Flood Modelling for Yalding Enterprise Park

Model report

August 2019

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Revision History

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Contract

This report describes work commissioned by Paul Medhurst of Civils Contracting Ltd, by an email dated 27 March 2019. Aaron Barber and Ben Gibson of JBA Consulting carried out this work.

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Purpose

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Abbreviations

1D	One-dimensional
2D	Two-dimensional
AEP	Annual Exceedance Probability
Cum ME	Cumulative Mass Error
DSM	Digital Surface Model
DTM	Digital Terrain Model
dVol	Difference in Volume (a TUFLOW output)
ECF	ESTRY Control File
FRA	Flood Risk Assessment
IED	ISIS (Flood Modeller) Event Data
IEF	ISIS (Flood Modeller) Event File
LIDAR	Light Detection and Ranging
mAOD	Metres Above Ordnance Datum (Newlyn)
TBC	TUFLOW Boundary Condition
TCF	TUFLOW Control File
TGC	TUFLOW Geometry Control
UAV	Unmanned Aerial Vehicle
YEP	Yalding Enterprise Park

1 Introduction

1.1 Objectives of this document

The Yalding Enterprise Park (YEP) Flood Risk Assessment (FRA) is supported by evidence prepared using a version of the Environment Agency's River Medway Model 3 flood risk model (obtained via request reference *KSL/111101/18 RB*), which has been updated and refined in the area of interest to enable the baseline and proposed development conditions to be developed. The Model 3 flood risk model was developed as part of the Medway Catchment Mapping and Modelling study[1], delivered in October 2015. Following completion of the 2015 mapping study, the modelling was also used to prepare climate change flood risk mapping for scenario in which flood flows were increased by +35% and +70% as part of a follow-on Environment Agency commission[2]. This modelling and its outputs were also made available for the YEP FRA modelling.

This technical reporting provides context to the scenarios being considered as part of the FRA evidence base and provides details on the updates made to the flood risk model to:

- prepare an updated flood risk model with greater detail in the area of interest, applying latest ground level datasets;
- prepare a version of the model representing the Planning Baseline (as agreed with Maidstone Borough Council); and
- prepare a version of the model which represents the Proposed Development scenario.

The changes in flood risk in the development scenario have been assessed for the defended case 5%, 1% and 1% (+35% increase in flow) Annual Exceedance Probability (AEP) scenarios. The +35% flow scenario represents the upper of the two flow allowances (+25% and +35%) which the Environment Agency guidance[3] advocates is used for less vulnerable development (the category in which commercial development falls).

The area of interest is located with 'output zone 3' within the River Medway Model 3 model (output zones within the model are displayed in Figure 1-1). Output zones reflect areas of the model where different input hydrology is used to inform the same magnitude event (i.e. different zones have different 1% AEP design event inflows) and GIS outputs of predicted flooding are only exported by the model for these zones. The flood flow hydrology for output zone 3 has formed for the focus of the assessment, which is associated with the following model simulation events:

- 5% AEP: 0020_16Oct2356
- 1% AEP: 0100_10Jan1924
- 1% AEP +35% flows 0100plus35pc_10Jan1924

A summary of the modelling prepared for the assessment and outcomes was presented to the Environment Agency at a planning advice meeting held 23 July 2019, and the presentation given was made available after the meeting.

1 JBA Consulting for the Environment Agency. Medway Catchment Mapping and Modelling, Final Report, October 2015.

2 JBA Consulting for the Environment Agency. Medway Scenario Modelling, Climate change modelling workstream. December 2016.

3 https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

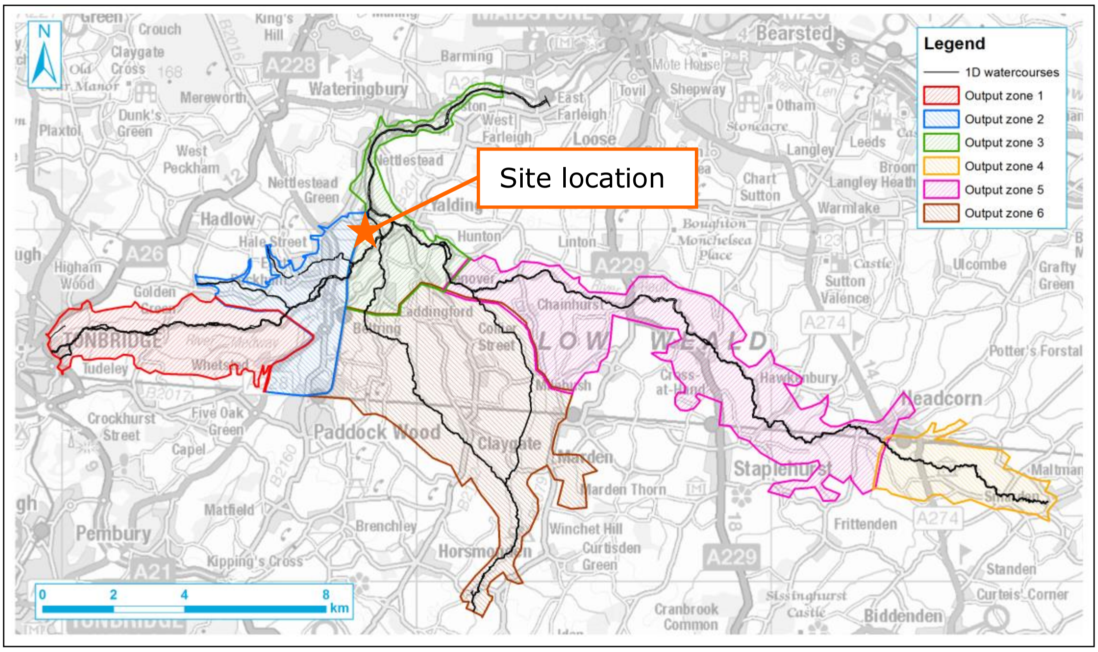


Figure 1-1: River Medway Model 3 output zones
(Figure reproduced from the 2015 study reporting)

This reporting has not sought to provide details of the Model 3 flood risk modelling which can be obtained from the 2015 study[1] reporting and its associated appendices (Appendix A: Hydrology report, and Appendix B: Model operation manual). Instead, it has focused on the changes made to the hydraulic modelling for the purpose of the YEP FRA modelling. The reader should refer to the previous reporting for further information as necessary.

1.2 Background to the proposed development and planning baseline comparison scenario

The proposed development comprises commercial development on the site of the former Syngenta works in Yalding. The site (displayed in Figure 1-2) is located adjacent to the canal at Hampstead, bordered to the north by Hampstead Lane, the west by the railway line, with open space to the south.

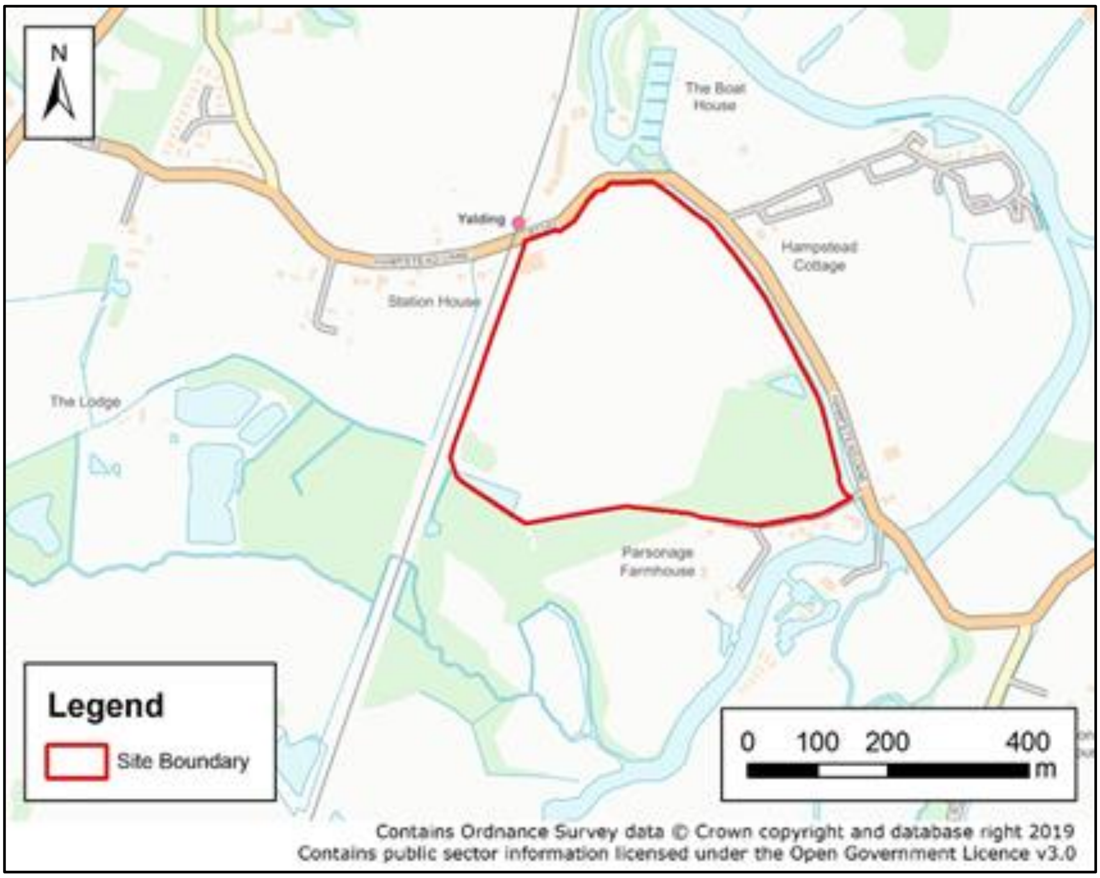


Figure 1-2: Location of the development site

Key features of the proposed development are as follows (letter referencing used refers to markers indicated on the proposed site plan displayed on Figure 1-3):

- **A:** Commercial development buildings, with floor levels raised above the 1% AEP +35% flows level (floor level of 13.7mAOD) and void space beneath
- **B:** Flood conveyance route, sloping from south to north. The invert level of the inlet is set to below the 20% AEP event flood level, improving conveyance through the site and allowing flood water to flow via this route for smaller magnitude events when it otherwise would not
- **C:** Basin at the downstream of the flood conveyance route. The culverts under Hampstead Lane (which are currently blocked) and the chambers connecting to the former mill race under Hampstead Lane (which are currently sealed) connect to this location and will be opened to permit flow of flood water. The structures were not represented in the Environment Agency's original flood risk mapping model. Their presence was not known during the mapping model development, and given that they are currently closed by bricks, these would not have been included as flow routes in the model
- **D:** Parking at the site entrance, including other initial transport routes are at the existing site level, circa 11.7mAOD
- **E:** Road bridge across the flood conveyance route
- **F:** Forecourt areas to the commercial developments. The forecourts slope up from raised roads (at 13.35mAOD) which link to the lower level transport routes via ramps
- **G:** Location of culverts and the former mill race under Hampstead Lane.

