

Appendix L

Hydraulic Modelling

WESTBURY ROAD, WARMINSTER

HYDRAULIC MODELLING REPORT

FINAL

December 2025

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1. Introduction

Chris Whitlow & Associates Ltd. were instructed by Barrett Homes via Phoenix Design Partnership to undertake a hydraulic modelling study for a proposed residential development to the West of Westbury Road in Warminster, Wiltshire.

A watercourse flows onto the site from a small catchment to the north west where it is joined by another watercourse flowing south from beneath the A350 and a further watercourse flowing from New Farm. It then flows beneath another railway culvert and into the Portway Pond from which it discharges into the River Were.

For the purposes of this report, the main watercourse will be referred to as the Portway Stream.

The purpose of this exercise is to inform more accurate flood risk mapping local to the proposed residential development site.

The approximate location of the Westbury Road development is shown in Figure 1 together with the latest (November 2025) Environment Agency Flood Zones.



Figure 1: Location of current Environment Agency fluvial flood zones relative to proposed development site

An indicative masterplan for the proposed residential development for the site is shown below in Figure 2. This was developed by Phoenix Design Partnership.



Figure 2: Preliminary Illustrative Masterplan for Westbury Road site

The areas proposed for residential development are shown in Figure 2 together with a proposed new SUDS pond.

It is noted that this site layout was subject to revision depending on the results from the current detailed modelling exercise.

1.1 Existing Fluvial Flood Mapping

The Environment Agency flood zone mapping shown in Figure 1 shows some overlap between the fluvial flood zone 2 extents and the proposed development but it is noted that all proposed residential development is outside the current Environment Agency flood zones.

This map shows the extent of Flood Zones 2 and 3 which arise from the 1 in 100 year return period (1% Annual Event Probability (AEP)) and the 1 in 1000 year return period (0.1%AEP) respectively.

Figure 1 indicates that part of the proposed development site is at risk from fluvial flooding in the immediate vicinity of the main Portway Stream watercourse.

1.1 Existing Surface Water Flood Mapping

As well as fluvial flood mapping, the Environment Agency publishes another map which indicates the risk of flooding from surface water. The surface water flood mapping (as updated in June 2025) local to the proposed development is presented in Figure 3 for the 1000 year return period (0.1%AEP) event.

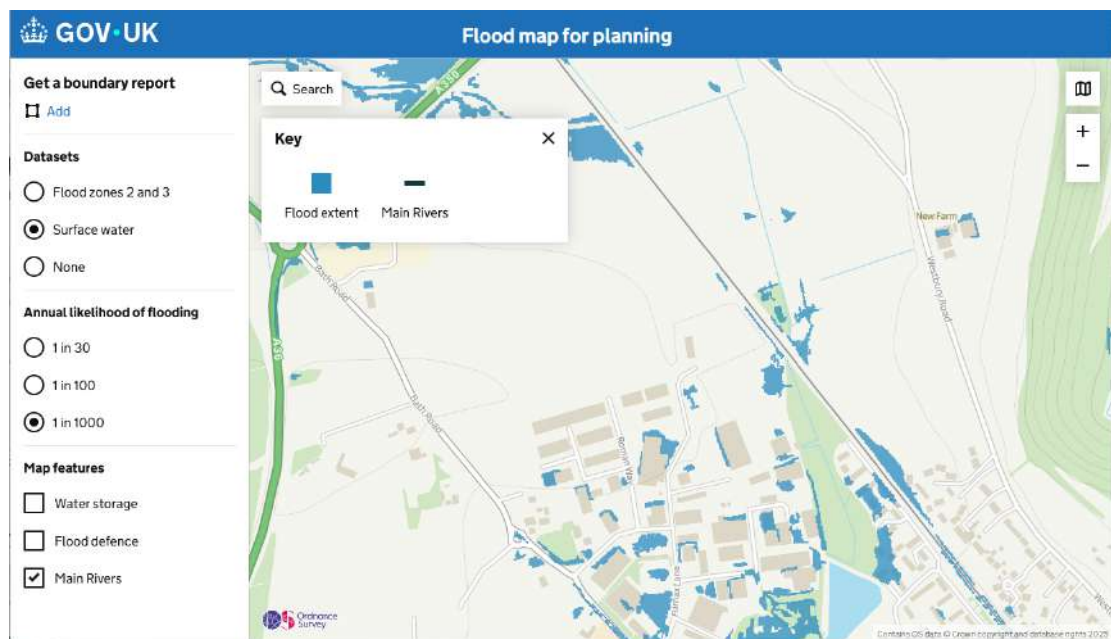


Figure 3: Environment Agency Surface Water Flood Risk Map for 1 in 1000 year return period (0.1%AEP) Storm

Figure 3 also shows that the current Environment Agency surface water mapping indicates there is very little surface water flood risk on the proposed development site.

1.2 Existing Environment Agency Detailed Hydraulic Models

The Environment Agency publishes a GIS shapefile showing the location of their detailed hydraulic models and a map showing this is shown in Figure 4. The model extent is indicated by the white line.



Figure 4: Extent of Existing Environment Agency Detailed Hydraulic Models

As shown on Figure 4, the detailed hydraulic model is in InfoWorks ICM format and was completed in August 2020. Figure 4 shows that in the existing model of the Cannimore Stream and Were, the Portway Stream reach extents only from the railway culvert to the confluence with the River Were and does not cover the proposed development site. InfoWorks ICM models are not ideal sources of historic information as the underlying data cannot be extracted with purchasing a licence for the software.

Figure 4 indicates that the Portway Stream reach though the proposed development site has not been modelled in detail and instead would have been covered by the Environment Agency's National Generalised Modelling (JFLOW). Since March 2025, this has been renamed as the New National Model (NNM). It does not contain detailed channel survey

data or culvert geometry and neither peak levels or flows are available. Consequently it is unsuitable for detailed flood risk assessment.

1.3 Historic Flooding

The Environment Agency also publishes a GIS layer showing the extent of recorded historical flooding for the whole of the UK. This map shows no out of bank flooding reported on the proposed development site or indeed anywhere else in Warminster.

1.4 Construction of new detailed hydraulic model

Partly due to the lack of a suitable and available detailed hydraulic model from the Environment Agency, it was decided to construct a new hydraulic model from upstream of the railway culvert carrying the Portway Stream onto the proposed development site as far as the River Were confluence, including the northern catchment watercourse from the A350 and the ditch between New Farm to the Portway Stream.

In this location, the Portway Stream is not classified as a Main River and maintenance responsibility lies with the Lead Local Flood Authority which is Wiltshire Council.

2. New Survey Data

New survey of the Portway Stream local to the proposed development was commissioned and undertaken by Infomap Survey and Mapping in March 2025.

Figure 5 shows the locations of the new surveyed open channel cross sections between the northern upstream railway culvert (Drain 2) and the downstream (southern) railway culvert.

Drain 1 indicates the watercourse from New Farm.

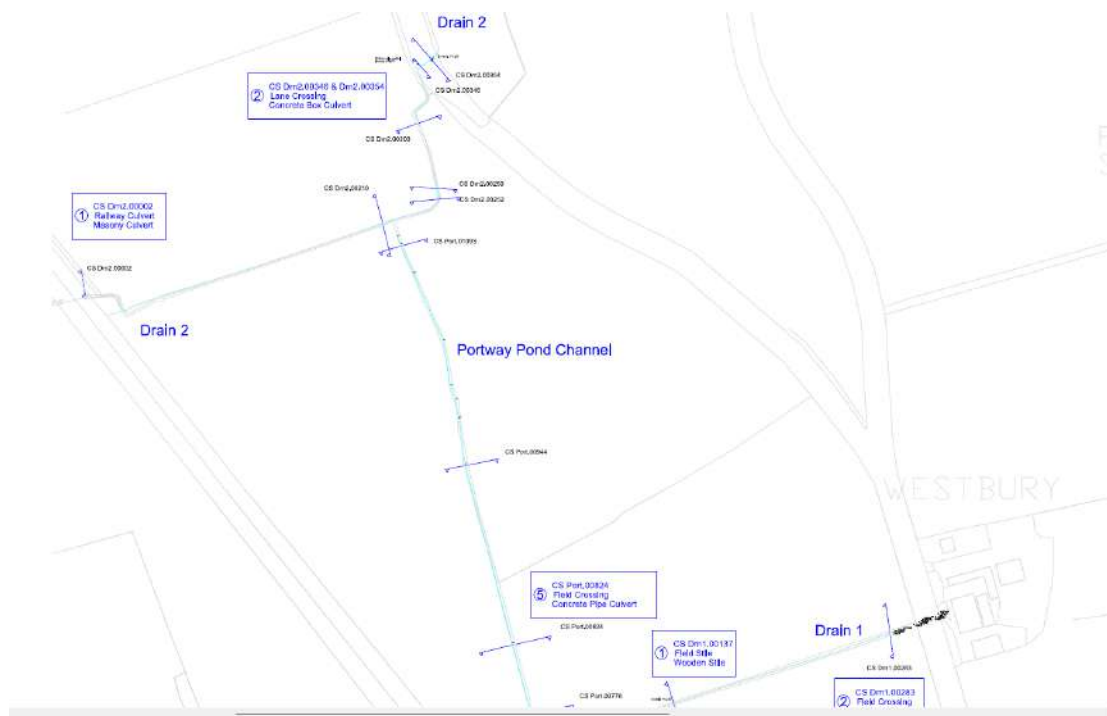


Figure 5: Upstream area of Portway Stream Survey

The surveyed cross sections and structures in the central area of the survey are shown in Figure 6.

