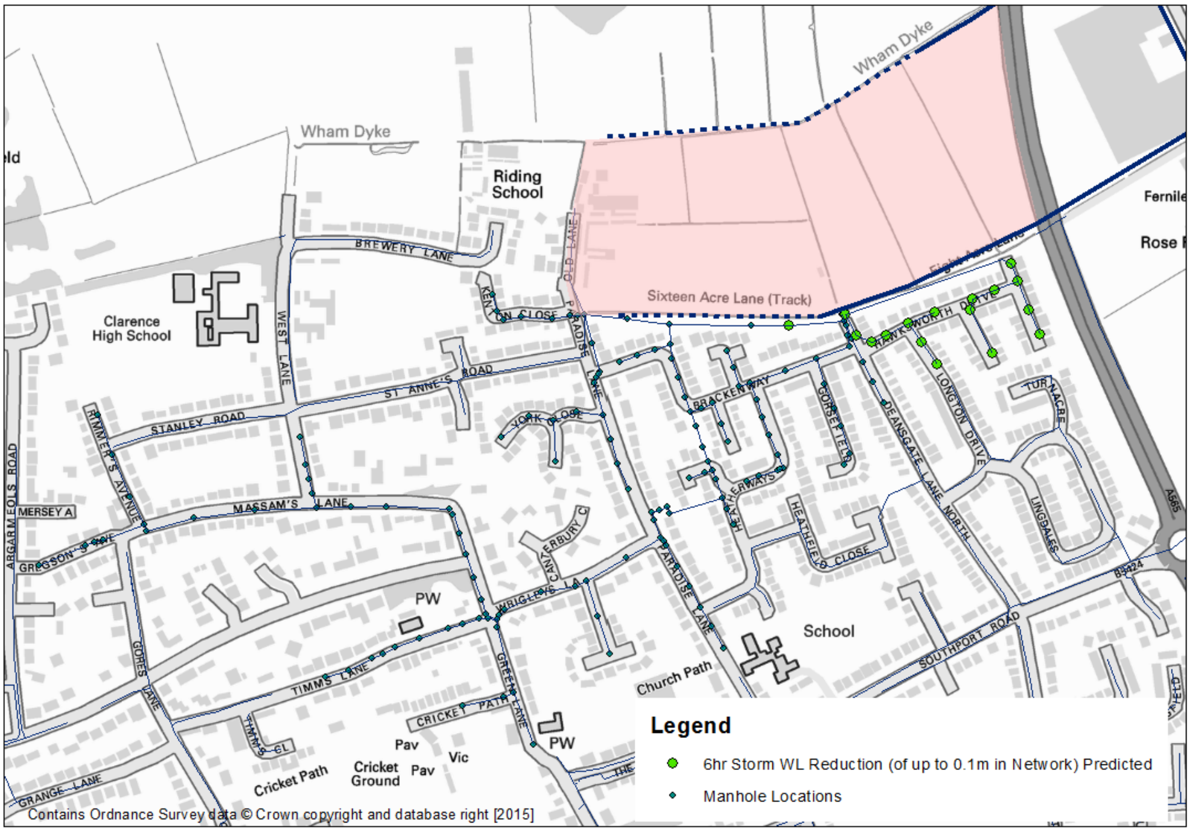


Table 3-4 Manholes with an Increase in Predicted Flood Volume Resulting from the Proposed Development - 1hr Storm

Node ID	Relative Increase in Predicted Flood Volume (m^3)	Easting	Northing
SD30080709*	637	330078	408774
SD30081403	78	330116	408420
SD30081303	22	330145	408369
SD29088411	57	329872	408418
SD29088503	39	329803	408543
SD30081304	13	330130	408397
SD29085502	21	329560	408542
SD29089404	24	329918	408439
SD29089204	17	329908	408250
SD30081404	21	330102	408447
SD29088410	12	329865	408411
SD29088408	13	329863	408405
SD29089406	24	329974	408453
SD29088409	12	329840	408406
SD29088303	11	329871	408309
SD30080302	18	330003	408362
SD29088504	11	329807	408536
SD29088202	15	329820	408297
SD29084505	11	329425	408516
SD29087502	11	329725	408546
SD29088405	11	329834	408458
SD29086506	7	329628	408581
*Manhole SD30080709 represents a localised low spot in the network			

It should be noted that the outputs from the UU model (either pre or post development versions) do not predict any existing surface water flood risk to Hawkesworth Drive in the 1% AEP event. This indicates that the predicted outputs from the model are not consistent with past observed flood history and this should be assessed further as part of any more detailed modelling exercise. In particular, the manhole cover levels set (ground level attribute) should be cross checked against the most recent filtered LiDAR dataset.