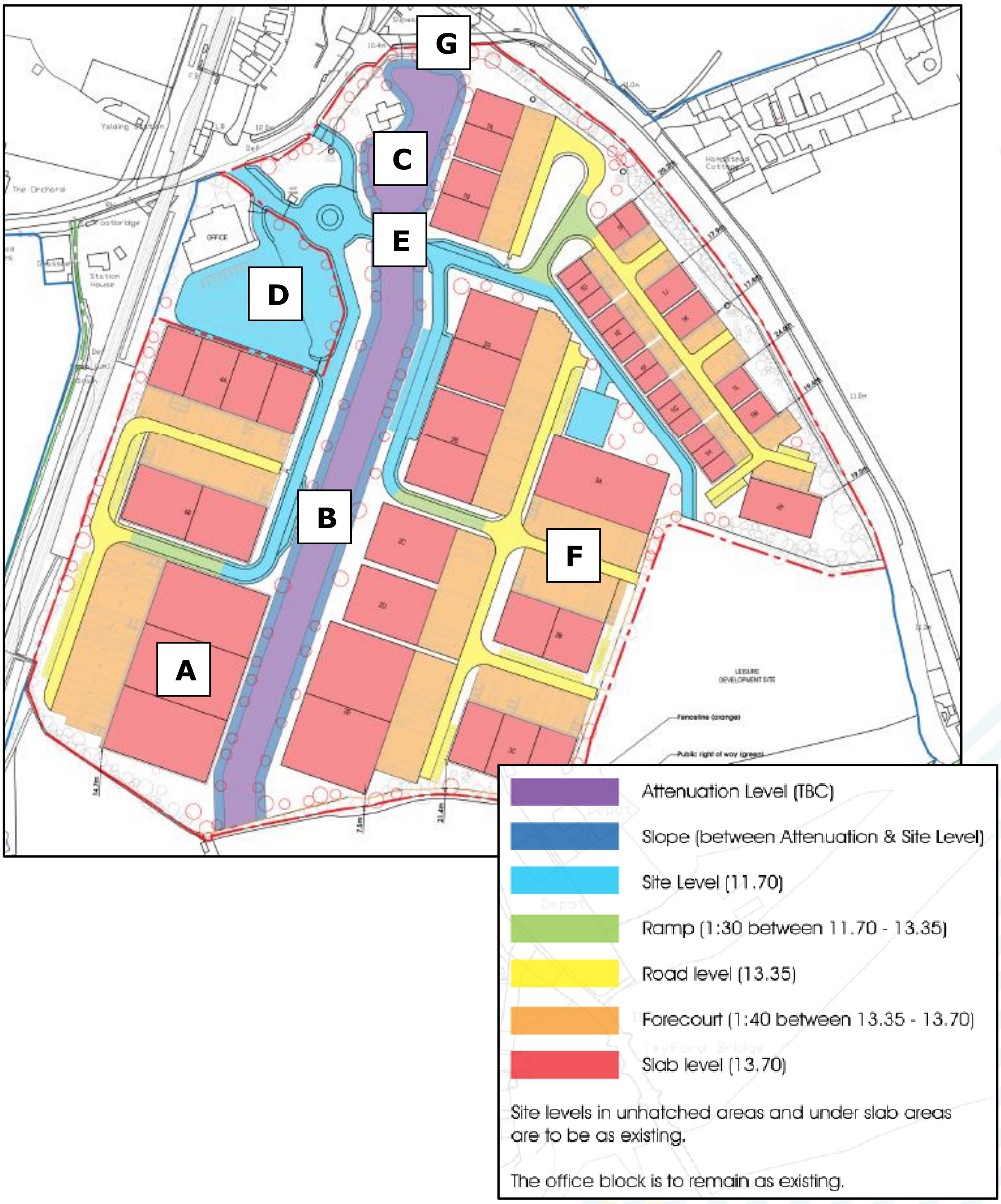


Figure 1-3: Proposed site layout

1.3 Overview of updates made to the hydraulic model

The updates made to the hydraulic model can be simplified into three main stages, as described within Table 1-1.

Table 1-1: Summary of the stages of model updates

Stage	Update	Reason
1. Base model update	Tested and used latest Flood Modeller and TUFLOW software versions	Updated software from ISIS 3.7.2 and TUFLOW 2013-12-AE to the latest versions of Flood Modeller 4.5 and TUFLOW 2018-08-AE so that latest modelling options, bug fixes and parameters etc are implemented.
	Implementation of a 5m grid size domain (previously 20m grid size) in the area of interest	Detail, added through the application of a fifth domain in the model, was required to better resolve flow routes across the floodplain and the proposed site layout to be configured to a sensible resolution.
	Updated ground levels on the floodplain in the new 5m grid domain	Improved the understanding of ground levels of the site: informed by UAV survey of the site, and adjustments made the Environment Agency's existing LIDAR data, where the UAV ground truthing control points indicated a consistent discrepancy in levels within the LIDAR data.
2. Planning baseline	Applied ground levels and the location of buildings from the original topographic survey to represent the Planning Baseline condition (the development circa 2005)	Ground levels at the site for the planning baseline model are informed to be reflective of this previous condition. The elevations are informed by topographic survey collected in October 2005 by Capita Symonds to inform the remediation works at the site.
3. Proposed development	Schematised the proposed development ground levels in the model, including void space under buildings	Ground levels at the site for the proposed development.
	Schematised the proposed flood conveyance route through the centre of the site	Elevations and geometry of the proposed flood conveyance route through the site, a key element of flood management (and betterment) associated with the development.
	Represented the proposed opening up of the 5 no. culverts under Hampstead Lane	Indicative geometry data (informed by site observations) for the 5 no. arch culverts under Hampstead Lane. These culverts are currently blocked off, but the proposed development scenario involves

Stage	Update	Reason
		opening these flow routes to improve conveyance of flood water through the site.
	Represented the proposed connectivity of the former mill race channel under Hampstead Lane	Indicative geometry data (informed by site observations) for the 2 no. chambers which direct water under Hampstead Lane via the mill race. The entrance to these chambers are currently sealed, but the proposed development scenario involves opening these flow routes to improve conveyance of flood water through the site.

1.4 Available data

Data available to inform the flood modelling for the proposed development is summarised in Table 1-2.

Table 1-2: Data used to inform the flood modelling

Dataset	Supplier	Detail	Use in the study
Model data			
Flood risk model: Medway Model 3	Environment Agency	Present day and climate change flood risk modelling prepared under two Environment Agency studies: Medway Catchment Mapping and Modelling (2015) and Medway Scenario Modelling (2016)	This modelling formed the base model which was updated for use in this study
Ground level / survey data			
LIDAR data (DTM and DSM)	Environment Agency	LIDAR data available at 25cm resolution for the study area, collected in 2010	LIDAR data informs floodplain and bank elevations throughout the majority of the Medway Model 3 hydraulic model. The latest data has been applied to the 5m grid size domain added to the model, with a global +0.07m uplift applied reflecting the average difference in elevation between the LIDAR data and ground control points collected as part of the UAV survey.
UAV survey, April 2019, Ref: R232	Grid Point Holdings Ltd	UAV survey of the site, informed by collection of a point cloud dataset, cross-checked and adjusted against	Elevations from this dataset have been implemented within the model where vegetation is not recorded (at which no bare-earth ground levels

Dataset	Supplier	Detail	Use in the study
		ground control survey points	are recorded). Additionally, the ground control points were used to inform adjustments to LIDAR data within the 5m grid size domain added in the area of interest. This data is provided as part of Appendix A and the grid applied to the model is available in the model input files.
Topographic survey (October 2005) Original drawing ref: EDS/LS/ 604-1	Civils Contracting Ltd (drawing ref 2210-30)	The data of the former site layout and ground levels was collected by Capita Symonds in October 2005 to inform the Phase 1 remediation works at the site	Ground levels, and building position/slab levels, were used to inform the site condition for the planning baseline scenario. This data is provided as part of Appendix B.
Dimensions of culverts under Hampstead Lane	Civils Contracting Ltd	Dimensions of the 5 no. arch culverts under Hampstead Lane, informed by site measurements taken by Civils Contracting Ltd during a site visit held 9 May 2019	Used, in conjunction with ground level datasets described above, to inform the representation of the structures in the proposed development scenario. Refer to Appendix C for details.
Dimensions of Mill Race inlets under Hampstead Lane	Civils Contracting Ltd	Dimensions of the 2 no. inlet chambers to the Mill Race under Hampstead Lane, informed by site measurements taken by Civils Contracting Ltd during a site visit held 9 May 2019	Used, in conjunction with ground level datasets described above, to inform the representation of the structures in the proposed development scenario. Refer to Appendix C for details.
Proposed site details			
Proposed site layout (drawing ref: 4092/SK03h)	Civils Contracting Ltd	Position of the features within the proposed development and their corresponding ground levels	Used to inform the schematisation of the proposed development form at the site. This data is provided as part of Appendix D.

2 Base model updates

A summary of the updates made to the original flood risk mapping study model, prior to schematising the planning baseline and development scenarios is presented below.

This involved five main updates to the modelling, as follows:

1. Tested and adopted latest software versions of Flood Modeller and TUFLOW
2. Implemented a fifth domain (Domain 5) with a 5m grid size in the area of interest (removing part of the area previously included with the 20m grid size Domain 3)
3. Implemented a new Output Zone 'YEP_001' covering the site and land to the west
4. Made updates to the 1D model for consistency across scenarios.
5. Implemented updated ground level information from UAV survey and adjusted LIDAR data elevations.

The sections below summarise these updates.

2.1 Use of latest software versions

The original flood risk mapping model was developed in ISIS version 3.7.2 and TUFLOW Build 2013-12-AE. Since this time several updated releases of the software (ISIS is now Flood Modeller) have been made, and so latest software versions (Flood Modeller 4.5 and TUFLOW 2018-03-AE) were tested and adopted to make sure that latest functionality, bug fixes and any modelling default parameter adjustments were captured.

The original mapping model was simulated for each of the 5%, 1% and 1% (+35% flows) AEP events with these latest software versions and the change in peak flood levels were assessed. Changes in peak water levels were less than ±0.01m. The latest software versions were retained.