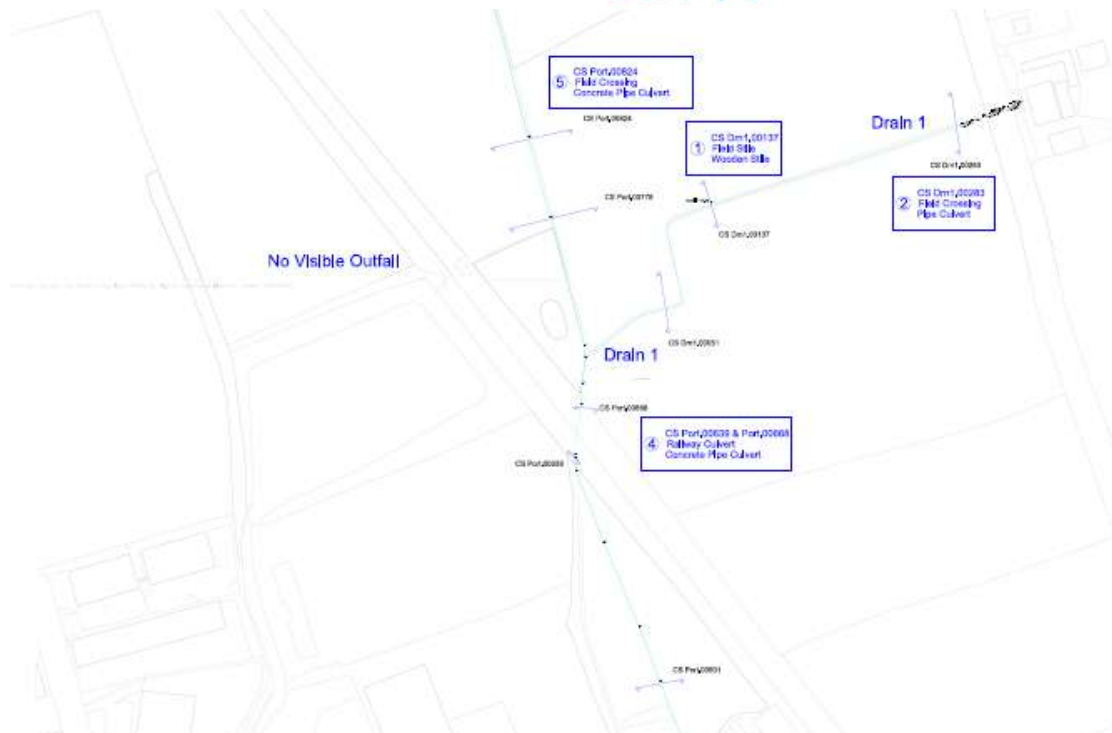


Figure 6: Central area of Portway Stream Survey

Figure 7 shows the southern extent of the survey to the confluence with the River Were.

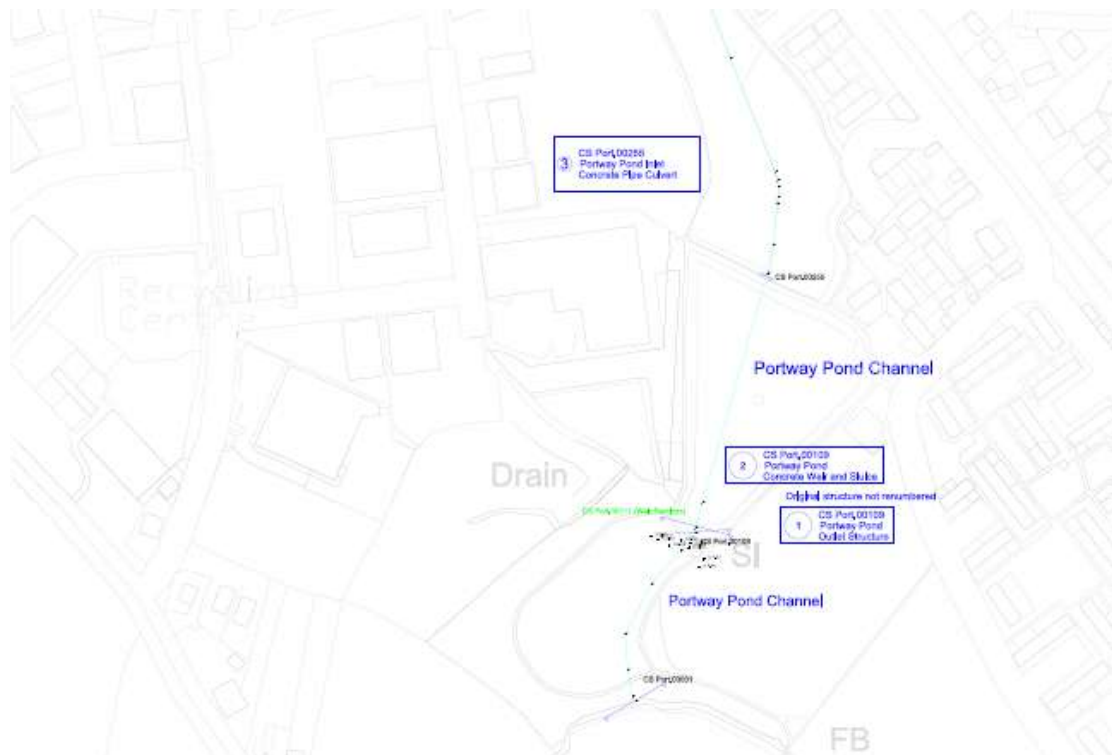
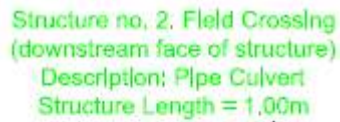


Figure 7: Downstream area of Portway Stream Survey



The long section of the Portway Stream is shown in Figure 10.

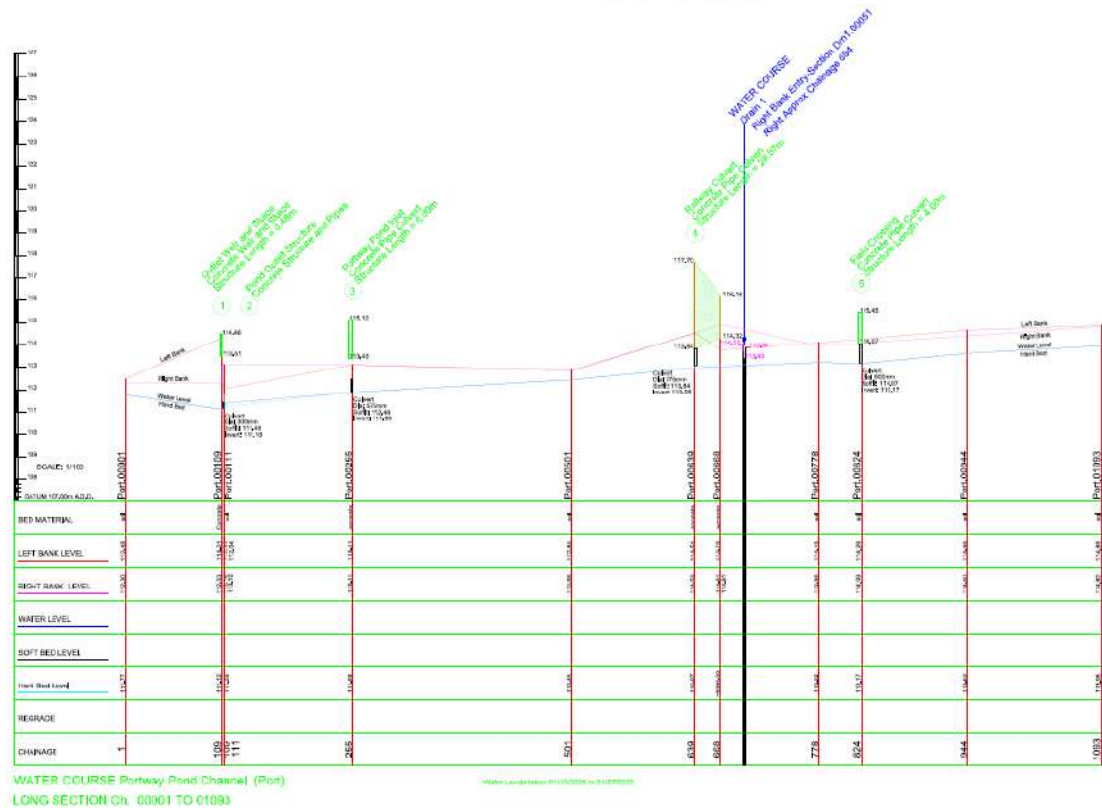


Figure 10: Long Section of Portway Stream

Figure 9 shows that the watercourse is of moderate slope with bed levels reducing from 113.96m AOD at the confluence of the ditches from the western and northern catchments to 111.77m AOD at the River Were confluence. This is a bed slope of 1 in 499.

The full survey drawings are included in Appendix A.

3. Hydrology

A hydrological assessment has been undertaken, according to the latest 2025 Environment Agency Flood Estimation Guidance, to establish peak flows at the upstream boundaries of the model which correspond to the furthest upstream surveyed cross sections at the northern railway culvert, A350 and New Farm.

As well as this, the catchment draining to Westbury Road from Arn Hill Down was considered via derivation of design rainfall.

3.1 Catchment Delineation

The delineation of the catchment was undertaken using data from the Flood Estimation Handbook (FEH Web Service¹).

The FEH catchments were chosen as that from the Western catchment to the Portway Stream at the northern railway culvert, the Northern catchment draining to the confluence of the northern drain and the Portway Stream and the combined catchment downstream of the southern railway culvert. These catchments and estimation points are shown on Figures 11, 12 and 13.