As floodwater is predicted to be contained within the network in the Hawkesworth Drive area in the pre-development case, and remain so in the post-development case there are no clear 'overland' flood benefits predicted from the post-development version of the model (in terms of reducing the extent or depth of flooding). However, for the 6hr storm event, localised peak water levels in the vicinity of Hawkesworth Drive are predicted to reduce by up to 0.11m, as shown in Figure 3-5. These water level reductions demonstrate a local increase in available flood storage within the network, for the 6hr storm. Predicted peak water levels in this area for the 1hr storm remain unchanged between the pre and post development cases, indicating that this reduction is dependent on storm duration.

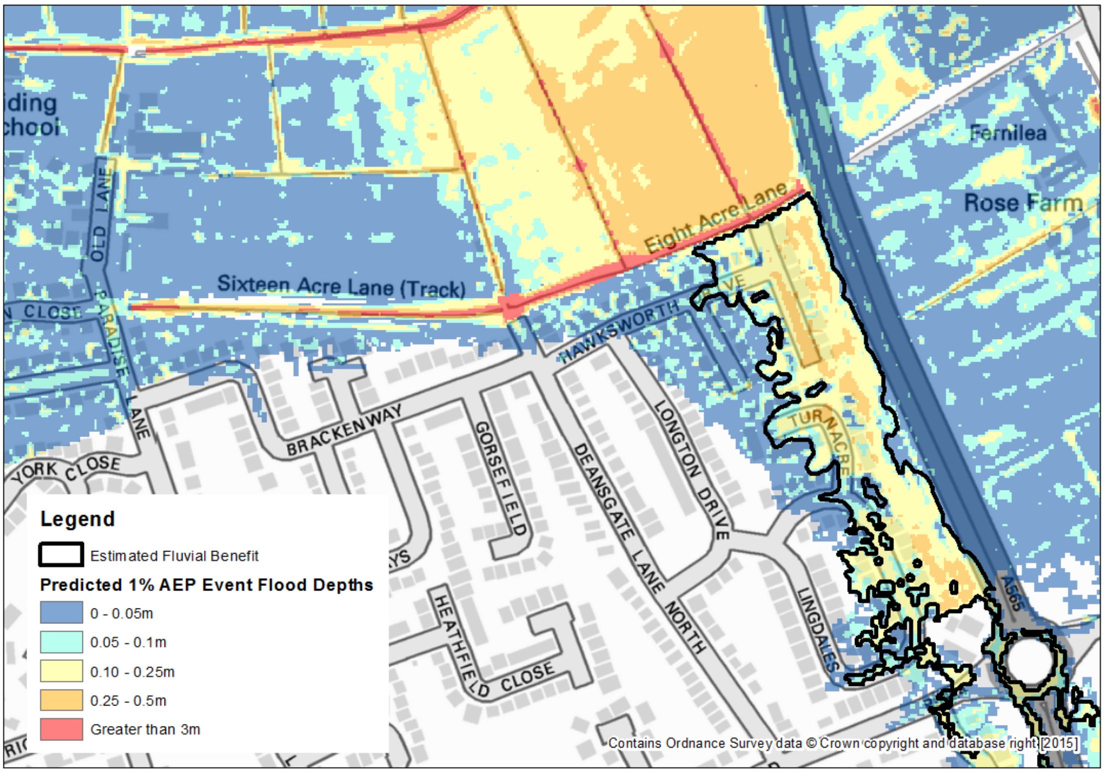
4 Flood Risk Benefits from the Development

This section of the review documents the modelled flood risk benefits to Hawkesworth Drive and surrounding area that would likely arise from the development with the proposed mitigation in place. The fluvial flood mitigation includes lowered areas on the development site, which provide flood storage, and the defence along the right bank of Eight Acre Brook.

The proposed new defence along the right bank of Eight Acre Brook between Deansgate Lane North and the Formby Bypass will contain flood levels on-site and prevent fluvial overtopping onto Hawkesworth Drive. Given that every cell in direct rainfall models will be 'wet' at some point in the model run and that surface water runoff will likely pond up behind the defence (because flow routes into the surface water network are not represented), it is difficult to definitively determine the area (extent) that will benefit from this defence. The assessment of fluvial benefit is also complicated by the flat topography and localised flow routes that are being modelled within the floodplain, which dictate that flood depths across the residential area on the right bank of Eight Acre Brook remain low. These matters would need to be addressed in greater detail in the final FRA at planning application stage.