2.2 Implementation of Domain 5

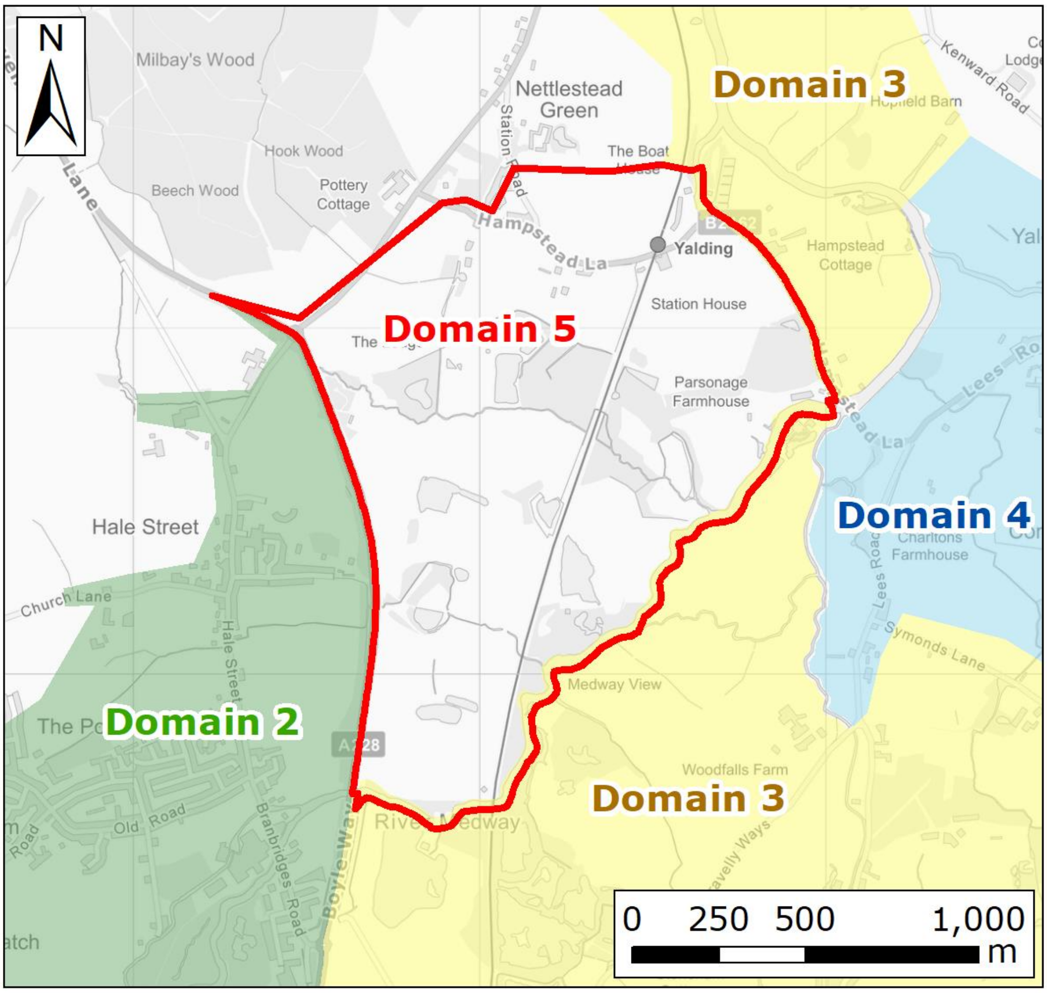
A new domain (Domain 5) was implemented for the site area. This was included in order to better represent the geometry of the floodplain and connectivity to the River Medway importantly allowing features of the planning baseline and proposed development configurations to be implemented.

Domain 5 has a cell size of 5m, reduced from the previous 20m grid size of Domain 3 that covered the area. Domain 5 covers the floodplain to the north of the River Medway and extends from the A228 road to the canal east of the site. It is bordered to the south by the River Medway and the natural narrowing of the floodplain north of Hampstead Lock forms the north extent. Domain 5, in the context of other domains in the area is displayed in Figure 2-1, while the change in grid size is displayed in Figure 2-2, where it can be seen that the revised model has much greater definition of the cells on the floodplain.

Model input files previously assigned to Domain 3 in this area were trimmed from the Domain 3 inputs and assigned to inputs for Domain 5. This included bank elevations, elevations for roads and railways, PO lines, and also boundary conditions along the banks, 2D-2D links and at structures. A new 2D-2D link was prepared at the north of the domain, linking to Domain 3.

Given the reduction on model cell size to 5m for the domain, the 1D and 2D timesteps associated with the simulation were reduced to 0.5s and 1s, respectively. Previously these were 1.5s and 3.0s for the 5% and 1% AEP runs and 0.75s and 1.50s for the 1% AEP +35% flows simulation. The timesteps adopted are within typical range.

The model was simulated for each of the 5%, 1% and 1% (+35% flows) AEP events with Domain 5 included and the change in peak flood levels assessed compared with the existing model configuration. Changes in peak water levels were more marked with ±0.05m, ±0.07m and ±0.02m predicted for the events, respectively. The changes are expected to result partly from change in flow rates across the Domain 5 floodplain (and from the banks), but also because of the changes to model timesteps which will alter the mass balance of the model slightly.



Contains Ordnance Survey data © Crown copyright and database right 2019.

Figure 2-1: Location of Domain 5

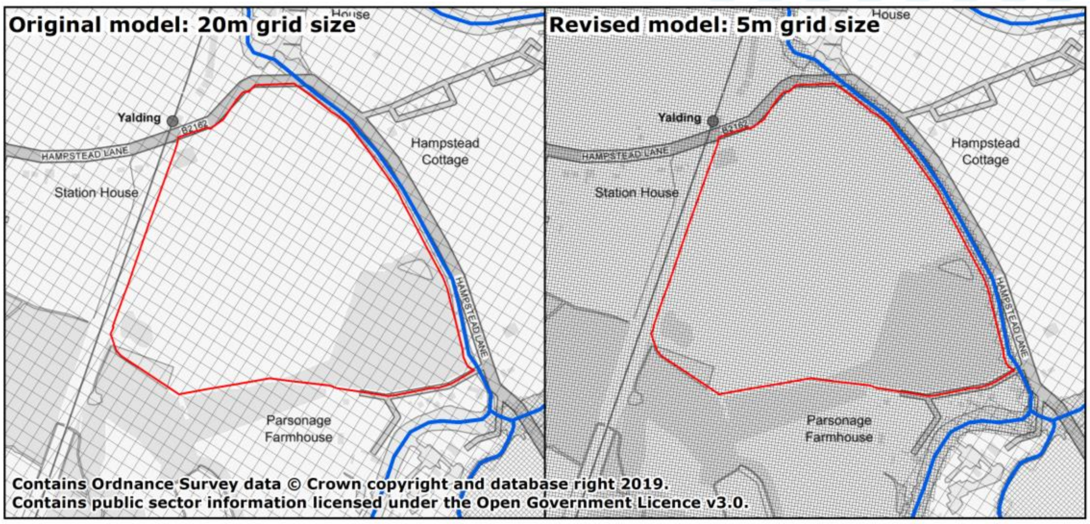


Figure 2-2: Change in grid size and the site area (red)

2.3 Implementation of a new output zone 'YEP_001'

While the flood flow input hydrology remained as per the existing output zone 3 (refer to Figure 1-1), a new output zone named 'YEP_001' was assigned to the model so that flood predictions were exported on the floodplain for this area, in addition to the existing output zone 3. The extent of output zone YEP_001 is the same as output zone 3, but extended to the A228 to the west so that, in addition to the site, assessment of model predictions could include the land between the A228 and railway line.

2.4 Updates to the 1D model

Relatively minor updates were made to the 1D Flood Modeller model of the River Medway. These changes are summarised below.

- All event magnitudes included modelling of the Coult Stream channel. Previously this was removed for the 1% AEP +35% flows modelling for stability reasons. The other model refinements, including reduction in timestep improved stability and enabled its inclusion into the model.
- Adjustments were made to sections close to Domain 5 where reversals in conveyance were identified in the section property plots and/or adjusting the width of the sections was deemed beneficial to better represent the channel width in the context of the new Domain 5 linkage. This was completed at the following:
    - CS152, CS154, CS162, CS169, S4.002u/S4.002bu/S4.002su/S4.002d, CST8U, CST9D, CST10

Other adjustments between Flood Modeller Data files made during the original flood mapping study for stability reasons in events larger than the 1% AEP were retained. This primarily involved widening of existing Flood Modeller River Sections, so these extended further into the floodplain.

2.5 Implementation of updated ground levels in Domain 5

Updates were made to ground levels within Domain 5. These updates involved two stages:

1. Incorporating UAV survey data.
2. Updating elevations of existing LIDAR data.

UAV survey, collected by Grid Point Holdings Ltd was applied to the model in the region displayed in Figure 2-3.

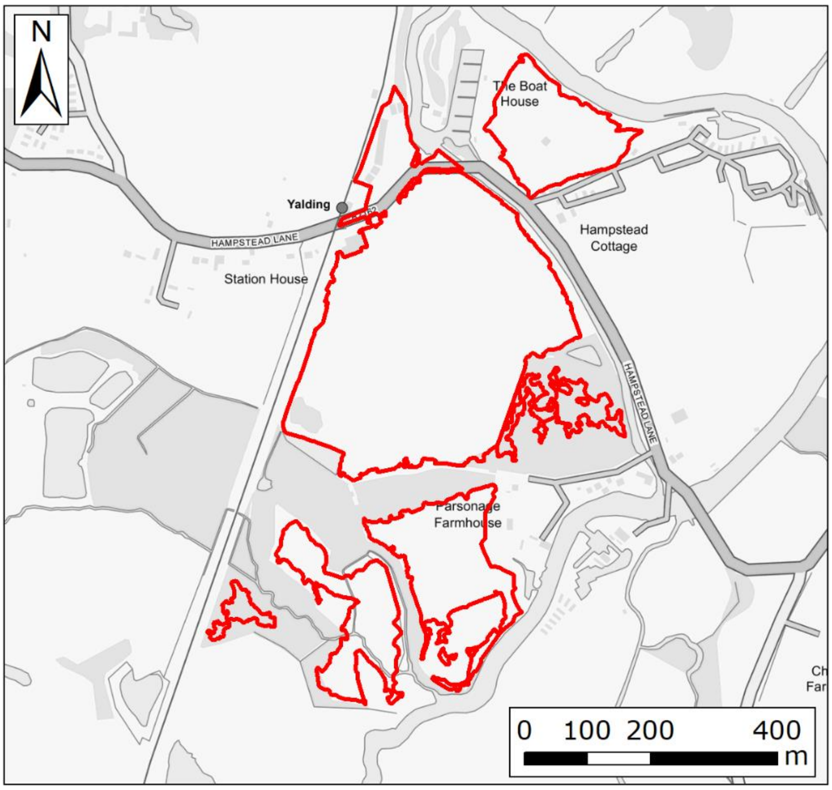


Figure 2-3: Areas of Domains 3 and 5 within elevations informed by the UAV DTM

This survey represents the most reliable record of ground levels on the site. The UAV data was updated in the region displayed as no vegetation is recorded here, so the UAV survey elevations represent the bare earth DTM levels (where vegetation is present a bare earth DTM is not recorded, but instead the UAV survey deliverables interpolate elevations from neighbouring areas which may not be representative).