¹ <https://fehweb.ceh.ac.uk/GB/map>

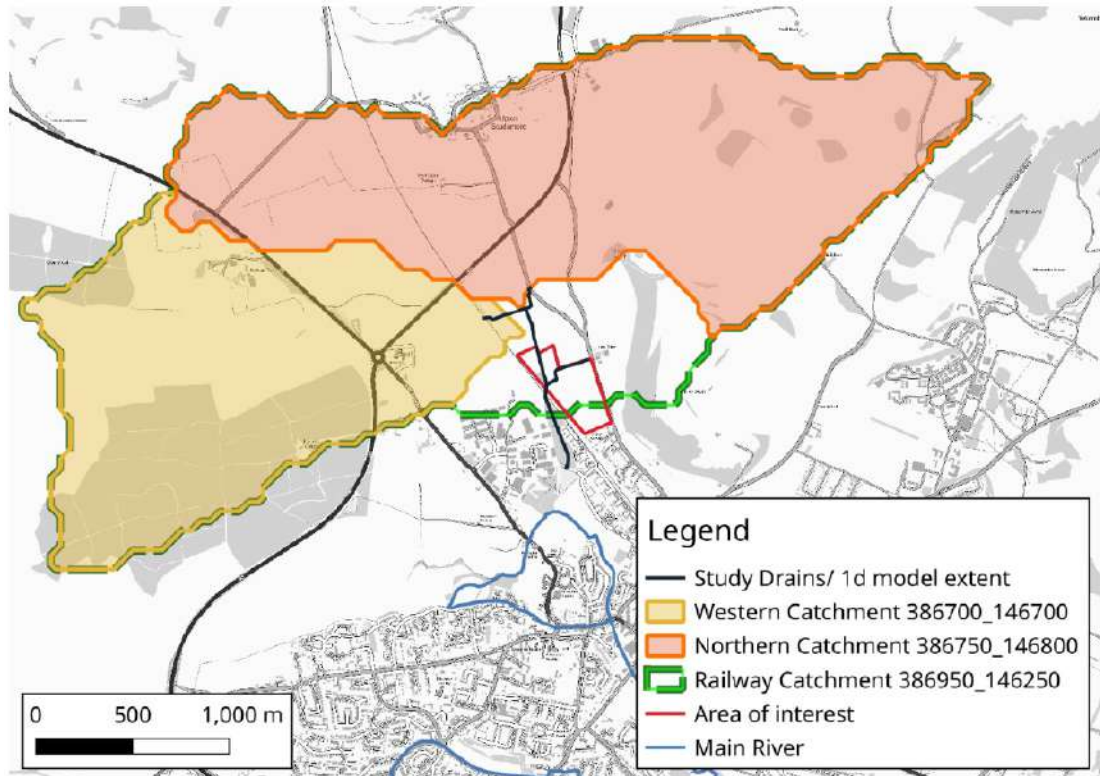


Figure 11: FEH drainage catchments and proposed development site



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& Associates

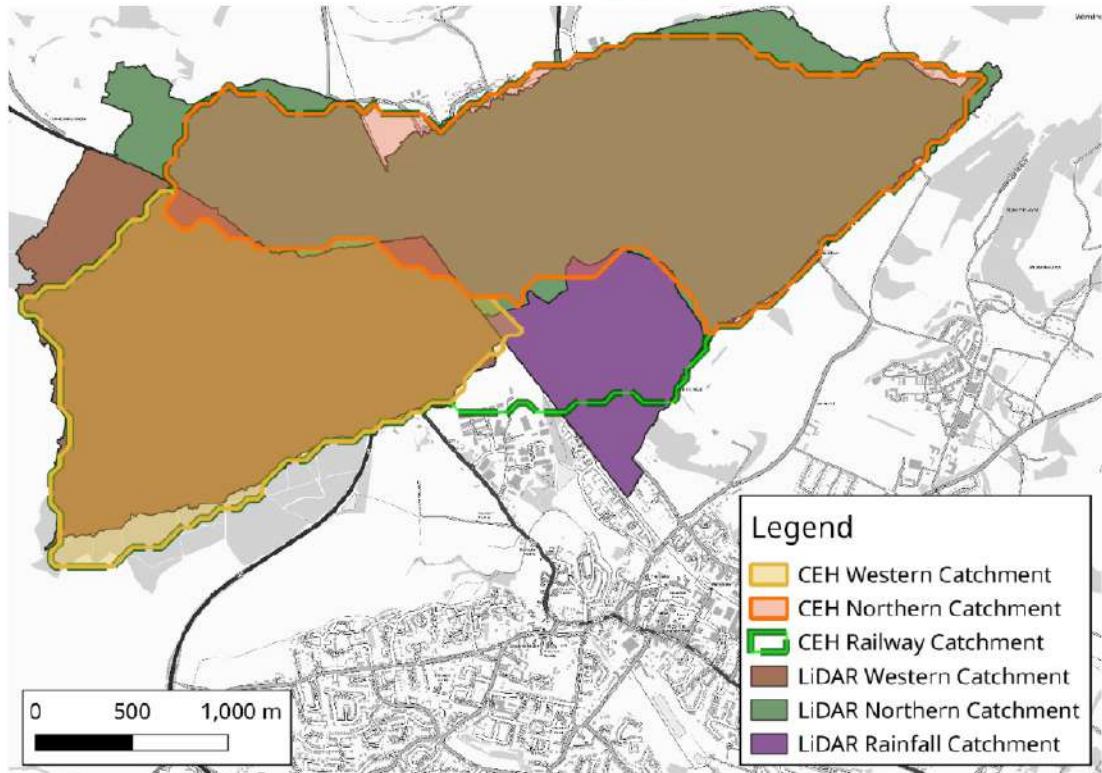


Figure 12: FEH and LiDAR Catchments draining to model inflow boundaries and downstream estimation point

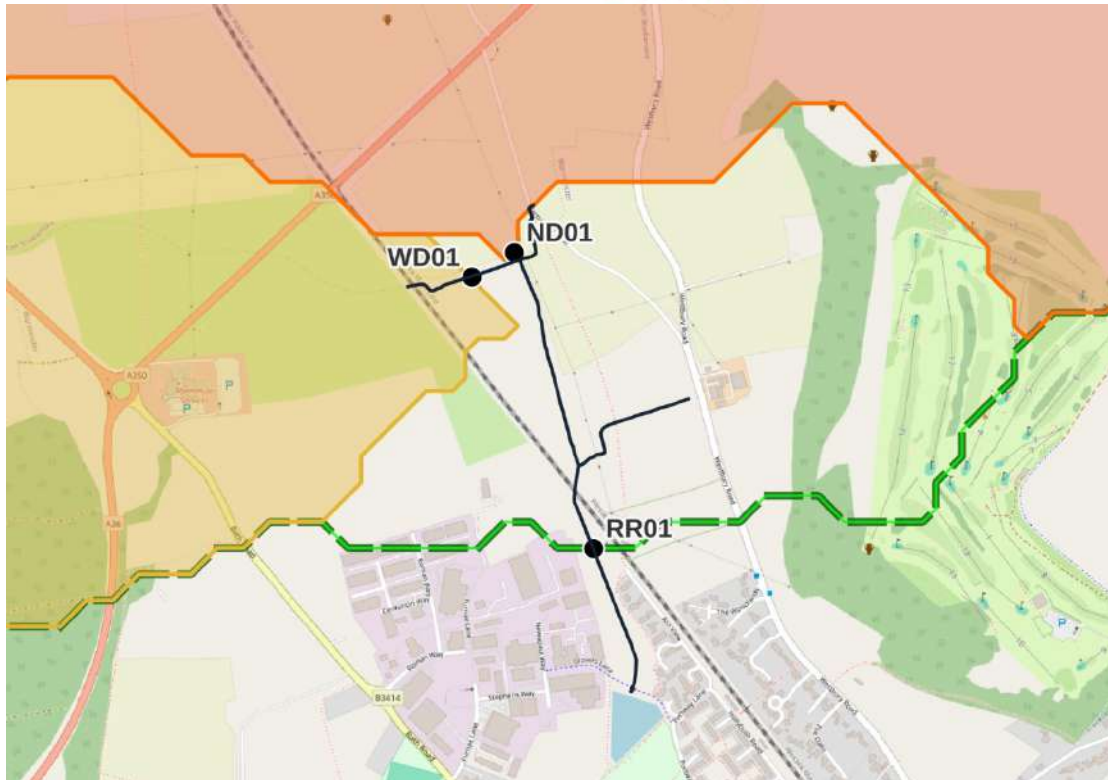


Figure 13: Location of the three hydrological estimation points

Figure 13 shows that the Portway Stream is a watercourse running in a north easterly direction through the northern railway culvert before joining the northern drain from the A350 and turning to the south east before passing through the southern railway culvert before joining the River Were via the Portway Pond.

The catchment details were supplied by the FEH Webservice are considered small, highly permeable and essentially rural catchments.

Details of the FEH estimation points are shown in Table 1.

Table 1: FEH Estimation Points

Site code	Type of Water-estimate course : lumped (L) or sub-catchment (S)	Site name / description	Easting	Northing	AREA on FEH Web Service (km ²)	Revised AREA (if altered) (km ²)
RR01	L	Unnamed drain where it crosses under	386950	146250	7.2	7.69

the railway line							
WD01	L	Unnamed drain	Unnamed drain from the west where it meets another unnamed drain	386700	146700	2.73	2.94
ND01	L	Unnamed drain	Unnamed drain from the north where it meets another unnamed drain	386750	146800	3.76	4
Rainfall_ pt	Other - rainfall	None	In the centre of the intervening catchment between RR01, WD01 and ND01	387244	146747	NA	0.74

The areas were checked by calculating the areas of the three catchments as defined by the Environment Agency's LiDAR data.

While the FEH areas were generally similar, they were updated using the GRASS Watershed tools. The catchment extents for all FEPs are slightly larger using this method than the FEH boundaries as shown in Figure 12.

