

CALA Homes (South Home Counties) Ltd

LAND EAST OF WESTERGATE ALDINGBOURNE

Hydraulic modelling report





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Hydraulic modelling report

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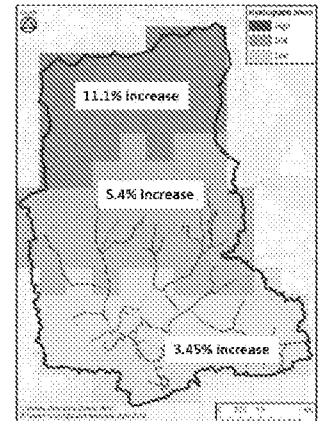
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EXECUTIVE SUMMARY

This Westergate model report provides the necessary information to effectively inform the Flood Risk Assessment for the Land East of Westergate Aldingbourne planning application.



The Environment Agency model has been modified to a smaller cut version, primarily for modelling the more extreme climate change event, with 36% increases in flows. In addition, the latest FEH2022 rainfall has been used instead of the FEH2013.

Particular care has been taken to ensure that the results are still consistent with the larger Environment Agency model.

Sensitivity tests on key parameters have been undertaken and the results indicate that climate change will have the biggest impact in terms of flood extents and flood depths within the study area.

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C

1 INTRODUCTION

1.1 BACKGROUND

- 1.1.1. WSP has been commissioned by CALA Homes (South Home Counties) to prepare a site-specific Flood Risk Assessment (FRA) and surface water drainage strategy for the Land East of Westergate Aldingbourne, West Sussex.

1.2 PURPOSE OF THIS MODELLING REPORT

- 1.2.1. This modelling report documents the technical details of the hydraulic modelling undertaken to inform the FRA.
- 1.2.2. The basis of modelling build is the Environment Agency 2015 Infoworks Aldingbourne Model by JBA (defined for the purpose of this report as the Environment Agency model) and it is mainly focused on producing flood extents for the 1 in 100 year plus 36% (Higher estimates) increases in river flows. This is because the Environment Agency model did not produce these results as the study was completed prior to the recent government climate change allowances. Additional sensitivity test modelling has been undertaken to assess the sensitivity of other model parameters (Upper estimates of climate change with 64% increases in peak flows, partial blockage of the railway culvert, change in Manning's n, etc).

1.3 THE ENVIRONMENT AGENCY MODEL

- 1.3.1. The Environment Agency model was licensed to WSP on 13 July 2016 (2015 Infoworks Aldingbourne Model CaVID data). This is an integrated fluvial and surface water model, as its hydrology is based on direct rainfall modelling. The reason for this is that the model better estimates the hydrology than the standard FEH approach (refer to Hydrology Modelling report by JBA).
- 1.3.2. The Environment Agency model was developed as part of their Flood Mapping studies, within the Water and Environmental Management (WEM) Lot 3 framework. The model did not include any defences as there were no defences along any of the modelled watercourses. The model covers the entire Aldingbourne Rife catchment and at its downstream end, it drains to the sea at Bognor Regis (refer to Figure 1-1).
- 1.3.3. The Environment Agency model was used to produce flood extents, flood depths, flood hazard and flow velocities for a range of return period events and for the update of the Flood Map.
- 1.3.4. The model was simulated for the following events: 1 in 2 (50%), 1 in 5 (20%), 1 in 10 (10%), 1 in 20 (5%), 1 in 30 (3.3%), 1 in 50 (2%), 1 in 75 (1.3%), 1 in 100 (1%), 1 in 100 (1%) plus climate change (20% increases in flows), 1 in 200 (0.5%), 1 in 1000 (0.1%) Annual Exceedance Probability undefended scenarios.
- 1.3.5. As mentioned above, flow estimates were derived using the direct rainfall method. The hyetographs were generated using Depth-Duration-Frequency descriptors for the catchment. The rainfall losses due to infiltration were calculated in the hydraulic model. These parameters were calibrated during the model verification process.



Figure 1-1 - Aldingbourne Rife catchment

Source : Aldingbourne modelling and mapping report, JBA (v1 September 2015)

- 1.3.6. The Environment Agency model and the modelling report have been reviewed and it is concluded that this is suitable to be used as a basis from which a cut version model can be built, to inform the FRA for the Land East of Westergate Aldingbourne. The schematic of the Environment Agency model 2D domain and its main components (buildings layer, watercourses, infiltration zones, etc) is shown in Figure 1-2.