When the ground control points collected by Grid Point Holdings Ltd (to calibrate their UAV survey DEM) were compared with elevations in the existing LIDAR data, it became apparent that the LIDAR data was typically lower across the area. Figure 2-4 displays the difference in elevation between the LIDAR and UAV survey DTM across the UAV survey area. A consistent difference is present (expect for where features such as the lagoon embankments have vegetation) and comparison of the control points versus LIDAR data revealed an average difference of -0.07m (LIDAR is 0.07m lower on average). This is within typical tolerances stated for LIDAR, but given the apparent difference it was deemed appropriate for Domain 5 to globally adjust the LIDAR elevations, so that any areas of floodplain not covered by the UAV DTM would be corrected accordingly. Changes were not made to LIDAR elevations in other model domains, given ground control information is not available to validate whether adjustments were needed.

The model was simulated for each of the 5%, 1% and 1% (+35% flows) AEP events with updated Domain 5 ground levels and the change in peak flood levels assessed compared with the model configuration prior to updating the ground levels. Changes in peak water levels are more marked between the A228 and railway line rising from +0.02m change in the 5% AEP event to up to +0.06m changes in the 1% AEP +35% flows event. East of the railway line changes in flood depth vary by no more than ±0.01m. Conceptually this seems sensible, given that land between the A228 and railway line is constrained and so increased ground levels are more likely to result in a larger increase in water levels. East of the railway, flood water can flow more freely to the east and north, so changes are less notable.

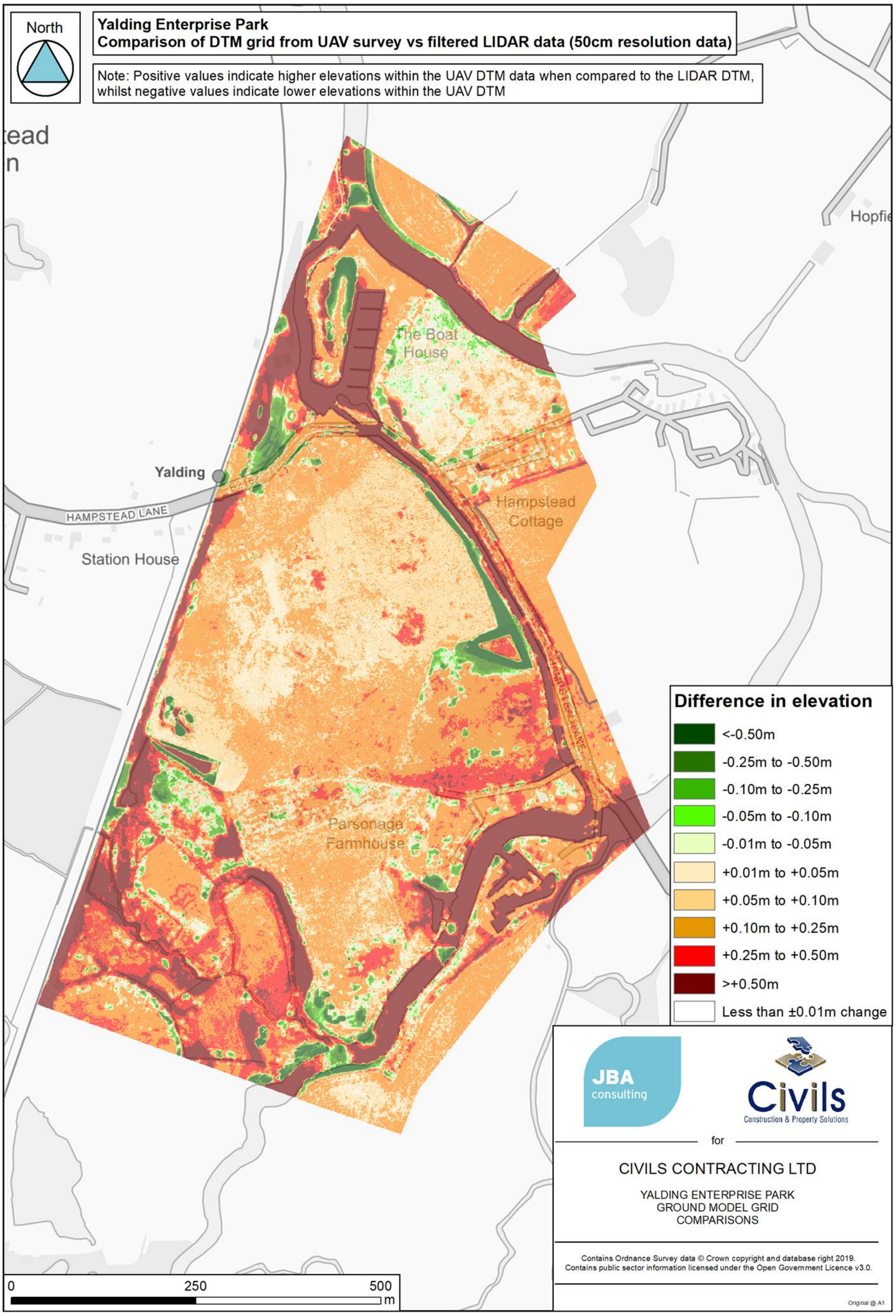


Figure 2-4: Difference in elevation between the UAV DTM and LIDAR data

Positive [beige to red colours] values indicate the UAV DTM elevations are greater than the LIDAR data

3 Planning baseline modelling

The topography of the site, as built prior to demolition of the majority of the buildings on site to allow for remediation of site soils, is informed by topographic survey points, building outlines and slab levels stamped on top of the adjusted LIDAR ground levels. The topographic survey was collected in October 2005 by Capita Symonds to inform the remediation works. The updates to the site levels as informed by the 2005 topographic survey are constrained to the proposed development site survey. Elsewhere the modelled elevations remain as described in section 2.5. Figure **3-1** provides an indication of the spatial extent of the topographic survey, which is provided in full in Appendix B.

The topographic adjustments are made via the application of Z-Shape features as recorded in Table 5-3. The final model grid is displayed in Figure 7-1.

Buildings were extensive across the former site layout. The slab levels are enforced into the model grid, and the presence of buildings is further represented by applying a Manning's n roughness coefficient of 0.3. This approach is consistent with the approach adopted for buildings elsewhere within the original flood risk mapping model. The approach allows flood water to flow through the model cells in the building footprints, but the increased hydraulic roughness reduces the efficiency of the flow.

Although this is a typical approach to representing the presence of buildings in models, it is likely that this may underestimate the obstruction that the presence of the former buildings had on flood flows, given the size, construction and contents of the buildings. Increased obstruction to flood flows could be achieved in the modelling by increasing the hydraulic roughness value further, or applying flow constrictions to the model cells. For the modelling submitted as part of the FRA, the existing approach has been retained, meaning the increase in flood risk brought about by the planning baseline scenario is lower than might otherwise be expected. Testing of alternative scenarios during model development supported this (25% and 75% flow constrictions applied to model cells at buildings), as it revealed increased flood levels compared to the n=0.3 approach.

Figure 3-1: Overview of the October 2005 topographic survey

4 Development scenario modelling

The proposed development configuration has been informed from proposed site drawings, reference SK01E (refer to Appendix D).

The levels of the flood conveyance route, roads, ramps, forecourts and adjustments to remove the presence of the lagoons from model grid are applied as Z-Shapes input into the TUFLOW geometry file. Refer to Figure 1-3 for an overview of site levels and Table 5-3 for details of these features and others described below. Figure 7-2 displays the final model ground levels at the site.

Layered flow constriction files are used to represent the flow constriction brought about by the buildings and the bridge crossing the flood conveyance route.

- For the buildings:
  - Based ground levels remain unadjusted.
  - Layer 1 (representing the void space under the buildings): A 6% loss in cell width is applied to represent the presence of walls, columns etc. A soffit level of 13.4mAOD is assigned, above the 1% AEP +35% flows flood level. A form loss of 0.1 is applied, meaning each 5m cell has a total form loss of 0.5 applied.
  - Layer 2 (representing the building between the void soffit and the building flood level): This layer is 0.3m thick (top level of 13.7mAOD) and is set to 100% blocked.
  - Layer 3 (representing the building): This layer is set to 10m high. The bottom level of 13.7mAOD is above the maximum water level, so does not interact with the flood water.
- For the bridge:
  - Base ground levels remain unadjusted.
  - Layer 1 (representing the bridge opening): No loss in cell width is assigned. A form loss of 0.2 is applied, meaning each 5m cell has a total form loss of 1.0 applied. A soffit level of 11.2mAOD is assigned.
  - Layer 2 (representing the bridge deck): This layer is 0.5m thick (top level of 11.7mAOD representing the road level) and is set to 100% blocked, representing an assumed thickness of the deck.
  - Layer 3 (representing the railings above the bridge): This layer is 1.4m thick (top of railings at 13.1mAOD) and is set to 10% blocked, representing the presence of assumed railings. A form loss of 0.2 is applied, meaning each 5m cell has a total form loss of 1.0 applied.
  - Layer 4 (above the railings): Above this level the flow is unimpeded.

A storage reduction factor layer is used to represent the small change in floodplain volume in the void space under buildings as a result of the presence of columns, pillars, walls etc. A 6% loss in volume is assigned.

The two mill chamber connections to the mill race are represented by SPILL units connected to the pond/basin at the downstream of the flood conveyance route via SX links. They connect into the River Medway downstream of Hampstead Lock. Each has a width of 3.77m, representing the circumference of each 1.2m diameter inlet. A weir coefficient of 1.1 is applied

ESTRY 1D bridge units are used to represent the five arches under Hampstead Lane which connect to the floodplain immediately to the north (refer to Appendix C.1 for photos). For each the distance between the springing level and soffit level of the arch is assumed to be 0.3m. Again, these are connected via SX links, either side of Hampstead Lane.

5 Model input and control files

5.1 Flood Modeller input and control files

A summary of the Flood Modeller input and control files relevant to the planning baseline and proposed development scenario models is presented within Table 5-2 with a summary provided of whether changes have been made from the original 2015 study[1] files.