3.2 Catchment Descriptors

The key FEH catchment descriptors are shown in Table 2. Corrected values are indicated using a green font.

Table 2: Key FEH catchment descriptors

Site code	FARL	PROP WET	BFIHO ST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990	URBEXT 2000	FPEXT
RR01	1	0.35	0.94	2.42	40.5	852	0.02	0.032	0.15
				3.058				0.0335	
WD01	1	0.35	0.94	1.88	16.7	862	0	0	0.15
				1.807					
ND01	1	0.35	0.95	1.92	47.3	845	0.41	0.006	0.15
				2.138				0.0063	
Rainfall_pt		0.35	0.94	-	-	849	-	-	-

BFIHOST values were found to be consistent with information provided by geology and soil maps. These indicate the presence of freely draining chalk formation.

The FARL parameter was checked against Ordnance Survey mapping and found to be consistent with that. The FARL parameter is a measure of the influence of reservoirs or lakes in the catchment and a value of 1.00 shows that there is no influence on peak flows from this source.

The SAAR parameter is the standard annual average rainfall (mm), a measure of catchment wetness associated with the geographical location.

URBEXT2000 has been updated to 2025 using the national average UEF (Urban Expansion Factor).

Based the slight area increase, DPLBAR has also been modified using FEH catchment descriptor adjustment methods.

The remaining catchment descriptors were not subject to any revision. A review of the catchment descriptors determined they did not require amendment.

3.3 Climate Change

The Environment Agency guidance is clear that climate change should be accounted for in the assessment of flood risk for planning applications.

The site is located within the Hampshire Avon Management Catchment for peak river flow climate change allowances.

In line with the Environment Agency guidance “Flood risk assessments: climate change allowances” (updated in May 2022), for a Flood Risk Assessment, the central allowance for the 2070’s epoch should be assessed and for development with a lifetime beyond 2100 and the central allowance for the 2080s epoch should be assessed for development with a lifetime between 2061 and 2100. The allowance should be applied to the 1% (100 year return period) events.

Hampshire Avon Management Catchment:

- The central allowance for the 2080s epoch is a 38% peak flow uplift for the 1% annual exceedance probability event.

The peak flow uplift was applied by adjusting the design peak flow by the appropriate allowance for use with a hydrograph from a rainfall-runoff method (ReFH2 used for this study).

3.4 Design Flow Estimation

Both the Revitalised Rainfall Runoff model (ReFH2) and the FEH Statistical Method were used to derive peak flows for the catchment. Both of these methods are industry standard and Environment Agency approved methods used to estimate peak flows.

The peak flow derivation for the FEH Statistical Method is described in Appendix B: FEH Calculation Record

Table 3: Statistical Method Peak flow values for different (present day) design events

Site code	2	5	10	20	30	50	75	100	200	1000
	50%	20%	10%	5%	3.3%	2%	1.33%	1%	0.5%	0.1%
RR01	0.32	0.49	0.62	0.75	0.83	0.94	1.02	1.09	1.26	1.7
WD01	0.14	0.21	0.27	0.32	0.36	0.41	0.45	0.48	0.56	0.79
ND01	0.18	0.27	0.34	0.41	0.46	0.52	0.57	0.61	0.71	0.99

The RefH2 peak flows were based on catchment descriptors obtained from the FEH catchment. These are presented in Table 4.

Table 4: Summary of RefH2 model parameters

Site code	Method	Tp (hours) rural	Cmax (mm)	BL (hours)	Area modelled as urban (km2)	TP urban IF scaling factor	IRF	DS	
RR01	CD	3.71	1279.78	61.68	0.04	0.75	0.4	0.7	0.5
WD01	CD	3.64	1279.78	54.99	0	0.75	0.4	0.7	0.5
ND01	CD	2.88	1289.79	57.16	0.04	0.75	0.4	0.7	0.5
Rainfall_pt	CD	1.88	1263.26	59.61	0	0.75	0.4	0.7	0.5

The RefH2 method also generates design flow hydrographs.

Flow hydrographs have been generated for the 3.33% (30 year return period), 1% (100 year return period), 1% (100 year return period) plus climate change, and 0.1% (1000 year return period) annual event probability (AEP) flood events.

The design event details are shown in Table 5 for each estimation point.

Table 5: Details of RefH2 parameters for estimation points

Site code	Rainfall DDF model	Urban or rural	Highly permeable?	Season of design event	Storm duration (hrs)	Initial soil moisture Cini	Initial baseflow BFO
RR01	FEH22	Rural	Yes	Winter	6.5	46.1	0
WD01	FEH22	Rural	Yes	Winter	6.5	46.1	0
ND01	FEH22	Rural	Yes	Winter	5.5	45.87	0
Rainfall_pt	FEH22	Rural	Yes	Winter	3.25	46.49	0

The estimated peak design flows from RefH2 for different design return periods for the three catchment are presented in Table 6. Flood peaks are shown in m³/s for the return periods in years or AEP (%) events.

Table 6: RefH2 Peak flow values (m³/s) for different (present day) design events

Site code	2 50%	5 20%	10 10%	20 5%	30 3.3%	50 2%	75 1.33%	100 1%	200 0.5%	1000 0.1%
RR01	0.29	0.41	0.51	0.61	0.67	0.76	0.84	0.9	1.08	1.73
WD01	0.12	0.17	0.21	0.25	0.27	0.31	0.34	0.36	0.43	0.7
ND01	0.17	0.24	0.3	0.36	0.4	0.45	0.5	0.53	0.63	1

Table xxx shows a summary of the differences in peak flows for each catchment calculated from both the Statistical Method and RefH2 methods. As the ratio does not exceed unity, the highest estimates of peak flows are obtained from the Statistical Method.

Table 7: Summary of Peak Flow differences between Statistical Method and RefH2

Site code	Ratio of ReFH2 to stationary statistical peak, 50% AEP	Ratio of ReFH2 to stationary statistical peak, 1% AEP
RR01	0.92	0.83
WD01	0.86	0.75
ND01	0.96	0.87

The final design peak flow estimates should be calculated using the FEH Statistical Method according to Environment Agency guidance for small ungauged permeable catchments such as those considered in this study. Consequently the Statistical Method peak flows were adopted for use in the new hydraulic model.

3.5 Peak Flow Comparison with Previous Work

It was not possible to compare the peak flows calculated for the present study with those calculated from previous studies as no data from previous studies was available.

4. New Model Development

A linked 1D-2D modelling approach was adopted using the ESTRY-TUFLOW (version 2025.1.2-iDP-w64) software. This included a direct rainfall component for the catchment draining from Arn Hill Down as well as the proposed development site itself.

4.1 Terrain Data

Environment Agency Light Detection and Ranging (LiDAR) data was available for the catchment. This is in the format of a Digital Terrain Model (DTM) at 1m resolution. Environment Agency National LiDAR Programme LiDAR data, published in 2022 was used in the new model build.

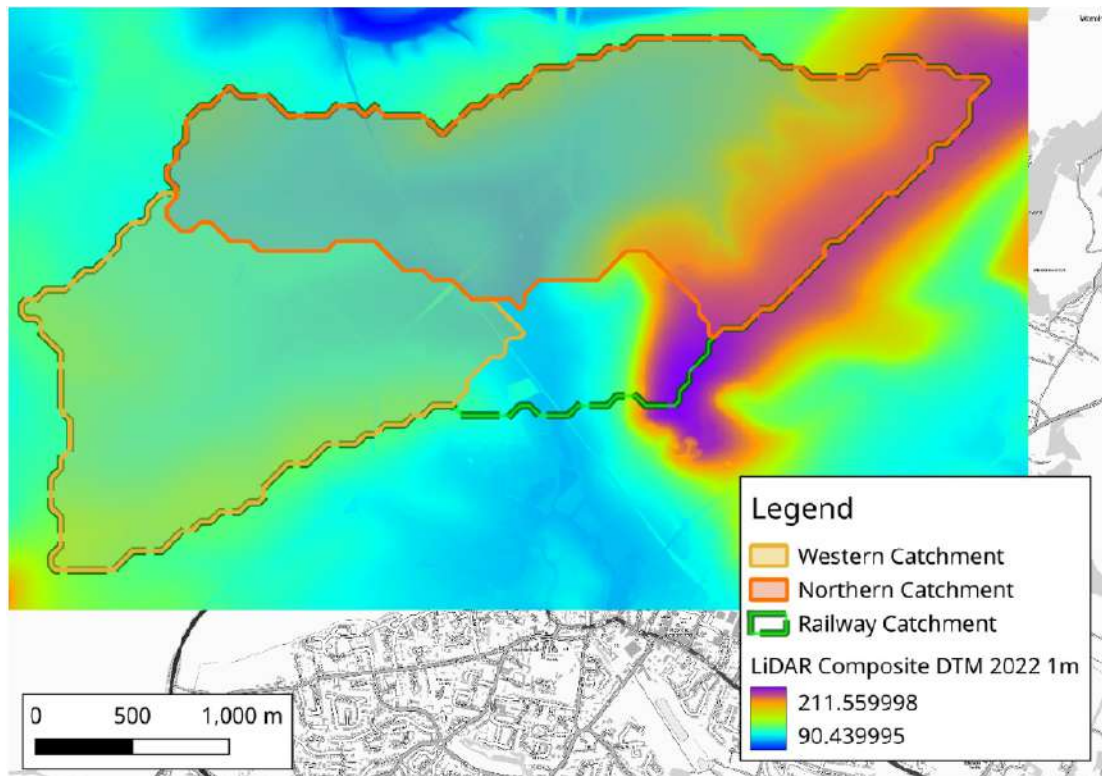


Figure 14: Environment Agency 2022 Composite terrain data

Figure 14 shows fairly shallow gradient towards the proposed development site apart from the eastern extent where there is a greater elevation at Arn Hill Down.