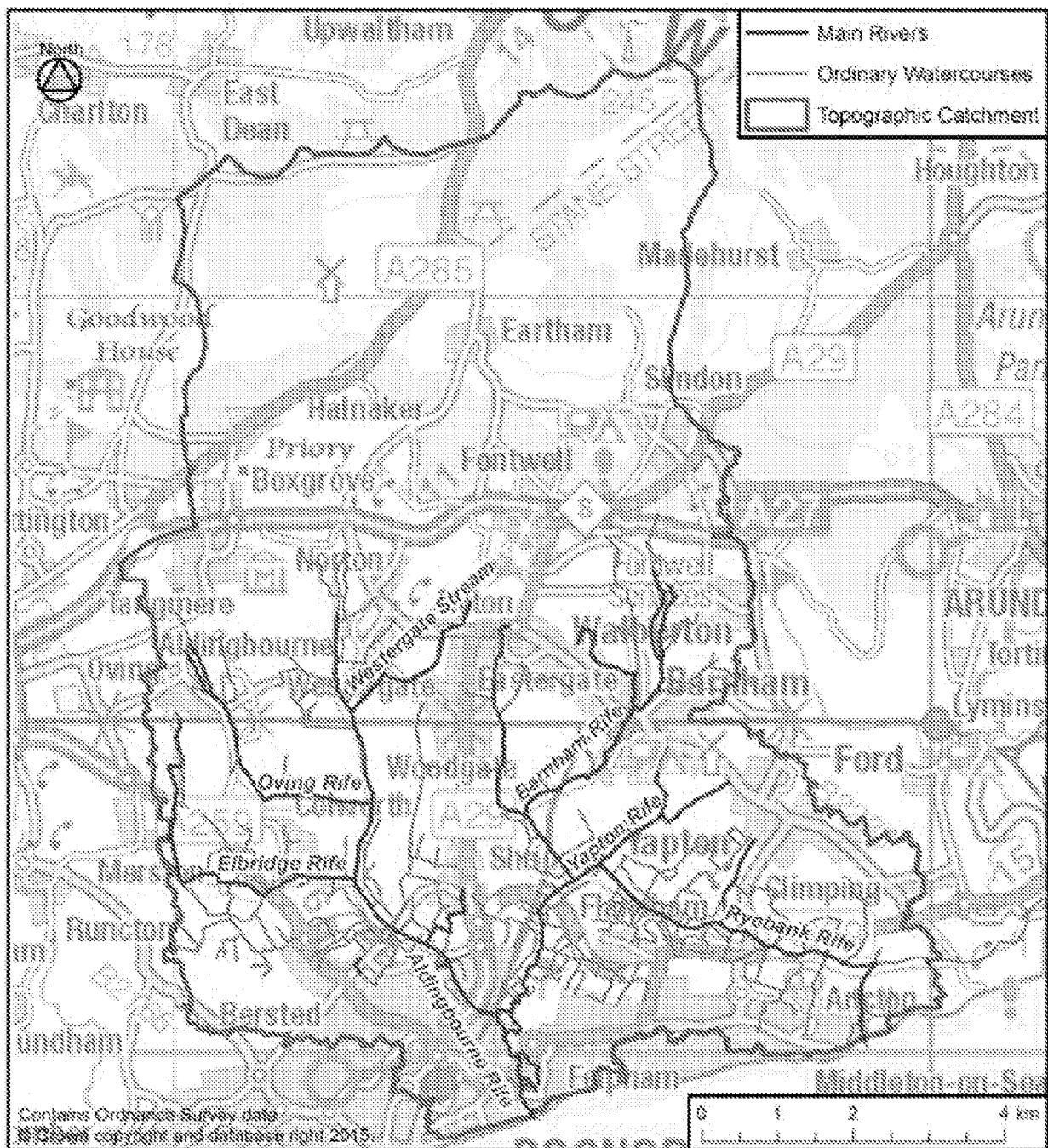


Figure 1-2 - Schematic of the Environment Agency model

2 MODIFICATIONS TO THE ENVIRONMENT AGENCY MODEL – THE WESTERGATE MODEL

2.1 SUMMARY OF OVERALL APPROACH

- 2.1.1. The Environment Agency model has been modified to a smaller cut version for the purpose of this study in order to run the more extreme climate change event, with 36% increases in flows (Higher estimates). This event uses the FEH2022 rainfall, and it is the focus of this study, as potential compensation storage and property finished floor levels are based on this model scenario.
- 2.1.2. The cut version has also been used to run the 100 year event with the new FEH2022 rainfall and for sensitivity runs. The cut version of the Environment Agency model has much faster run times and it is defined for the purpose of this report (and in the FRA document) as the Westergate model. Particular care has been taken to ensure that the results are still consistent with the larger Environment Agency model. This has been achieved by:
- keeping the same 2D domain as for the Environment Agency model to the north of Westergate, within Westergate and at a sufficient distance south of Westergate (refer to the Westergate model 2d domain in Figure 2-1);
 - the storm duration and winter rainfall profile have been maintained however the rainfall hyetographs have been increased by percentages to convert the FEH2013 to FEH2022 rainfall;
 - using the same model parameters as for the Environment Agency model; and
 - with no modifications to the watercourse layer which drains to the sea.

- 2.1.3. The following modifications have been undertaken within the Westergate model 2d domain:

- Inclusion of a refined mesh zone within the catchment area draining to Westergate (refer to blue area in Figure 2-1);
- Removal of eleven conduits and one inline bank which were far beyond the Westergate topographic catchment; this was creating major model instabilities and excessively increasing modelling run times (for further details refer to Sections 2.7 and 2.8).