Table 5-1: Summary of Flood Modeller input and control files

File	File name	AEP (%)	Comment
IEF	M3_146_YEP_Def_0020_16Oct2356_Extant_Planning M3_146_YEP_Def_0100_10Jan1924_Extant_Planning M3_146_YEP_Def_0100plus35pc_10Jan1924_Extant_Planning	5 1 1 (+35% flows)	Planning baseline
	M3_150_YEP_Def_0020_16Oct2356_Site_Layout3_Voids M3_150_YEP_Def_0100_10Jan1924_Site_Layout3_Voids M3_150_YEP_Def_0100plus35pc_10Jan1924_Site_Layout3_Voids	5 1 1 (+35% flows)	Proposed development
DAT	Medway_Model3_124b Medway_Model3_124c_006ext	5% and 1% AEP 1% AEP (+35%)	Planning baseline Two versions of the model were retained from the original flood risk mapping studies. For events larger than the 1% AEP, an alternative model with some stability adjustments was used.
	Medway_Model3_125b Medway_Model3_125c_006ext	5% and 1% AEP 1% AEP (+35%)	Proposed development This model includes orifice units representing the two inlets to the Mill Race channel Two versions of the model were retained from the original flood risk mapping studies. For events larger than the 1% AEP, an alternative model with some stability adjustments was used.
IED	**1.** 0020\16Oct23562100 **2.** 0100\10Jan19241100 **3.** 0100plus35pc\10Jan19241100	5 1 1 (+35% flows)	Used for both the planning baseline and proposed development modelling

5.2 TUFLOW control files

A summary of the TUFLOW control files relevant to the planning baseline and proposed development scenario models is presented within Table 5-2 with a summary provided of whether changes have been made from the original 2015 study file.

Table 5-2: Summary of TUFLOW control files

Domain	Control file	File name	Comment
-	TCF	M3_146_YEP_~e~_ Extant_Planning M3_150_YEP_~e~_ Site_Layout3_Voids	Planning baseline Proposed development
-	ECF	M3_104 M3_108_YEP_ Site_Layout3	Planning baseline (unadjusted) Proposed development
1	TGC	Medway_Model3_ Domain1_004_ext	Unchanged from the original flood risk mapping model
	TBC	Medway_Model3_ Domain1_004	Unchanged from the original flood risk mapping model
2	TGC	M3_D2_107c_ext	Updated Changes made reflect the adjustment of geometry files where these are now represented in Domain 5
	TBC	M3_D2_111b	Updated Changes made reflect the adjustment of boundary condition where these are now represented in Domain 5
3	TGC	M3_D3_107c_ext_ YEP_UAV_DTM	Updated Changes made reflect the adjustment of geometry files where these are now represented in Domain 5
	TBC	M3_D3_110c	Updated Changes made reflect the adjustment of boundary condition where these are now represented in Domain 5
4	TGC	Medway_Model3_ Domain4_007_ext	Unchanged from the original flood risk mapping model
	TBC	Medway_Model3_ Domain4_009b_ext	Unchanged from the original flood risk mapping model
5 (new)	TGC	M3_D5_123_YEP_ Extant_Planning M3_D5_130_YEP_ Site_Layout3_Voids	Planning baseline Proposed development
	TBC	M3_D5_103 M3_D5_106_YEP_ Site_Layout3	Planning baseline Proposed development

5.3 TUFLOW geometry files

A summary of the TUFLOW geometry input files relevant to the planning baseline and proposed development scenario models is presented within Table 5-3, with a summary provided of each.

Table 5-3: Adjusted or new TUFLOW geometry input files

Domain	File name	Comment
2	2d_code_deactivate_ Model3_Domain2_003d_R	Adjusted from version 003c to include the deactivation area for Coult Stream now included in all DAT files used to model the 1D domain
3	2d_code_activate_ Model3_Domain3_103b_R	Adjusted from version 003b
	Q1997_Yalding_DTM_020.asc | Q1997_Yalding_DTM_020_mask_ Domain3_102_R.shp	Reading in the UAV DTM for a small area of the domain east of Hampstead Lock
	2d_zln_roads_railways_raised_ Model3_Domain3_101_L | 2d_zln_roads_railways_raised_ Model3_Domain3_DTM_101_P | 2d_zln_roads_railways_raised_ Model3_Domain3_DSM_101_P	Updated from versions 001 to reflect the reduced extent of Domain 3, where Domain 5 has been implemented
	2d_zln_banks_Model3_ Domain3_103_L | 2d_zln_banks_Model3_ Domain3_DTM_103_P | 2d_zln_banks_Model3_ Domain3_DSM_103_P	Updated from versions 003 to reflect the reduced extent of Domain 3, where Domain 5 has been implemented
	2d_zln_floodplain_culverts_ Model3_Domain3_001_L	Removed The culverts that these adjustments related to are now located in Domain 5
5	**Files for both planning baseline and proposed development models**	
	2d_loc_Model3_ Domain5_101_L	Defining the start point and orientation of the grid
	2d_code_activate_Model3_ Domain5_101_R	Activates model cells
	2d_code_deactivate_Model3_ Domain5_101_R	Deactivates model cells (where represented in the Flood Modeller model)
	LIDAR_filtered_Medway_ Model3_2m.asc LIDAR_filtered_Medway_ Model3_1m.asc LIDAR_filtered_Medway_ Model3_50cm_A.asc LIDAR_filtered_Medway_ Model3_50cm_B.asc LIDAR_filtered_Medway_ Model3_50cm_C.asc LIDAR_filtered_Medway_ Model3_25cm_A.asc LIDAR_filtered_Medway_ Model3_25cm_B.asc LIDAR_DTM_25cm_2010_v2.asc	LIDAR data layers for the site. As implemented within the 2015 mapping model for Domain 3
	2d_zln_roads_railways_raised_ Model3_Domain5_102_L | 2d_zln_roads_railways_raised_ Model3_Domain5_DTM_102_P	Elevations of roads and railways, informed by LIDAR data. Information extracted from the trimmed extent of Domain 3
5	2d_zln_banks_Model3_ Domain5_101_L | 2d_zln_banks_Model3_ Domain5_DTM_101_P |	Elevations of banks, informed by LIDAR data. Information extracted from the trimmed extent of Domain 3

Domain	File name	Comment
	2d_zln_banks_Model3_ Domain5_DSM_101_P	
	2d_zsh_LIDAR_adjust_ Model3_Domain5_104_R	Global +0.07m adjustment to the base LIDAR elevations, informed by the average difference in elevation between LIDAR and the ground control points collected as part of the Grid Point Holdings Ltd UAV survey
	2d_zln_floodplain_culverts_ Model3_Domain5_103_L	Elevations of the approach to floodplain culvert, informed by LIDAR data. Information extracted from the trimmed extent of Domain 3
	Q1997_Yalding_DTM_020.asc | Q1997_Yalding_DTM_020_mask_ Domain5_102_R	Reading in the UAV DTM for parts of the site where vegetation is not present and the elevations are more representative
	2d_zln_Hampstead_Lane_Model3_ Domain5_102_L | 2d_zln_Hampstead_Lane_Model3_ Domain5_102_P	Crest level data for Hampstead Lane extracted from the UAV survey data. This was implemented where filtering issues in LIDAR data meant part of the road had been removed.
	2d_zsh_East_Bank_Restoration_ Model3_Domain5_101_R | 2d_zsh_East_Bank_Restoration_ Model3_Domain5_102_P	Region with associated points, enforcing the elevation of a bank/bund at the east of the site which was not fully captured in base model zpts due to the grid resolution and filtering issues in LIDAR
	2d_zsh_East_Bank_Restoration_ Model3_Domain5_101_L | 2d_zsh_East_Bank_Restoration_ Model3_Domain5_103_P	Line with associated points, enforcing the crest elevation of a bank/bund at the east of the site which was not fully captured in base model zpts due to the grid resolution and filtering issues in LIDAR
	2d_mat_Model3_001a_R 2d_mat_Model3_001b_R 2d_mat_Model3_001c_R 2d_mat_Model3_001d_R 2d_mat_Model3_001e_R 2d_mat_Model3_001f_R 2d_mat_Model3_001g_R	Materials files retained from the original modelling
	Files for the planning baseline model only	
	2d_zsh_Extant_Planning_Topo_ 2210_30_Model3_Domain5_104_R | 2d_zsh_Extant_Planning_Topo_ 2210_30_Model3_Domain5_103_L | 2d_zsh_Extant_Planning_Topo_ 2210_30_Model3_Domain5_103_P	October 2005 topographic survey data implemented to inform ground levels
5	2d_zsh_Extant_Building_Topo_ 2210_30_Model3_Domain5_101_R | 2d_zsh_Extant_Building_Topo_ 2210_30_Model3_Domain5_101_P	October 2005 topographic survey data implemented to inform the building threshold levels
	2d_zsh_Extant_Lagoon_Topo_ 2210_30_Model3_Domain5_101_L | 2d_zsh_Extant_Lagoon_Topo_	October 2005 topographic survey data implemented to inform the lagoon crest and invert levels

Domain	File name	Comment
	2210_30_Model3_Domain5_101_P	
	2d_mat_Extant_Buildings_Topo_ 2210_30_Model3_Domain5_101_R	Material file for buildings on the site, retaining n=0.3 as per the 2015 mapping study approach
	Files for the proposed development model only	
	2d_zsh_YEP_PondFill_201_R | 2d_zsh_YEP_PondFill_202_P	Z-shape file to raise the elevation of lagoons on current site (captured in LIDAR/UAV data) to the proposed site level
	2d_zsh_YEP_ GroundAdjustments_201_R | 2d_zsh_YEP_ GroundAdjustments_201_P	Removing a high point in the current ground level (captured in LIDAR/UAV) that would be lowered as part of the development
	2d_zsh_YEP_SiteLevel_302_R	Implementing the typical 11.7mAOD level of areas. Refer to Figure 1-3 for details.
	2d_zsh_YEP_Ramp_302_R | 2d_zsh_YEP_Ramp_302_P	Implementing the ramp areas, rising from 11.7mAOD to 13.35mAOD. Refer to Figure 1-3 for details.
	2d_zsh_YEP_RoadLevel_301_R	Implementing the raised roads with an elevation of 13.35mAOD. Refer to Figure 1-3 for details.
	2d_zsh_YEP_Forecourt_301_R | 2d_zsh_YEP_Forecourt_301_P	Implementing the forecourt areas, rising from 13.35mAOD to 13.70mAOD. Refer to Figure 1-3 for details.
	2d_lfcsh_YEP_Buildings_301_R	Layered flow constriction representing the raised buildings. Ground levels remain unadjusted. <u>Layer 1</u> A 6% loss in cell width is applied to layer 1 (soffit of 13.4mAOD, above the 1% AEP +35% flows flood level), reflecting the void space under the buildings, but the presence of walls, columns etc. A form loss of 0.1 is applied, meaning each 5m cell has a total form loss of 0.5 applied. <u>Layer 2</u> This layer is 0.3m thick and is set to 100% blocked, representing the supports above the void. <u>Layer 3</u> Representing the building, is set to 10m high. The layer is raised above the maximum flood level so does not interact with the flood water.
5	2d_zsh_YEP_FCR_106_R | 2d_zsh_YEP_FCR_106_L | 2d_zsh_YEP_FCR_109_P	Indicative geometry of the proposed flood conveyance route. The inlet level is set below the 20% AEP flood level and linearly sloped northwards to the invert level of the pond/basin at the north of the site.