4.1 One Dimensional (ESTRY) Component

The ESTRY 1D component was developed by incorporating the new surveyed cross section data and structures into a completely new model for the Portway Stream and associated drainage ditches.

An initial 0.5 second timestep has been utilised for the one dimensional (ESTRY) model component.

Manning roughness values were applied as informed by survey photographs. Chow (1959) was utilised as a method by which to assign values. The Manning roughness value was set to 0.05 within the channel with the points at either end of the cross section were set to 0.07. These values were checked against survey photos. Due to the vegetated and overgrown nature of the channel (but without upstanding vegetation), and the increase density of the foliage on the bank tops, these values were deemed appropriate.

Figure 15 shows an example of a typical channel bed at node label DRN1_00051. At the date of the survey, the channel was dry and vegetated but without upstanding vegetation, trees or larger shrubs.



Figure 15: Example of a typical dry but vegetated channel bed at DRN1_00051

As noted in Section 2, a total of 20 new surveyed cross sections were used to build the new model, together with 9 hydraulic structures.

4.3 Two Dimensional (TUFLOW) Component

All parameters were retained as default and HPC adaptive time-stepping was utilised for the two dimensional (TUFLOW) model component.

For this model a 2m resolution was selected as the model extent was sufficiently small and there were fine detailed features that need representing in two dimensions such as farm crossings. Additionally due to the narrowness of the one dimensional channel at about 5m, a smaller two-dimensional cell resolution was required to prevent instability as it is recommended there be at least two grid cells within the 1d channel. Due to the limited size of the model, even with a fine cell resolution, runs to completion in a few hours.

Publicly available Environment Agency 1m resolution Composite LiDAR DTM (2022) data was used as the basis for the 2D floodplain areas.

The model initial timestep has been set to be 1 second for the 2D domain and 0.5 seconds for the 1D domain. This is in line with the TUFLOW manual recommendations on appropriate timesteps (for HPC, TUFLOW recommends that the timestep should not be less than a factor of ten smaller than the cell size and the 1D timestep is recommended as being half that of the 2D domain in linked simulations). The timestep does not drop below 0.445 seconds throughout the duration of the simulations.

Two dimensional Manning roughness values were applied as informed by OS Open Data mapping and aerial photography. Chow (1959) was utilised as a method by which to assign values. Specific materials were defined for roads, buildings and woodland, elsewhere a roughness value of 0.05 was applied to the floodplain areas based on aerial imagery.

Buildings were modelled with a 0.3m threshold using the so-called as the 'stubby buildings' approach along with higher roughness of 0.3.

The linked 1D-2D hydraulic model domain covering the reach between the upstream, northern railway culvert and the River Were confluence is presented in Figure 16.

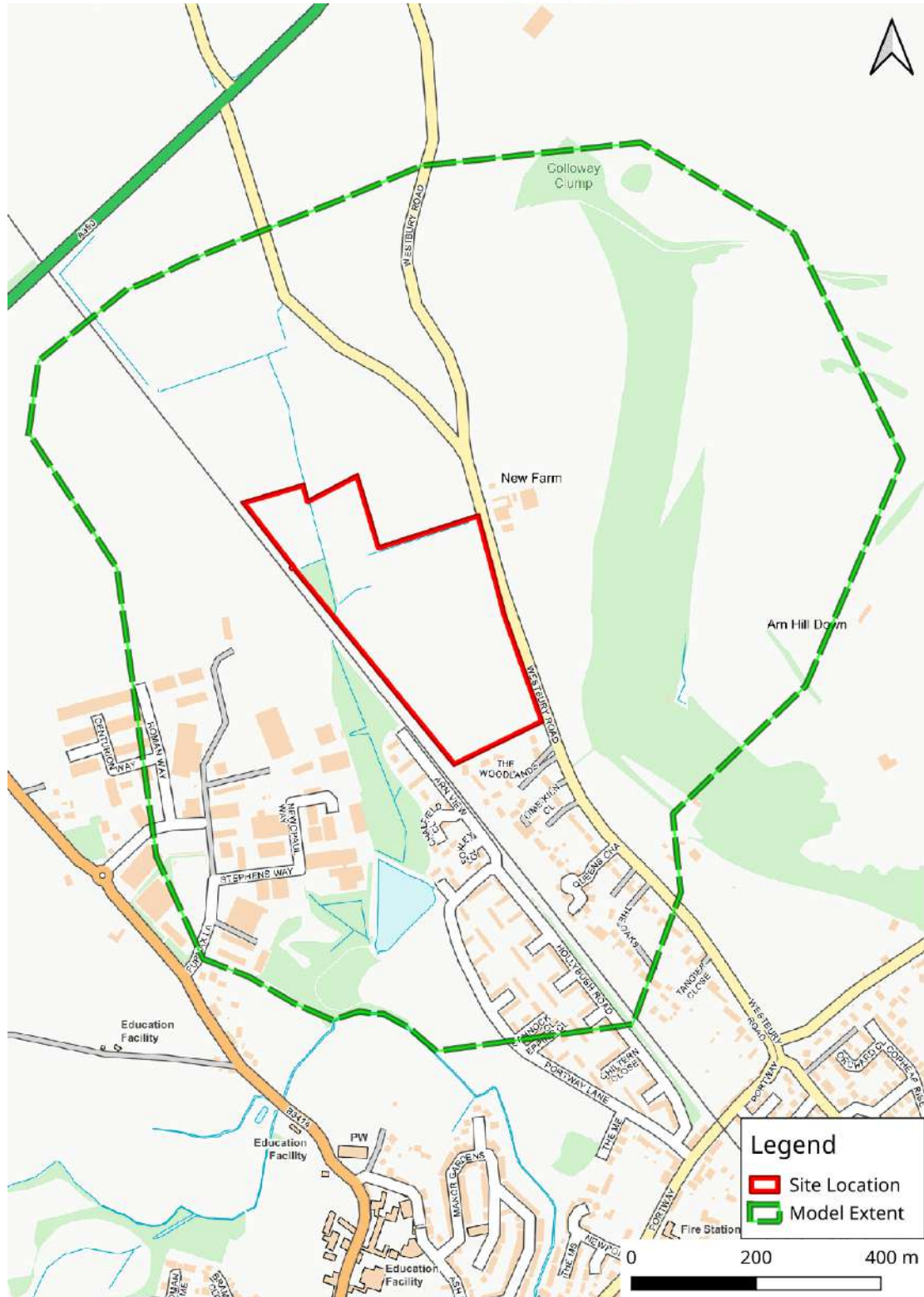
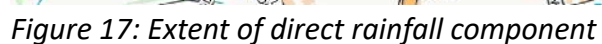


Figure 16: New Model Domain Extent for Portway Stream

4.4 Boundary Conditions

The model is a direct rainfall model which is fed by discrete inflow boundaries corresponding to the northern catchment and western catchments as shown on Figures 11 and 12. A rainfall hyetograph was applied to the model domain downstream of these locations as well as the catchment draining from Arn Hill Down as shown in Figure 17.



An iterative approach was used to define hyetograph scaling for the direct rainfall component of the study catchment. Net rainfall was applied from the ReFH2 information and scaled until the outflow matched the peak flow derived from the Statistical Method at the downstream railway culvert. A scaling factor of 2 was calculated in this way. A simplified setup was used at the railway embankment – by removing the embankment and culvert from the model - for this calibration, to ensure parity with the hydrological calculations which do not account for the attenuation in this location.

The 1D (ESTRY) domain for the channel was linked to the 2D (TUFLOW) domain representing the floodplain via a '2d_bc' layer with type 'HX' links.

The location of the HX lines were digitised to follow the bank levels as far as possible.

Likewise channel bank and floodplain levels were verified against the survey data where possible. A good linking between the 1D and 2D domain was established.

At the downstream extent of the new modelling, a normal depth relationship was applied at the River Were confluence. HQ boundaries based on the channel and floodplain slope have been applied to the 2D domain to enable floodplain flows to exit the model at this location.

4.5 Design Events

The new Portway Stream model was simulated for the following key design flood events:

- 3.3% AEP
- 1% AEP
- 1% AEP + 38% allowance for climate change
- 0.1% AEP

5. Model Results

Model simulations were carried out for each of the return period or annual event probability flood events specified in Section 4.5.

Peak flood extents have been simulated for the 1 in 30 year return period (3.33%AEP) design event and presented in Figure 18. The extent of this outline would correspond to Environment Agency Flood Zone 3b.