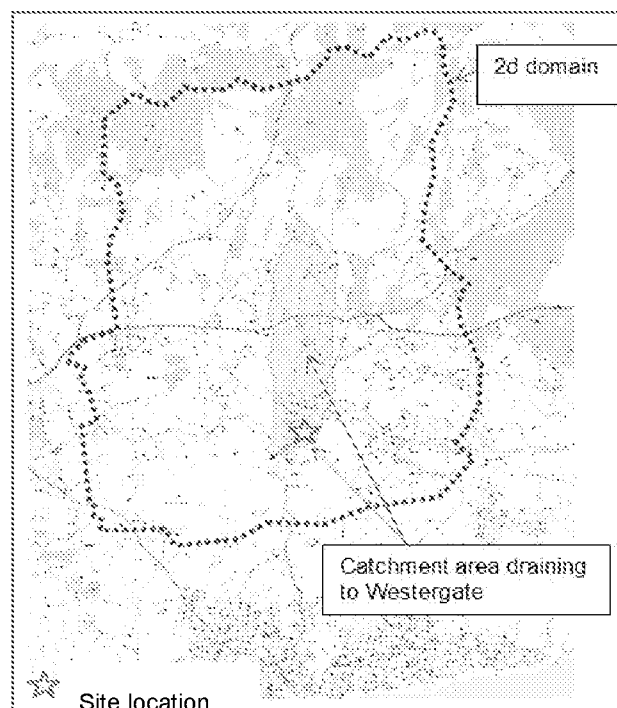


Figure 2-1 - Westergate model 2d domain

- 2.1.4. These modifications have resulted in similar results at Westergate. However, they are considered to be an improvement due to: a) more refinement of the mesh triangular sizes at Westergate compared to that of the Environment Agency model and b) with the use of a topographic survey, which replaces the DTM within the site (refer to results in Section 4).

2.2 DTM AND 2D DOMAIN

- 2.2.1. The DTM for the Environment Agency model is based on the ASCII tiles of 1m and 2m resolution LIDAR data and 5m resolution uFMfSW DTM as shown in Figure 2-2. All ASCII tiles have been mosaicked into one file for the creation of the DTM in the Environment Agency model.
- 2.2.2. The Westergate model utilised the same Environment Agency model DTM, except for the site area where the topographic survey has been used. As the 2D domain has been reduced in the Westergate model, the uFMfSW data has not been used, as shown in Figure 2-2 below.
- 2.2.3. The Westergate model 2D domain area is 6597ha whereas the catchment area draining to Westergate with a refined mesh zone has a much smaller area of 474ha only (refer to blue area in Figure 2-1).

Figure 2-2 - ASCII data used in the EA model DTM and Westergate model DTM

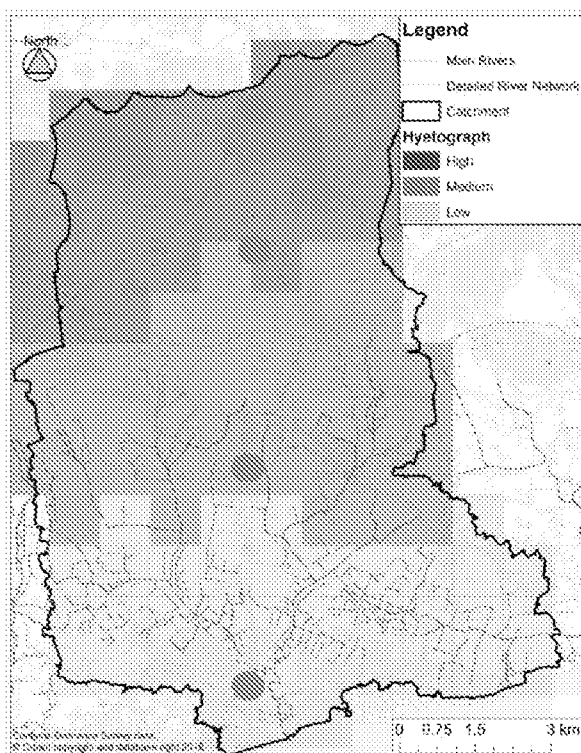


Source : Aldingbourne modelling and mapping report,(v1 September 2015)

2.3 FEH2013 AND FEH2022 RAINFALL

- 2.3.1. Rainfall data has been obtained from the Environment Agency model and multiplied by percentage increases to convert FEH2013 to FEH2022 rainfall (for further details refer to Sections 2.3.7 and 2.3.8). The same winter rainfall profiles with 10.25h storm duration has been used.
- 2.3.2. A brief summary of the approach undertaken in the Environment Agency model using the FEH2013 rainfall is provided below (in *italics*):
- 2.3.3. *Design rainfall statistics for each of the 1km grid squares across the catchment were extracted from the FEH CD-ROM (v3) in order to assess the variability in rainfall depths and storm duration across the catchment.*
- 2.3.4. *Higher rainfall depths were generally observed in the upstream part of the catchment and the rainfall totals gradually decrease further downstream. There was a significant difference between the upstream catchment rainfall total (120.5mm in the north-east) and the downstream catchment rainfall total (89mm in the south) for a 1% AEP event. As a result, different hyetographs were applied across the catchment in the hydraulic model in order to represent the variability in rainfall depths.*
- 2.3.5. *To create a hyetograph specific to these areas, the DDF parameters from the grid squares covering the modelled 2D domain were amalgamated to create average parameters for each hyetograph. Three hyetographs (low, medium and high) were used within the hydraulic model using representative FEH design rainfall statistics applied to each 'hyetograph catchment'. Figure 2-3 represents the rainfall hyetographs utilised in the model.*

Figure 2-3 - Rainfall Hyetographs



Source : Aldingbourne modelling and mapping report,(v1 September 2015)

- 2.3.6. The average FEH design rainfall parameters derived for each of the three hyetographs are shown in Table 2-1. These DDF parameters were used to derive the design rainfall inputs (i.e. without losses) for the suite of AEP events. Only the ARFs and the Seasonal Correction Factors (SCFs) were applied to the DDF rainfall depth in order to derive the design storm rainfall depth; these factors account for the conversion of point rainfall into spatially averaged rainfall (ARF) and applying the Winter rainfall profile to the DDF rainfall (SCF). These rainfall inputs were used to inform the combined fluvial-surface water model.