Domain	File name	Comment
	2d_lfcsh_YEP_FCR_Bridge_201_R	Layered flow constriction representing the raised buildings. Layer 1 Representing the bridge opening. Ground levels as per the flood conveyance route channel. A form loss of 0.2 is applied, meaning each 5m cell has a total form loss of 1.0 applied. Soffit level of 11.2mAOD. Layer 2 Representing the bridge deck. This layer is 0.5m thick and is set to 100% blocked, representing the thickness of the deck. Layer 3 Representing the railings above the bridge This layer is 1.4m thick and is set to 10% blocked, representing the presence of railings. A form loss of 0.2 is applied, meaning each 5m cell has a total form loss of 1.0 applied. Soffit level of 11.2mAOD. Above this level, flow is unimpeded.
	2d_SRF_YEP_Buildings_6pc_301_R	Storage reduction factor of 6% applied to model cells at buildings, reflecting the presence of walls, columns etc in the void space under the buildings
	2d_mat_YEP_Model3_FCR_201_R 2d_mat_YEP_Model3_Forecourt_301_R 2d_mat_YEP_Model3_SiteLevel_301_R 2d_mat_YEP_Model3_RoadLevel_301_R 2d_mat_YEP_Model3_Ramp_301_R 2d_mat_YEP_Model3_Buildings_302_R	Materials files for the various land cover classes at the site, retaining materials codes that align with the 2015 mapping study model.

5.4 TUFLOW boundary condition files

A summary of the TUFLOW geometry input files relevant to the planning baseline and proposed development scenario models is presented within Table 5-3, with a summary provided of each.

Table 5-4: Adjusted or new TUFLOW boundary input files

Domain	File name	Comment
2	2d_bc_hxi_Model3_ Domain2_007b_L	Re-instated the HX connections along Coult Stream (compared with previous file '007c'), where previously this had been removed for events larger than the 1% AEP
	2d_bc_2d_Model3_ Domain2_Domain3_101_L	Updated 2D-2D connections reflecting the reduction in size of Domain 3.
	2d_bc_2d_Model3_ Domain2_Domain5_102_L	Updated 2D-2D connections reflecting the inclusion of Domain 5.
3	2d_bc_hxi_Model3_ Domain3_109c_L	Updated 1D-2D HX connections reflecting the reduction in size of Domain 3.
	2d_bc_SX_floodplain_ structures_Domain3_103_L	Updated 1D-2D SX connections reflecting the reduction in size of Domain 3.
	2d_bc_2d_Model3_ Domain2_Domain3_101_L	Updated 2D-2D connections reflecting the reduction in size of Domain 3.
	2d_bc_2d_Model3_ Domain3_Domain5_101_L	Updated 2D-2D connections reflecting the inclusion of Domain 5.
5	2d_bc_hxi_Model3_ Domain5_101_L	1D-2D HX connections for Domain 5, taken from the removed area of Domain 3.
	2d_bc_SX_floodplain_ structures_Domain5_103_L	Updated 1D-2D SX connections where structure connect to Domain 5.
	2d_bc_2d_Model3_ Domain2_Domain5_102_L	2D-2D connections for Domain 5 connecting to Domain 2.
	2d_bc_2d_Model3_ Domain3_Domain5_101_L	2D-2D connections for Domain 5 connecting to Domain 3.

6 Model convergence and stability

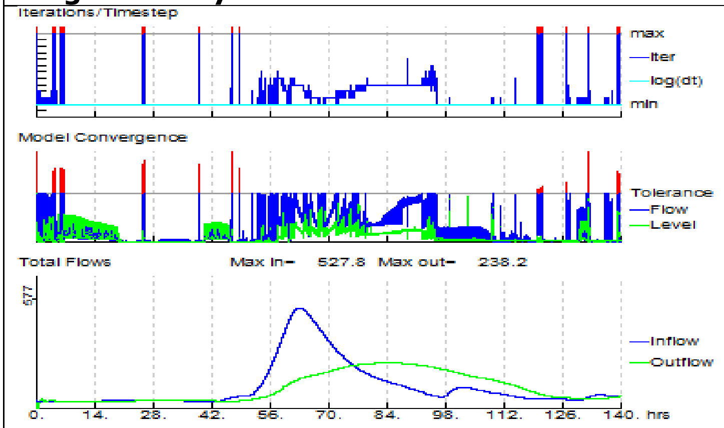
6.1 Flood Modeller convergence

Flood Modeller convergence plots are provided below for the 5%, 1% and 1% (+35% flows) AEP events in Table 6-1, Table 6-2 and Table 6-3, respectively. Plots are presented for the original mapping study modelling, as well as the planning baseline and proposed development scenarios. There is little change in the model convergence across the scenarios, with improvements evidenced for the 1% AEP modelling prepared for this study – which is likely to be attributable to the reduced timesteps used.

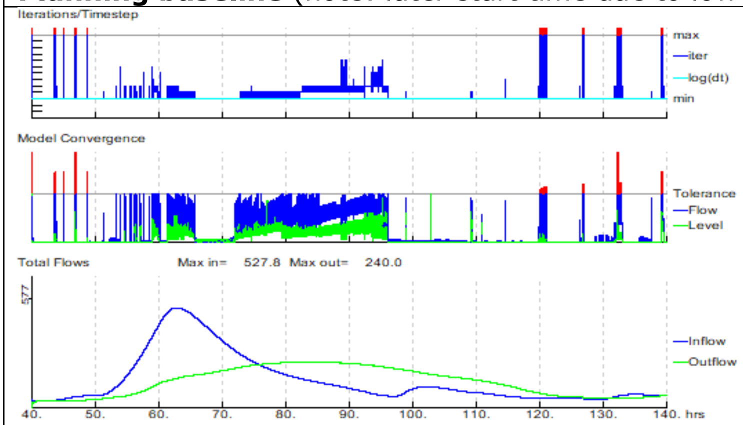
Table 6-1: Flood Modeller convergence plots for the 5% AEP event simulations

5% AEP

Original study model



Planning baseline (note: later start time due to low flows <40hrs)



Proposed development (note: later start time due to low flows <40hrs)

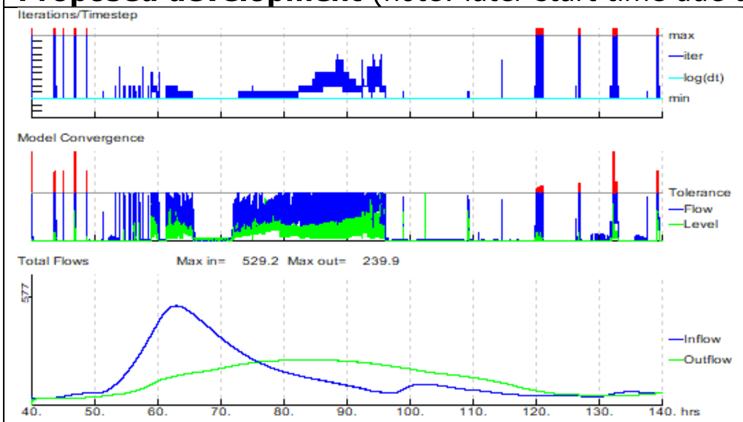
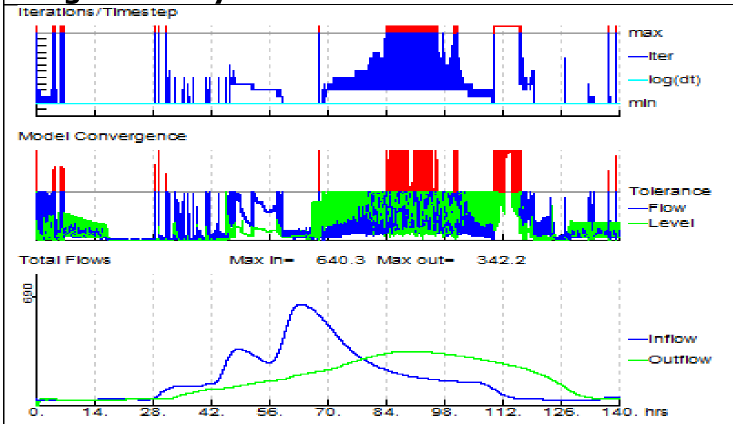


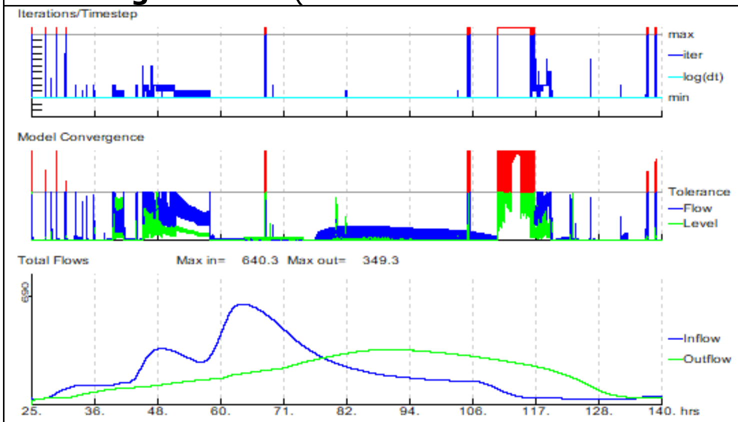
Table 6-2: Flood Modeller convergence plots for the 1% AEP event simulations

1% AEP

Original study model



Planning baseline (note: later start time due to low flows <25hrs)



Proposed development (note: later start time due to low flows <25hrs)