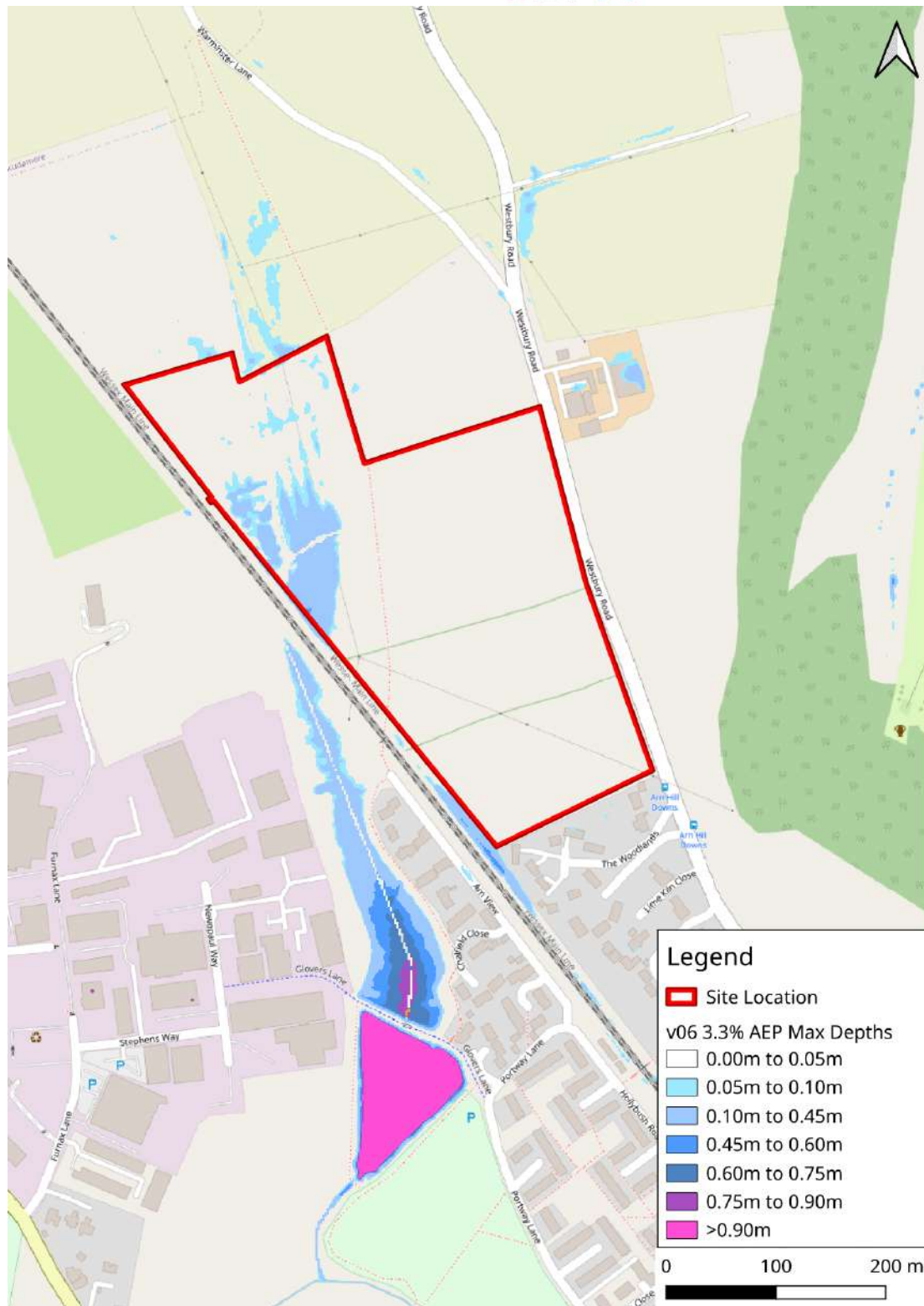


Figure 18: Peak flood depth map for 1 in 30 year return period (3.33%AEP) flood event



Peak flood extents have been simulated for the 1 in 100 year return period (1%AEP) event and presented in Figure 19. The extent of this outline would correspond to Environment Agency Flood Zone 3a.

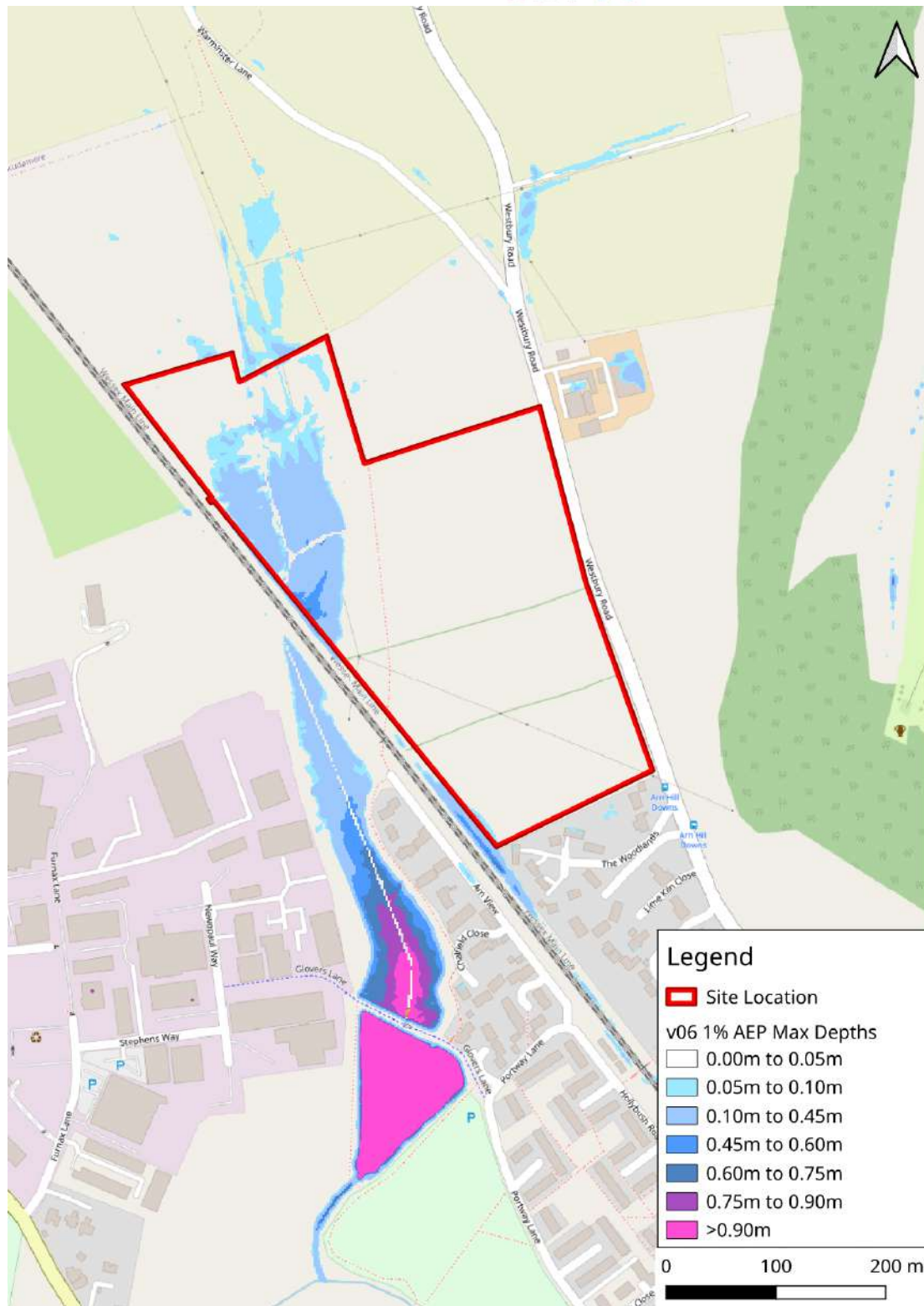


Figure 19: Peak flood depth map for 1 in 100 year return period (1%AEP) flood event

Similarly flood peak extents have been simulated for the 1 in 1000 year return period (0.1%AEP) and presented in Figure 20. The extent of this outline would correspond to Environment Agency Flood Zone 2.

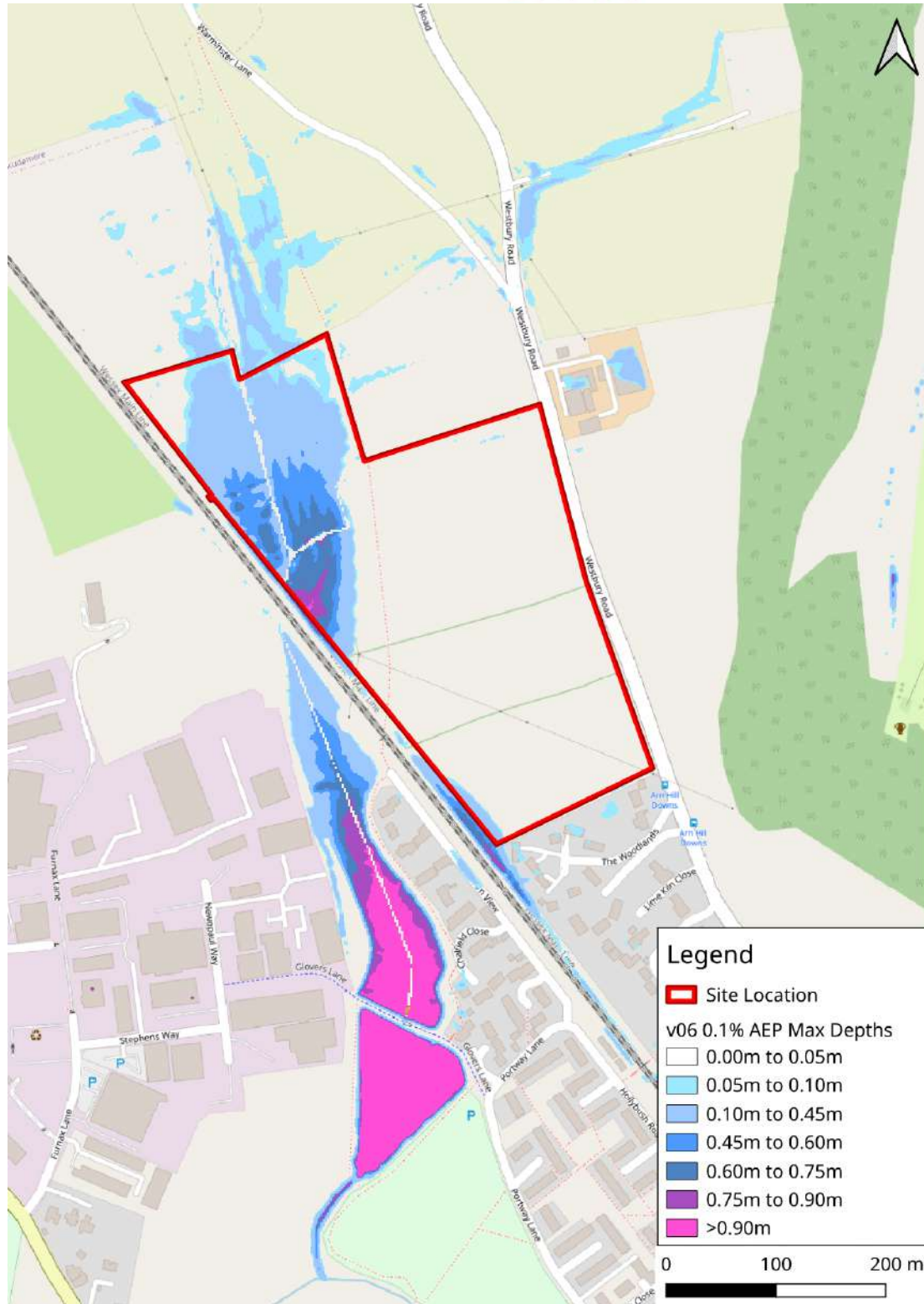
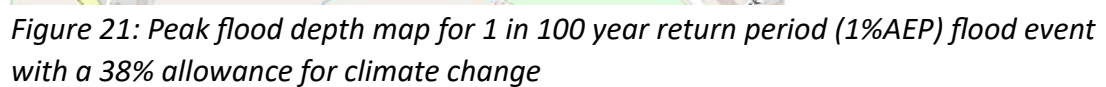