Table 2-1: Rainfall statistics for each hyetograph area

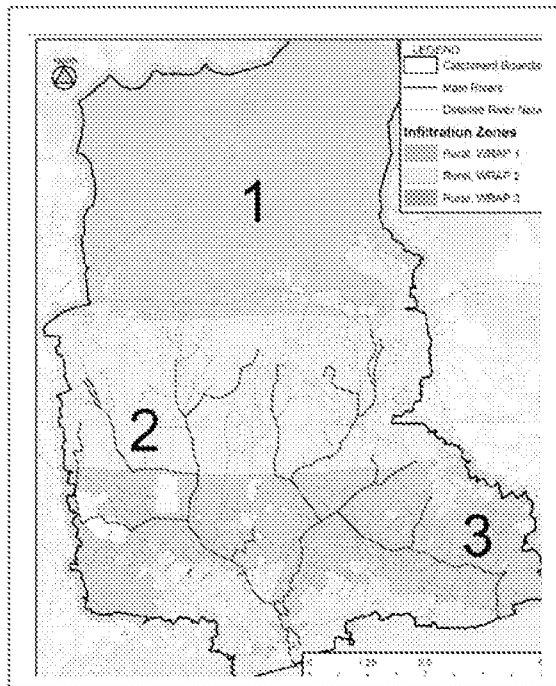
HYETOGRAPHS BASED ON THE FEH2013 RAINFALL	Area	FEH RAINFALL PARAMETER					
		C	D1	D2	D3	E	F
LOW	33.75	-0.026	0.397	0.247	0.410	0.309	2.312
MEDIUM	36.73	-0.026	0.414	0.247	0.379	0.309	2.330
HIGH	26.83	-0.027	0.439	0.270	0.361	0.311	2.368

- 2.3.7. Since the FEH2022 rainfall is available for use in the REFH2 tool, it has been possible to compare FEH2013 rainfall and FEH2022 rainfall at 4 points identified as red circles in Figure 2-3. The comparison indicated that the shape of the hyetographs did not change and therefore a percentage increase could be used to convert from FEH2013 to FEH2022. Using average values from the four points in Figure 2-3, it was possible to find the multipliers for the three rainfall regions in Figure 2-3, as follows: a) high region: 11.1%, b) medium region: 5.4% and c) lower region: 3.45%.
- 2.3.8. After the percentage increases, the resulting hyetographs have been used as direct rainfall for the three regions in Figure 2-3, for a range of return period events. Calculations can be provided on request.

2.4 INFILTRATION ZONES

- 2.4.1. The same infiltration zones using the Horton model equations have been used as for the Environment Agency model and there was no need to trim them within the Westergate model 2d domain. Figure 2-4 provides a snapshot of the infiltration zones used in the Environment Agency and the Westergate models.

Figure 2-4 - Infiltration zones in the model to represent rural areas of the catchment



Source : Aldingbourne modelling and mapping report,(v1 September 2015)

2.5 MESH ZONES

- 2.5.1. Mesh zones have been updated and further refined for the Westergate model. A total of 5 mesh zones have been removed as they fell outside the Westergate 2D domain. One additional mesh zone has been added to cover the catchment area draining to Westergate (refer to blue area in Figure 2-1), for the purpose of creating a very fine computational mesh zone at that location.
- 2.5.2. Figures 2-5 and 2-6 below show the mesh zones used in the Environment Agency and Westergate models respectively.

Figure 2-5 - Mesh zone used in the Environment Agency model

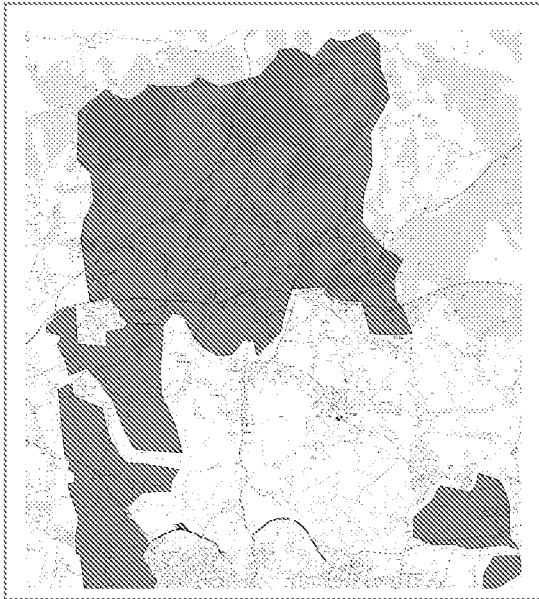
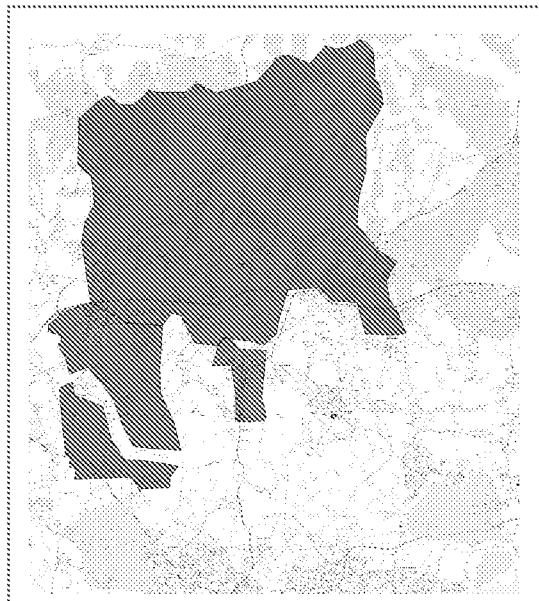