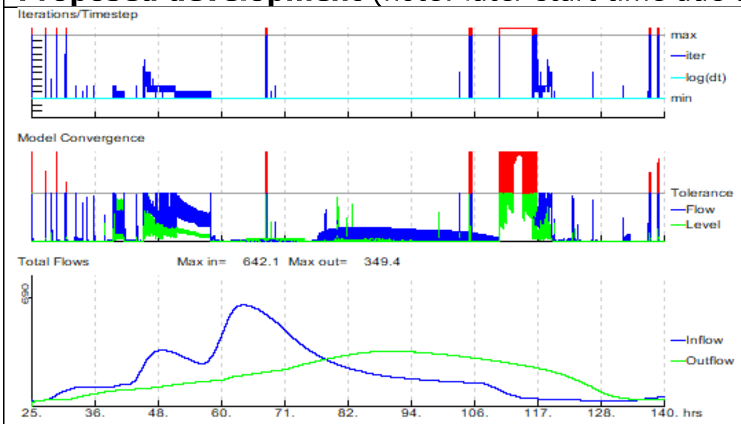
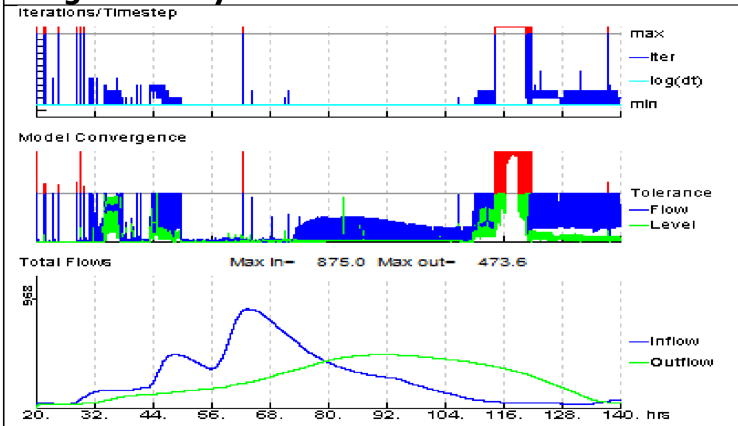
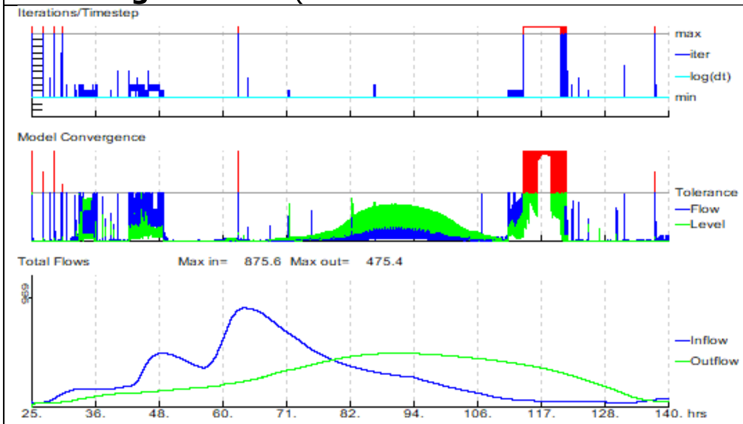
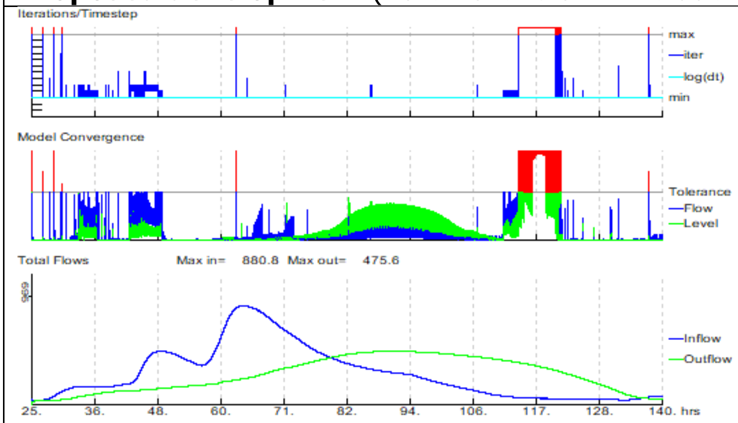


Table 6-3: Flood Modeller convergence plots for the 1% (+35% flows) AEP event simulations

1% AEP +35% flows
Original study model

Planning baseline (note: later start time due to low flows <25hrs)

Proposed development (note: later start time due to low flows <25hrs)


6.2 TUFLOW stability and mass balance

6.2.1 Difference in volume (dVol)

The change in volume model-wide, and when assessed just for the new Domain 5, shows a relatively smooth transition in flows, reflecting the rising limb of the inflows to the model and subsequent drainage of the floodplain during the recession limb. This indicates a stable model.

6.2.2 Cumulative mass error (Cum ME)

Final mass error for all simulations is very close to zero (±0.1%), well within the ±1% typically stated as acceptable for a fluvial flood risk model.

Model-wide (all domains) mass error across the full duration of simulations for the three scenarios is very similar for all events. This is expected given that the changes made to the model are within a relatively small spatial extent. All models start with an initial negative mass error (slightly beyond the typical 1% guidance value), when a small number of model cells are wetting, but the mass error is very close to zero at the time of peak flooding. The initial negative mass error is not cause for concern.

Within the new Domain 5, mass error is similar between the planning baseline and development scenario models for their respective AEP events. Again, in each case, an initial spike in mass error is predicted (slightly beyond the typical 1% guidance value), when a small number of model cells are wetting, but the mass error is very close to zero at the time of peak flooding. The initial negative mass error is not cause for concern.

6.2.3 Messages layer and negative depths

Messages that appear as part of the TUFLOW log reporting are those present in the original mapping study, and none are considered of concern for this modelling. No negative depths are recorded, indicating that the model is stable.

7 Sensibility checking of model setup and predictions

7.1 Ground levels on the site

Ground levels on the site as applied within the model were checked by inspecting the DEM_Z.flt file produced by TUFLOW for both the planning baseline and proposed development scenarios. These are displayed for the two scenarios in Figure 7-1 and Figure 7-2, respectively. Ground level adjustments across the site are as expected and representative of each condition being tested.

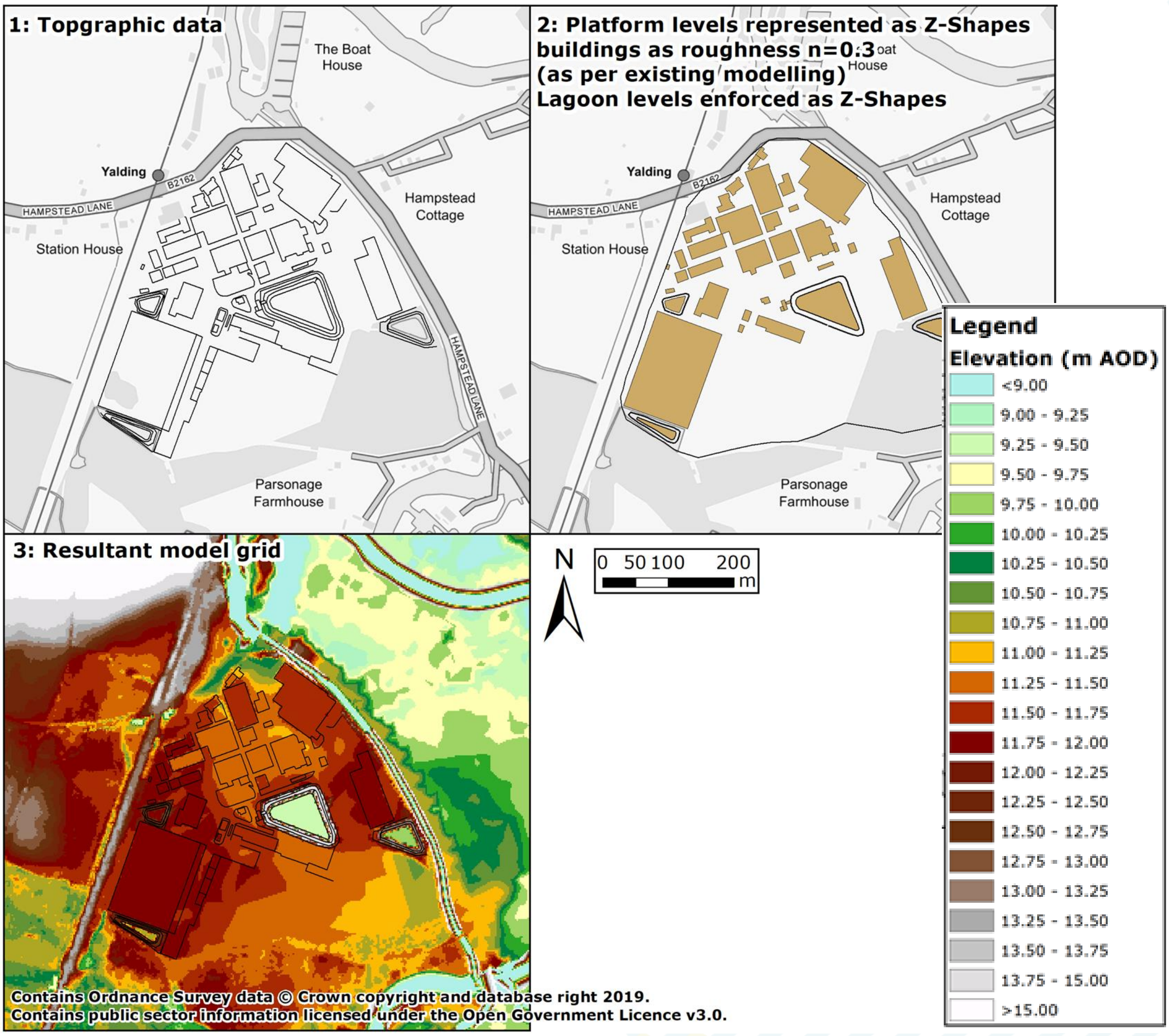


Figure 7-1: Planning baseline model grid and overview of topographic input files

Figure 7-2: Proposed development model grid and overview of topographic input files

7.2 Changes in flood extents and peak water levels

Changes in predicted flood extents and peak water levels between the planning baseline and proposed development site were made to sensibility check model predictions. These are presented in Appendix E. While the FRA document reports on what the changes mean from a planning context, this section reports on whether the changes observed are expected, given the model adjustments made.

The main findings of the comparison can be summarised as follows:

- Changes in flood extent are minor for the events tested
- For smaller magnitude events (e.g. the 5% AEP), peak water levels reduce south of the site, including towards Yalding to a greater magnitude than for larger events (e.g. the 1% AEP). For the 5% AEP event peak water levels south of the site reduce by up to 0.04m, reducing by up to 0.01m at Yalding village. The differences are closer to 0.002m for the 1% AEP event
- For the largest event tested, there is essentially a 'no change' position – with water levels changing by less than 0.001m

Conceptually, these changes are sensible. For the planning baseline scenario, no flood water flowed northwards across the full extent of the site, due to raised ground levels. The inclusion of the flood conveyance route facilitates the flow of flood water, reducing peak water levels to the south, meaning lower flow rates flow via the River Medway channel to the east (close to Yalding village). As flow rates increase (event magnitude increases), flood flows across the site were predicted in the planning baseline and, the conveyance measures implemented on site for the development scenario become less influential, hence changes in flood levels are less marked.