Figure 20: Peak flood depth map for 1 in 1000 year return period (0.1%AEP) flood event

Figure 21 shows a peak flood extent map for the 1 in 100 year return period (1%AEP) flood event with a 38% allowance for climate change.



Figures 18 to 21 all show flooding on the proposed development site but not for any areas proposed for residential development.

They also show high flood depths both in the Portway Pond downstream of the proposed development site and also upstream of the Glovers Lane footbridge.

The detailed modelling shows a reduced flood extent when compared with the existing Environment Agency flood zones particularly for the 1 in 100 year return period (1%AEP) event but also for the 1 in 1000 year return period (0.1%AEP) event. This applies both upstream and downstream of the southern railway culvert where properties are located. This is likely due to incorporation of detailed channel survey and hydraulic structure details into the new model which would not have been included in the existing Environment Agency flood zone mapping.

The peak flood levels for model nodes adjacent to the proposed development site are shown in Table 8. The model node locations used for Table 8 are shown in Figures 22-24 for northern, central and southern parts of the model respectively.

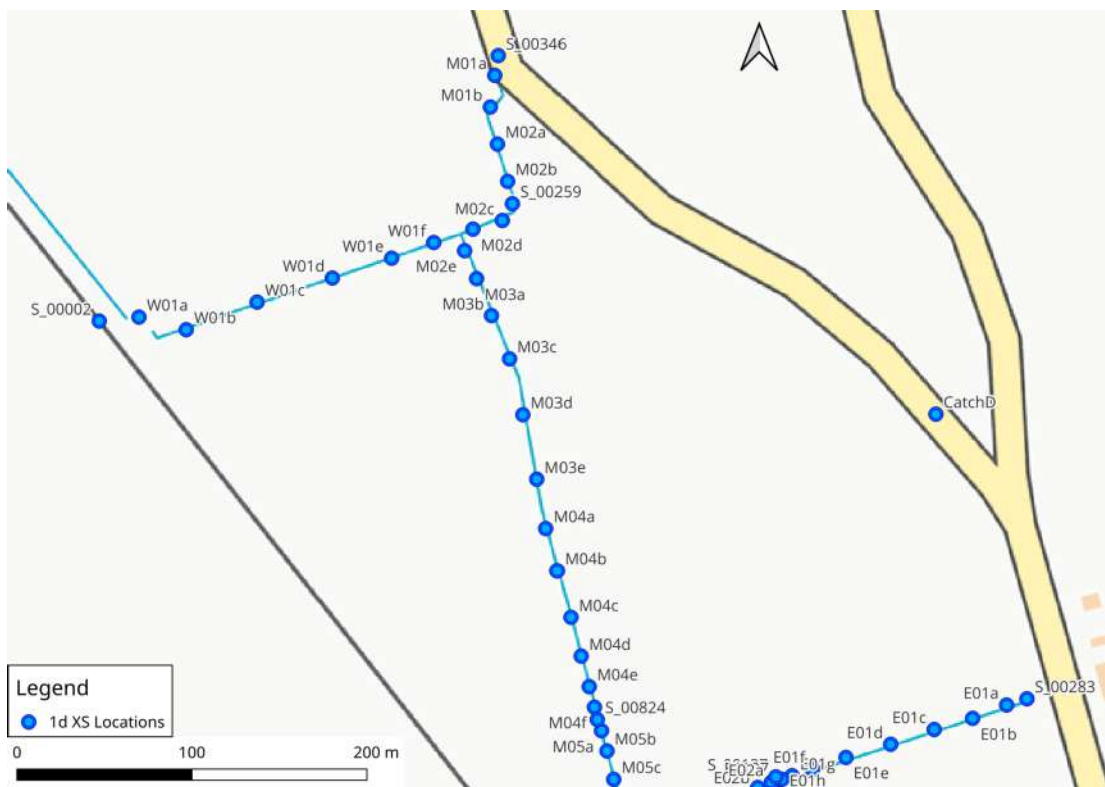


Figure 22: Model 1D Node Locations (north)

Figure 23 shows the location of the 1D model nodes in the central area of the model.



Figure 23: Model 1D Node Locations (central)

Figure 24 shows the 1D node locations in the southern area of the model.

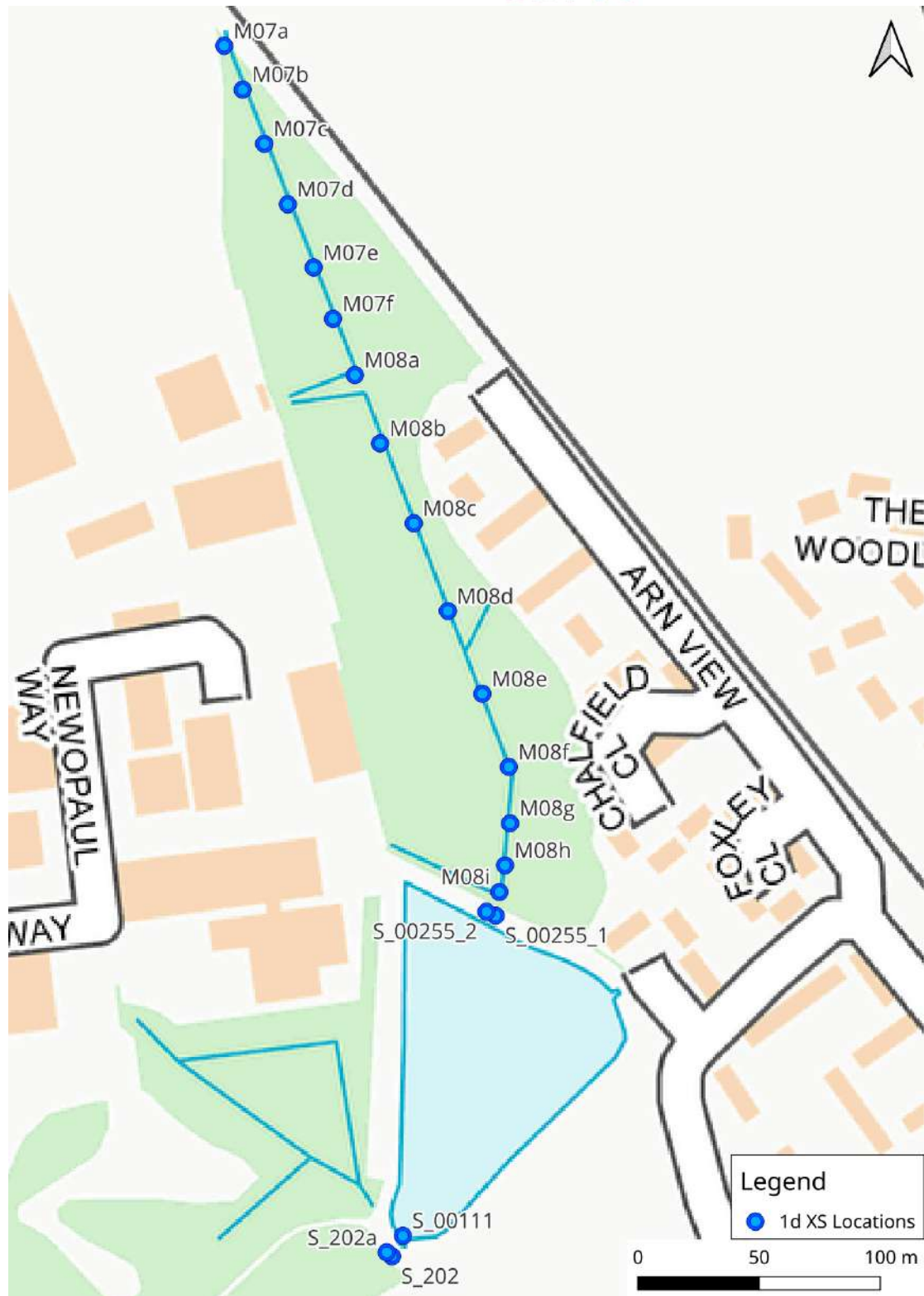


Figure 24: Model 1D Node Locations (south)

It should be noted that locations downstream of Portway Pond were modelled in the TUFLOW 2D model component.

Table 8 shows peak level results for each of the 1D nodes shown in Figures 22-24.