Figure 2-6 - Mesh zone used in the Westergate model



2.5.3. Table 2.2 provides details of the mesh zones used in the Environment Agency model.

Table 2-2 Details of mesh zones used in the Environment Agency model

ID	AREA (HA)	MAXIMUM TRIANGLE AREA (M2)	MINIMUM ELEMENT AREA (M2)	GROUND LEVEL MODIFICATION	RAISE BY (M)	LEVEL (M AOD)
exceedance_ds	0.001			Level	0	4.06
exceedance_us	0.001			Level	0	4.09
A259_rowan	3.437			Raise or lower	4	0
A259	1.906			Raise or lower	4.835	0
0	2.395			Raise or lower	4.1	0
FP_comp	2.361			Raise or lower	-1	0
Mesh Zone Rural 1	3856.589	1000		None	0	0
Mesh Zone Rural 2	659.642	1000		None	0	0
Mesh Zone Rural 3	49.986	1000		None	0	0
Mesh Zone Rural 4	275.683	1000		None	0	0
Mesh Zone Rural 5	456.885	1000		None	0	0
BRC	0.004	100		Level	0	3.38
Marshall	0.809	50	25	None	0	0
LB	0.017	50	25	Raise or lower	-1	0

2.5.4. Table 2-3 provides details of the the mesh zones used in the Westergate model.

Table 2-3 Details of mesh zones used in the Westergate model

ID	AREA (HA)	MAXIMUM TRIANGLE AREA (M2)	MINIMUM ELEMENT AREA (M2)	GROUND LEVEL MODIFICATION	RAISE BY (M)	LEVEL (M AD)
Mesh Zone Rural 1	3843.948	1000		None	0	0
Mesh Zone Rural 2	276.11	1000		None	0	0
Mesh Zone Rural 5	534.246	1000		None	0	0
Mesh zone	142.386	50	25	None	0	0
Bridge	0.049	5	4	Level	0	2.45
exceedance_ds	0.001			Level	0	4.06
exceedance_us	0.001			Level	0	4.09
BRC	0.004	100		Level	0	3.38
Marshall	0.809	50	25	None	0	0
LB	0.017	50	25	Raise or lower	-1	0

2.6 COMPUTATIONAL MESH

2.6.1. The creation of the mesh zones in the Westergate model has allowed the setting of a finer computational mesh in the Westergate and Barham areas. Figure 2-7 and 2-8 shows graphically the locations where a finer mesh (darker areas) is used in the Environment Agency and Westergate models respectively.