The area predicted to benefit from reduced fluvial flood depths between the pre and post development scenarios in the 1% AEP event is shown in Figure 4-1. Within this area, fluvial flood depths are shown to reduce by up to 120mm as a result of the mitigation measures to be constructed as part of the development. This reduction in fluvial flood depths represents the fact that fluvial floodwater would be contained in Eight Acre Brook by the new defence, which prevents the overtopping onto Hawkesworth Drive that would occur under existing conditions.

Figure 4-1 Estimated Fluvial Benefit Area Resulting from the Development in the 1% AEP Event



The surface water benefits cannot be quantified in the same way because the InfoWorks CS model is a 1D only model. Therefore, the predicted overland flood volumes have been used as an indicator of benefit or adverse impact. As noted in Section 3.4, there are a number of nodes where an adverse impact is predicted as a result of the development. The main cause of these adverse impacts is likely to be the change in river levels between the pre and post-development scenarios. It would be possible to mitigate these currently predicted, adverse impacts by increasing the available flood storage either on-site (to ensure that post-development fluvial levels were consistently below pre-development levels) or within the surface water network. The impacts of this should be demonstrated through further more detailed modelling.

As illustrated in Figure 3-5, there are 17 manholes in the vicinity of Hawkesworth Drive where a reduction in peak water levels within the network (of up to 0.11m) is predicted for the 6hr storm. These manholes are not predicted to flood within the model, but they do demonstrate a local increase in available flood storage within the network in the post development case, relative to the pre-development case for the 6hr storm. Predicted peak water levels in this area for the 1hr storm remain unchanged between the pre and post development cases, indicating that this reduction is dependent on storm duration.

These matters would need to be addressed in greater detail in the final FRA at planning application stage.

5 Conclusions

JBA Consulting have completed a technical review of the flood modelling work completed to support the future development of the land at Brackenway, in Formby. The outcomes from the original model review are summarised in Section 2 of this report. This highlighted several concerns and inconsistencies with the flood model, prompting a number of model updates and additional sensitivity tests.

The sensitivity tests that have been undertaken in regard to the construction of the 1D-2D model since the original review demonstrate that these issues will have only a small impact on the predicted peak water levels (±0.05m) and will not affect the consultant's conclusions about the viability of the proposed development.

To address concerns raised in the original model review, a further assessment of the impacts of the development on the neighbouring surface water network has also been completed using United Utilities (UUs) InfoWorks CS model. This additional assessment is documented in Section 3 of the report.

The key conclusions from the overall model review are noted below;

- The raised defence and on-site flood storage to be constructed as part of the development will introduce a fluvial flood risk benefit to Hawkesworth Drive and the surrounding area by preventing the overtopping of Eight Acre Brook in the reach adjacent to Hawkesworth Drive when flows are high on Wham Dyke and Eight Acre Brook. This is demonstrated by the clear reduction in flood depths that is modelled across this area in response to the post-development scenario.
- The surface water assessment has highlighted model nodes that could be adversely affected as a result of the development, which is due to an increase in water levels along Eight Acre Brook during the falling limb of the hydrograph. This is apparent in the predicted flood volumes from the InfoWorks CS model. These adversely influenced, model nodes occur outside of the area where the fluvial benefit has been demonstrated. It would be possible to mitigate these currently predicted, adverse impacts by increasing the available flood storage either on-site (to ensure that post-development fluvial levels were consistently below pre-development levels) or within the surface water network.
- The surface water assessment has identified 17 manholes in the vicinity of Hawkesworth Drive where a reduction in peak water levels within the network (of up to 0.11m) is predicted for the 6hr storm. These manholes are not predicted to flood within the model, but they do demonstrate a local increase in available flood storage within the network in the post development case for the 6hr storm. Predicted peak water levels in this area for the 1hr storm remain unchanged between the pre and post development cases, indicating that this reduction is dependent on storm duration.

Modelling Recommendations

Going forward, at the planning application stage, any further more detailed site specific risk assessments should draw on the comments and recommendations made within this report and should include;

- Any updates to the ESTRY-TUFLOW model as recommended within this report.
- Accurately proposed site levels and building footprints (not available at present), which will need to be incorporated into the final model since these will affect overland flow routes, roughness values and infiltration rates across the development. The assessment should consider the linkages between Whams Dyke and Eight Acre Brook and ensure that any change in flow pattern is fully understood.
- Verification of the UU model, inclusion of additional mitigation (to manage the adverse impacts predicted within the surface water system) and /or better quantify the localised change in surface water flood risk resulting from the development (for example from surcharged manholes). This could be achieved via additional 2D modelling or the development of a fully integrated model that includes the local surface water network.

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