The predictions noted above agrees with the assessment of flood flows passing across the site, as described in section 7.3.

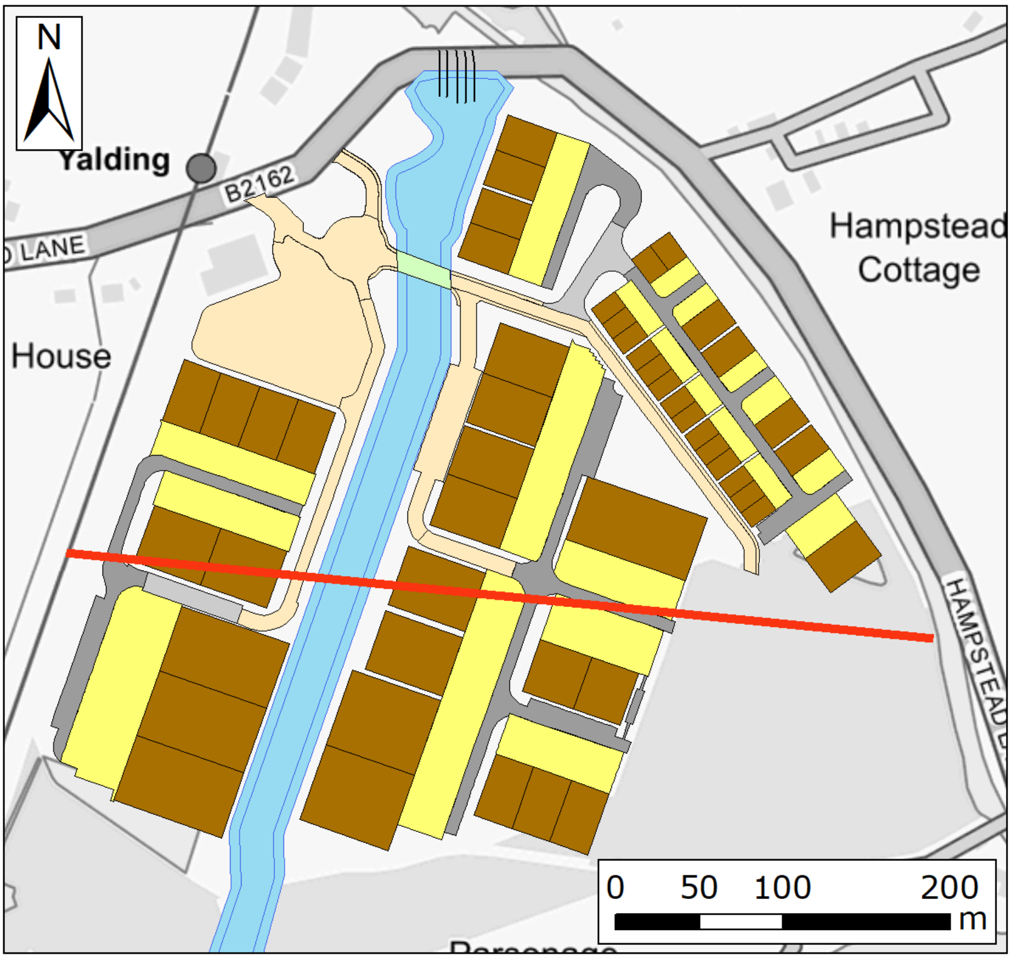
7.3 Flow across the site

Flood flow rates passing across the site were compared for each magnitude flood event between the planning baseline and development scenario models. Changes in flow across the site links with the change in flood levels explained in section 7.1.

For the 5% AEP event, very limited flow moves northwards across the site in the planning baseline scenario (and no flow extends across the whole area). Therefore, for the proposed development scenario, a notable increase in flow (up to $6m^3/s$) flows northwards via the flood conveyance route, which explains the reduction in peak flood levels to the south. A flow of $6m^3/s$ represents circa 3% of the total flow in the River Medway downstream of Yalding (approx. $230m^3/s$), and is the reason behind the modest reduction in peak water levels.

For the 1% AEP event, flow is predicted across the site in the planning baseline scenario, with an increase of up to $7m^3/s$ predicted in the proposed development scenario. A flow of $7m^3/s$ represents circa 2% of the total flow in the River Medway downstream of Yalding (approx. $340m^3/s$), and is the reason behind the smaller reduction in peak water levels predicted for this event.

For the 1% AEP +35% flows event, there is little difference in flows across the site at the peak of the event (but reductions are seen at lower flows during the event), evidencing that the capacity of the conveyance measures has been reached and a 'no change' scenario for predicted flooding is apparent.



Contains Ordnance Survey data © Crown copyright and database right 2019.

Figure 7-3: Transect (displayed in red) where flow at the site has been extracted

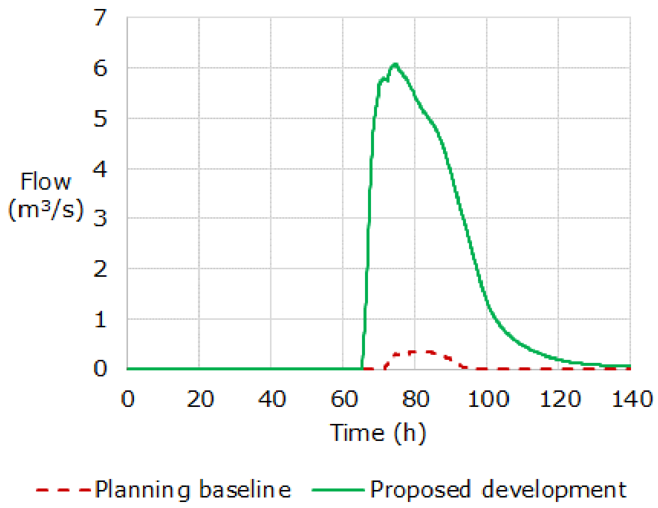


Figure 7-4: Flow across the site in the 5% AEP scenarios

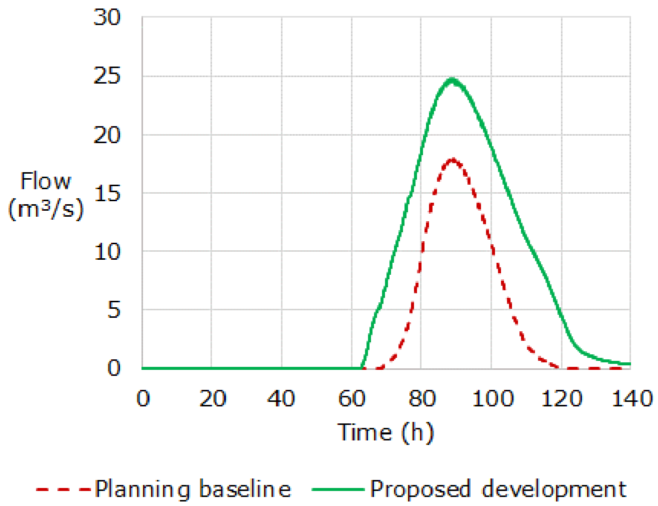


Figure 7-5: Flow across the site in the 1% AEP scenarios

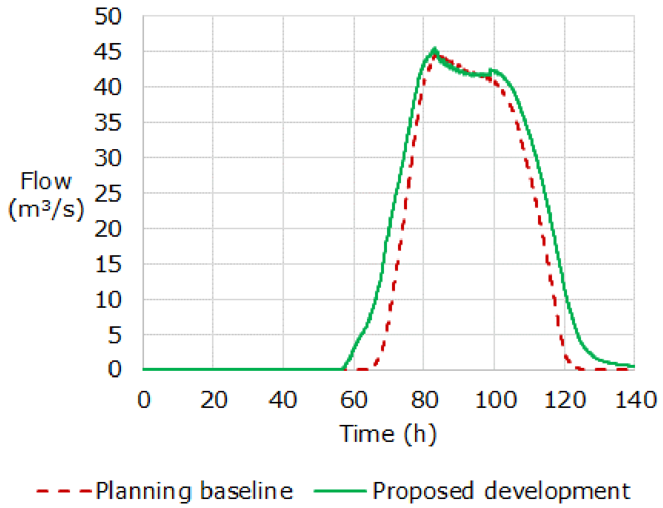


Figure 7-6: Flow across the site in the 1% AEP +35% flows scenarios

7.4 Flow through structures under Hampstead Lane

Flows through the five arches under Hampstead Lane are predicted for each of the events tested, given flows are directed via the flood conveyance route. The culverts were not represented in the Environment Agency's flood risk mapping model. Their presence was not known during the mapping model development, and given that they are currently closed by bricks, these would not have been included as flow routes in the model.

Some culverts display oscillations in flows through the culvert at the onset of wetting/drying, which is not cause for concern. Culvert 4 oscillates for the duration of flow in the 5% AEP event. While this should be resolved as part of more detailed modelling (e.g. for detailed design stage), it does not impact the overall findings of the 5% AEP event modelling. This oscillation is thought to be linked to the apparent re-circulation of flood water predicted principally via culvert 5, which is influenced by local ground levels. The low head difference across the road leads to negligible flow passing through the culverts at the peak of the 1% AEP and 1% AEP (+35% flows) events

Flows through the two SPILL units used to represent the inlets to the chambers which pass flow under Hampstead Lane via the mill race follow the expected pattern and are influenced by the water levels both south and north of the road (which influences the head of water available). Peak flow rates in each event range between 2.6m^3/s and 3.0m^3/s. The relatively small differences across events reflects the lower water levels in the 5% AEP event (but greater head difference) and higher water levels in the 1% AEP event (but smaller head difference).

Appendices

A UAV survey data

Refer to the digital appendix accompanying this document.

B October 2005 topographic survey

Refer to the digital appendix accompanying this document.

C Details of structures under Hampstead Lane

C.1 Five arch culverts

Five arches, each 3m wide, with heights above ground level of 1.2m, 0.8m, 0.66m, 0.45m and 0.30m.

Photograph 1 of the downstream face of the culverts

Photograph 2 of the downstream face of the culverts

Photograph viewed upstream through a culvert (displaying the blockage on the upstream face)

C.2 Mill race channel/inlet structures

Details of the mill race channel structures are described and displayed below

One of the two mill race inlet chambers, 1.2m diameter

Mill race outlet, circa 3.2m wide

D Proposed site layout

Refer to the digital appendix accompanying this document.

E Comparison maps: proposed development predictions vs planning baseline

Refer to the digital appendix accompanying this document.

Note that a ±1mm 'no change' band has been applied to the mapping, which shows greater detail on changes in flood levels compared with the mapping presented in the FRA document (which displays a ±1cm 'no change' band, as agreed with the Environment Agency).

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