Figure 2-7 - 2D computational zone and mesh in the Environment Agency model

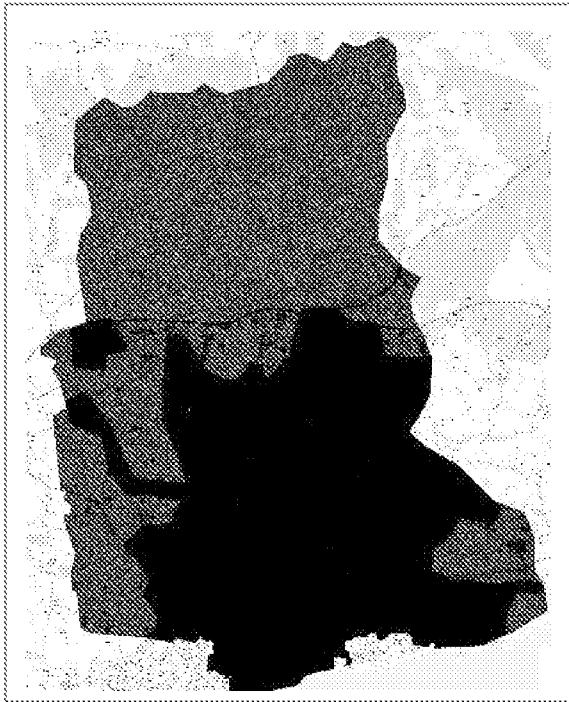


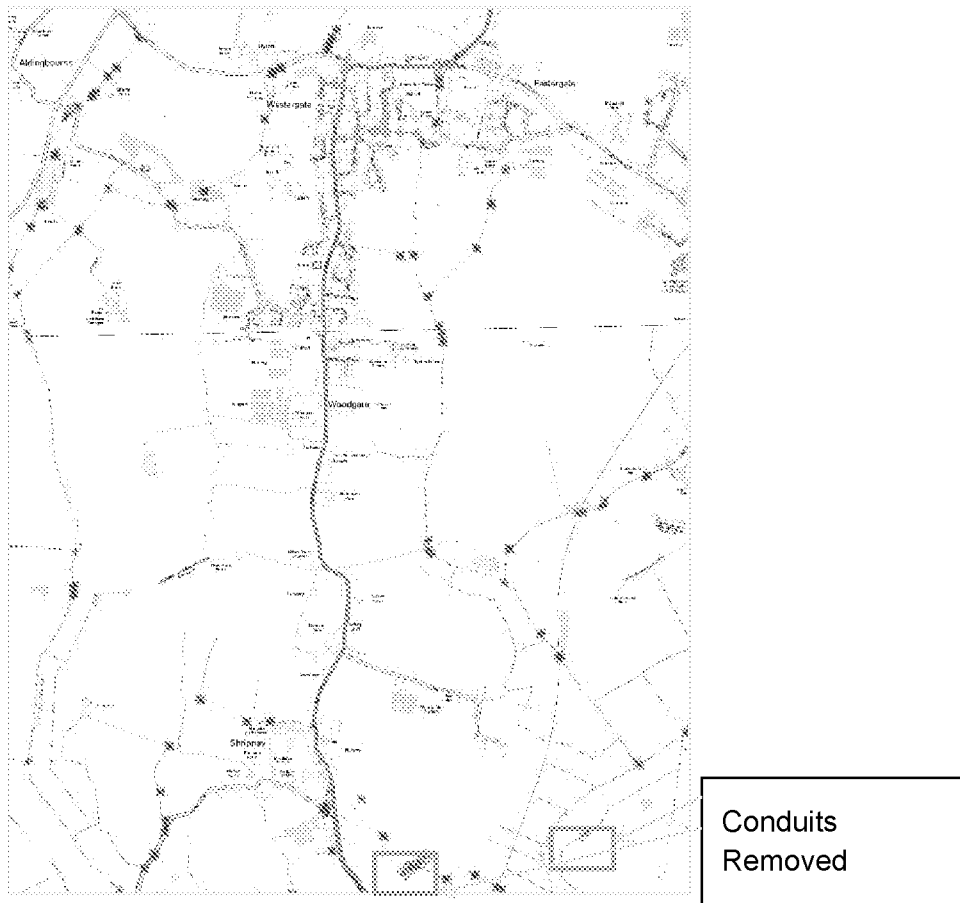
Figure 2-8 - 2D computational zone and mesh in the Westergate model



2.7 CONDUITS REMOVED IN THE MODEL

- 2.7.1. A total of 11 conduits have been removed from the Westergate model. These do not affect the results at Westergate as they are located 3.6km downstream from Westergate (refer to Figure 2-9).

Figure 2-9 - Conduits removed (shown in red) from the Westergate Model



2.8 INLINE BANK

- 2.8.1. Inline banks are used as flow inputs along lines. One inline bank has been removed in the Westergate model which does not affect the results at Westergate as it is located approximately 4,280km downstream. Table 2-4 summarises the inline banks in the Environment Agency and Westergate model and identifies the one that has been removed for the Westergate model.

2.10 SUMMARY OF CHANGES IN TABULAR FORMAT

2.10.1. Table 2-5 below provides a list of key model features, summarising the changes that have been applied to the Westergate model when compared to the Environment Agency model.

Table 2-5 Summary of changes in the Westergate model

FEATURES	ENVIRONMENT AGENCY MODEL	WESTERGATE MODEL	DESCRIPTION	COMMENT
Floodplain	-	-	2D continuous TIN	
Node	1527	1507	As manhole, break and outfall	
Conduit	889	879	As pipe	
2d Zone	1	1		
Subcatchment	3285	3285		
Bridge	11	11		
Banklines	543	543		
Culvert Inlet	158	158		
Culvert Outlet	162	162		
Flap valve	8	8		
Orifice	16	16		
Pump	4	4		
Screen	15	15		
Sluice	14	14		
Weir	1	1		
Irregular Weir	72	72		
Inline Bank	11	10		
River Reach	265	265		
General Line	62	62		
Porous Polygon	13024	13024	As building	
Mesh Zone	14	10		
Roughness Zone	1115	1115		
IC Zone-Infiltration 2D	19	19		
Infiltration Zone	23	23		
Cross-Section Line	1771	1771		
Storage Area	271	271		
Bridge Opening	11	11		
Kerbs	-	-		Not Included
Gully	-	-		Not Included
Area of 2D Domain	9819.867 (ha)	6597.501 (ha)	2D zone	
Resolution of TIN	Minimum element area-25 m ²	Minimum element area-100 m ²		Coarse mesh outside the refined mesh zones
	Maximum Triangle Area-100 m ²	Maximum Triangle Area-200 m ²		
Hydraulic roughness	Land covers- 0.06	Land covers- 0.06		Standard Manning's "n" value. Individual roughness zones however have been set to different values and these are the same for the Environment Agency and Westergate models.
	Pipe- 0.06	Pipe- 0.06		Colebrook-White
	Pipe-0.02	Pipe-0.02		Standard Manning's "n"

3 MODEL RUNS AND SENSITIVITY TESTS

3.1 MODEL RUNS

3.1.1. The Westergate model was run for the following events:

- 1% AEP (1 in 100 year);
- 1% AEP plus 36% Climate change flow increases (Higher estimates); and
- 1% AEP plus 64% Climate change flow increases (Upper estimates).

3.1.2. As the model is a direct rainfall model it was found that increasing the rainfalls by 20% in the entire model, resulted in increases in peak flows within the site of more than 36%. Also increases in rainfalls by 25% resulted in increases in peak flows above 64% within the site. Table 3-1 demonstrates this, by comparing peak flows within the site, at a number of locations on the Lidsey Rife and the Westergate Stream.

Table 3-1 – Peak flow increases as a consequence of increases in direct rainfall in the model

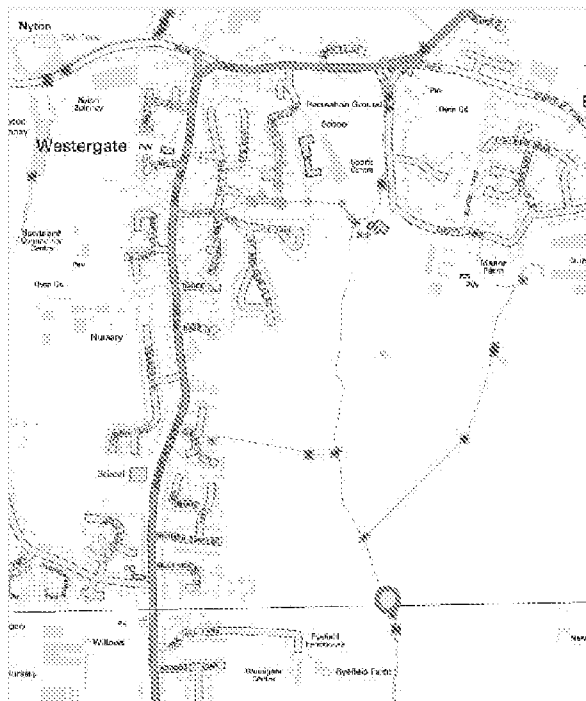
Watercourse	Cross section label	Peak Flow (100year)	Peak Flow (100 year plus 20% rainfall increase)	% Peak flow Increase (more than 36%)	Peak Flow (100 year plus 25% rainfall increase)	% Peak flow increase (more than 64%)
Lidsey Rife	1.022!	2.82	7.34	160	9.99	254
	1.019!	2.95	9.72	229	13.68	363
	1.019!-0-1.018!	2.97	9.49	219	13.55	356
	1.019!-1-1.018!	2.98	9.37	214	13.13	340
	1.018!	4.14	11.06	167	15.17	266
	1.018!ds-0-1.017!	4.38	9.79	124	12.33	182
	1.018!ds-1-1.017!	5.19	9.53	84	11.53	122
	1.015!!	7.04	10.61	51	13.37	90
Westergate Stream	2.003!-0-2.002!	2.01	3.82	91	4.26	112
	2.003!-1-2.002!	2.49	4.20	69	4.63	86
	2.003!-2-2.002!	2.65	4.69	77	5.25	98
	2.003!-3-2.002!	2.64	4.10	55	4.52	71

3.1.3. Since the climate change results are higher than the 36% and 64% increases in peak flows, the models with 20% and 25% increases in direct rainfall have been adopted conservatively as models that predict climate change increases of 36% and 64% respectively.

3.2 SENSITIVITY ANALYSIS

- 3.2.1. The sensitivity of model parameters is the same if the FEH2013 or FEH2022 rainfall is used. Therefore, for simplicity, this Section uses the results of the sensitivity tests undertaken for the previous planning application, using the FEH2013.
- 3.2.2. Sensitivity analysis has been conducted on the 1% AEP event (using the FEH2013 rainfall) for the following:
- Increasing the in Manning's n values by 20%;
 - Reduced size of Railway Arch sprung culvert (potential flow obstruction due to blockage). The Width of the Arch sprung conduit at the railway embankment has been reduced from 3.2m to 1.6m and the culvert height has been reduced from 2.6m to 2.1m.
- 3.2.3. The location of Railway Arch sprung culvert (red circle) is shown in Figure 3-1 below.

Figure 3-1 - Railway Arch sprung culvert location



4 MODEL RESULTS

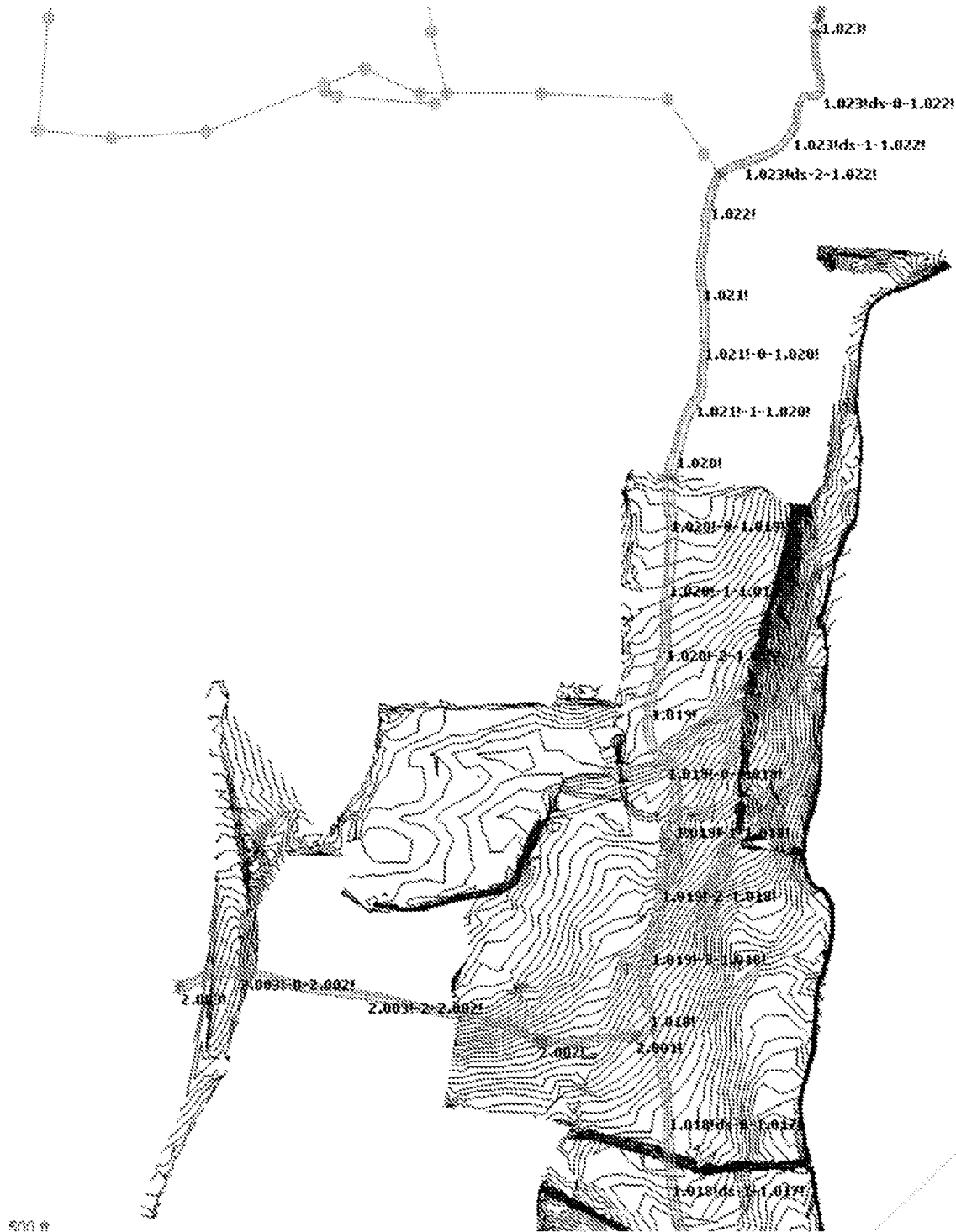
4.1 COMPARISON OF 1D RESULTS AT SELECTED CHANNEL SECTIONS

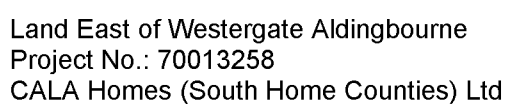
- 4.1.1. Peak flows and peak water levels for the 1 in 100 year and the 1 in 100 year plus 36% and 64% increases in flows are provided in Table 4-1. As it can be seen climate change has a significant effect on the watercourse peak water levels through the site. For the location of the cross sections in Table 4-1, refer to Figures 4-1 and 4-2.

Table 4-1 – 1D Peak Flows and Peak Water Levels

Watercourse	Cross section label	Peak Flow (m3/s)			Peak Water Level		
		100 year	100year +36%	100year + 64%	100 year	100year+36%	100year +64%
Lidsey Rife	1.022!	2.82	7.34	9.99			
	1.019!	2.95	9.72	13.68	4.48	5.07	5.31
	1.019!-0-1.018!	2.97	9.49	13.55	4.23	4.77	4.98
	1.019!-1-1.018!	2.98	9.37	13.13	3.95	4.46	4.69
	1.018!	4.14	11.06	15.17			
	1.018!ds-0-1.017!	4.38	9.79	12.33			
	1.018!ds-1-1.017!	5.19	9.53	11.53			
	1.015!!	7.04	10.61	13.37			
Westergate Stream	2.003!-0-2.002!	2.01	3.82	4.26	5.67	5.83	5.86
	2.003!-1-2.002!	2.49	4.20	4.63	5.48	5.62	5.64
	2.003!-2-2.002!	2.65	4.69	5.25	5.23	5.32	5.33
	2.003!-3-2.002!	2.64	4.10	4.52	4.95	5.00	5.01

Figure 4-1 – Location of cross sections for the Lidsey Rife and the Westergate Stream (part 1)







4.2 OTHER RESULTS

Flood depth maps are provided in the FRA for the 100 year, 100 year plus 36% and 100 year plus 64% increases in flows. Flood depth maps are also provided in the FRA for the sensitivity tests.

5 CONCLUSIONS

- 5.1.1. The Environment Agency model has been modified to a smaller cut version (the Westergate model) for the purpose of this study, primarily in order to run the more extreme climate change event, with 36% increases in flows. In addition, the latest FEH2022 rainfall has been used instead of the FEH2013.
- 5.1.2. The Westergate model has also been used to run sensitivity runs.
- 5.1.3. Particular care has been taken to ensure that the results are still consistent with the larger Environment Agency model. This has been achieved by:
- keeping the same 2D domain as for the Environment Agency model to the north of Westergate, within Westergate and at a sufficient distance south of Westergate;
 - the storm duration and winter rainfall profile have been maintained however the rainfall hyetographs have been increased by percentages to convert the FEH2013 to FEH2022 rainfall;
 - using the same model parameters as for the Environment Agency model; and
 - with no modifications to the watercourse layer which drains to the sea.
- 5.1.4. The results indicate that climate change will have the biggest impact in terms of flood extents and flood depths within the study area.
- 5.1.5. It is concluded that the Westergate model provides the necessary information to effectively inform the Flood Risk Assessment for the Land East of Westergate Aldingbourne planning application.



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