Table 8: Modelled Peak Flood Levels (mAOD) for all 1D ESTRY Nodes

Node Label	30 Year RP 3.33%AEP	100 Year RP 1%AEP	100 Year RP 1%AEP plus Climate Change	1000 Year RP 0.1%AEP
CatchD.1	119.294	119.311	119.311	119.360
CatchD.2	118.463	118.475	118.475	118.525
E0137.1	114.743	114.757	114.755	114.787
E0137.2	114.732	114.744	114.742	114.769
E01a.1	119.181	119.184	119.184	119.194
E01a.2	118.567	118.575	118.576	118.603
E01b.2	117.923	117.930	117.930	117.948
E01c.2	117.195	117.209	117.209	117.248
E01d.2	116.333	116.343	116.342	116.364
E01e.2	115.571	115.583	115.584	115.613
E01f.2	115.107	115.117	115.116	115.139
E01g.2	114.813	114.824	114.825	114.853
E02a.2	114.660	114.671	114.684	114.711
E02b.2	114.486	114.504	114.500	114.541
E02c.2	114.229	114.239	114.382	114.520
E02d.2	114.057	114.213	114.382	114.520
E02e.2	114.057	114.211	114.382	114.520
E03a.2	114.057	114.210	114.382	114.520
E03b.2	114.057	114.210	114.382	114.519
M01a.1	115.351	115.432	115.542	115.605
M01a.2	115.235	115.322	115.439	115.506
M01b.2	115.134	115.225	115.348	115.416
M02a.2	115.039	115.135	115.264	115.333
M02b.2	114.964	115.069	115.209	115.282
M02c.1	114.926	115.035	115.160	115.216
M02c.2	114.882	114.994	115.119	115.171
M02d.2	114.858	114.971	115.095	115.144

M02e.2	114.819	114.931	115.052	115.099
M03a.2	114.773	114.884	115.003	115.051
M03b.2	114.713	114.822	114.938	114.986
M03c.2	114.647	114.756	114.868	114.914
M03d.2	114.552	114.660	114.768	114.813
M03e.2	114.436	114.547	114.645	114.687
M04a.2	114.370	114.485	114.575	114.621
M04b.2	114.307	114.425	114.501	114.566
M04c.2	114.270	114.389	114.456	114.540
M04d.2	114.250	114.368	114.431	114.528
M04e.2	114.238	114.357	114.418	114.522
M04f.2	114.233	114.352	114.415	114.521
M05a.1	114.149	114.249	114.389	114.520
M05a.2	114.143	114.244	114.387	114.520
M05b.2	114.130	114.234	114.384	114.520
M05c.2	114.114	114.223	114.383	114.520
M06a.2	114.089	114.212	114.382	114.520
M06b.2	114.071	114.211	114.382	114.520
M06d.2	114.052	114.209	114.381	114.519
M06e.2	114.050	114.207	114.380	114.518
M07a.1	113.650	113.733	113.807	113.847
M07a.2	113.582	113.653	113.709	113.734
M07b.2	113.473	113.533	113.572	113.611
M07c.2	113.382	113.444	113.495	113.586
M07d.2	113.268	113.339	113.448	113.574
M07e.2	113.187	113.309	113.440	113.571
M07f.2	113.138	113.299	113.438	113.570
M08a.2	113.101	113.295	113.436	113.569
M08b.2	113.088	113.293	113.434	113.569
M08c.2	113.085	113.292	113.433	113.568
M08d.2	113.084	113.292	113.433	113.567

M08e.2	113.084	113.291	113.433	113.567
M08f.2	113.084	113.291	113.433	113.567
M08g.2	113.084	113.291	113.433	113.567
M08h.2	113.084	113.291	113.433	113.567
M08i.2	113.083	113.291	113.432	113.566
S_00002.1	115.502	115.599	115.717	115.795
S_00002.2	115.291	115.365	115.467	115.528
S_00111.1	112.855	113.062	113.157	113.197
S_00111.2	112.855	113.061	113.156	113.196
S_00255_1.2	113.079	113.079	113.157	113.197
S_00255_2.2	112.855	113.062	113.157	113.197
S_00283.1	119.842	119.843	119.843	119.847
S_00346.1	115.374	115.457	115.589	115.669
S_00668_1.2	114.038	114.192	114.361	114.489
S_202.1	112.855	113.061	113.156	113.196
S_202.2	112.757	112.992	113.084	113.127
W01a.2	115.177	115.257	115.363	115.424
W01b.2	115.071	115.157	115.268	115.328
W01c.2	114.951	115.051	115.170	115.225
W01d.2	114.894	115.003	115.126	115.177
W01e.2	114.868	114.980	115.103	115.153

6. Baseline Model Sensitivity Analysis

The Environment Agency specify that a set of sensitivity tests should be applied to any hydraulic model developed to inform a flood risk assessment report. These relate to channel or culvert blockage, hydraulic roughness and downstream boundary representation.

All the sensitivity testing in this section has been applied to the new model for the specified design flood event, namely the 1 in 100 year return period (1%AEP).

The first test was applied to blockage to the Glovers Lane footbridge at the inlet to Portway Pond where a 50% value was chosen.

The peak flood depth map is shown on Figure 25.

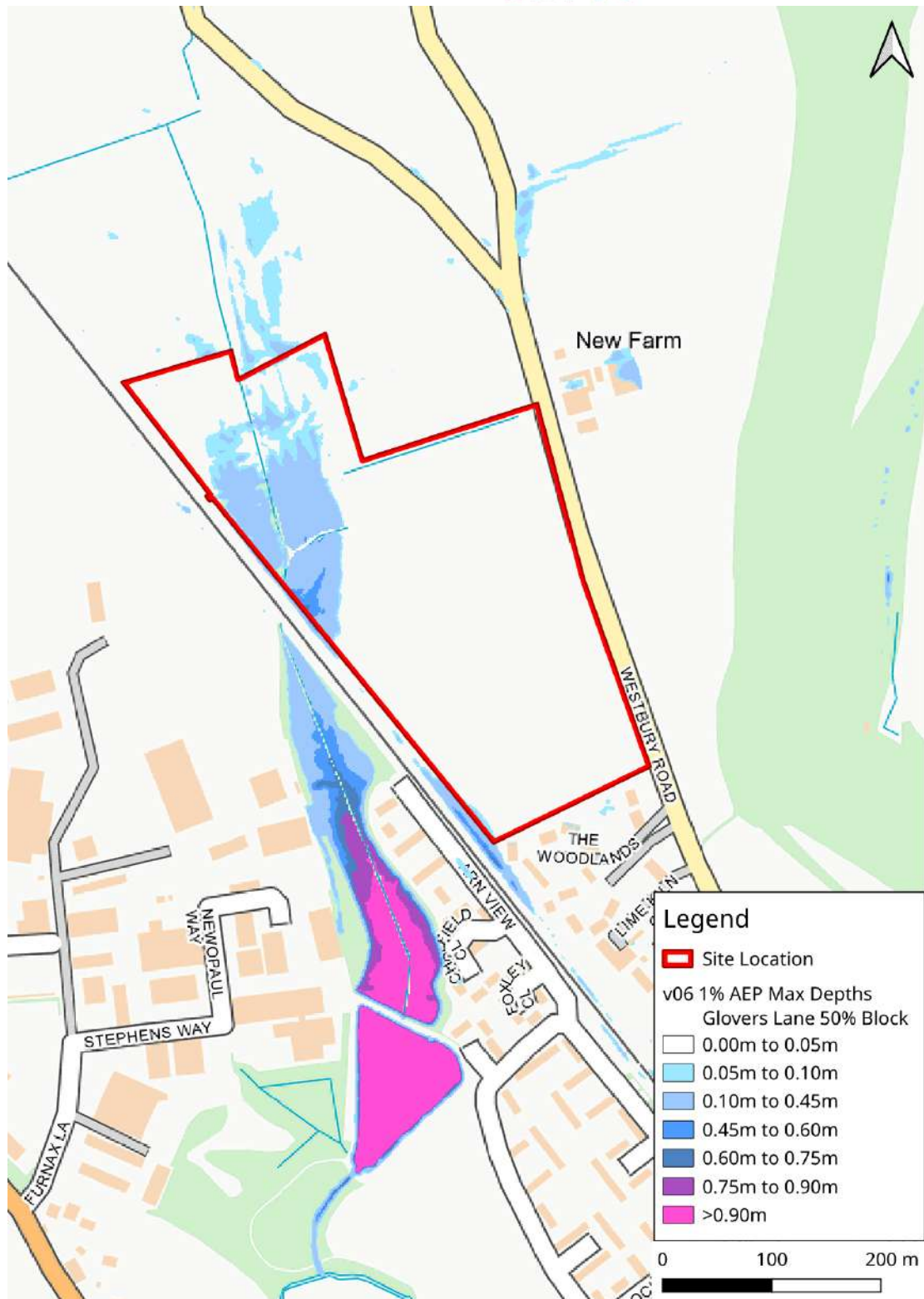


Figure 25: Peak flood depth map for the 1 in 100 year return period (1%AEP) for 50% blockage at Glovers Lane footbridge

Figure 25 shows that there is an upstream impact for the 50% blockage sensitivity test at Glovers Lane footbridge. Comparison of Figures 25 and 19 show that the flood extent is closer to properties downstream of the southern railway culvert if the footbridge is blocked. It also affects peak flood extents on the proposed development site but not at the locations where residential development is proposed.

The sensitivity to the downstream boundary condition in the model was applied by increasing and decreasing the boundary slopes in the normal depth boundary condition by 20%.

The impact on peak flood extent of the increased boundary slope sensitivity test, applied again to the 1 in 100 year return period, is shown on Figure 26.

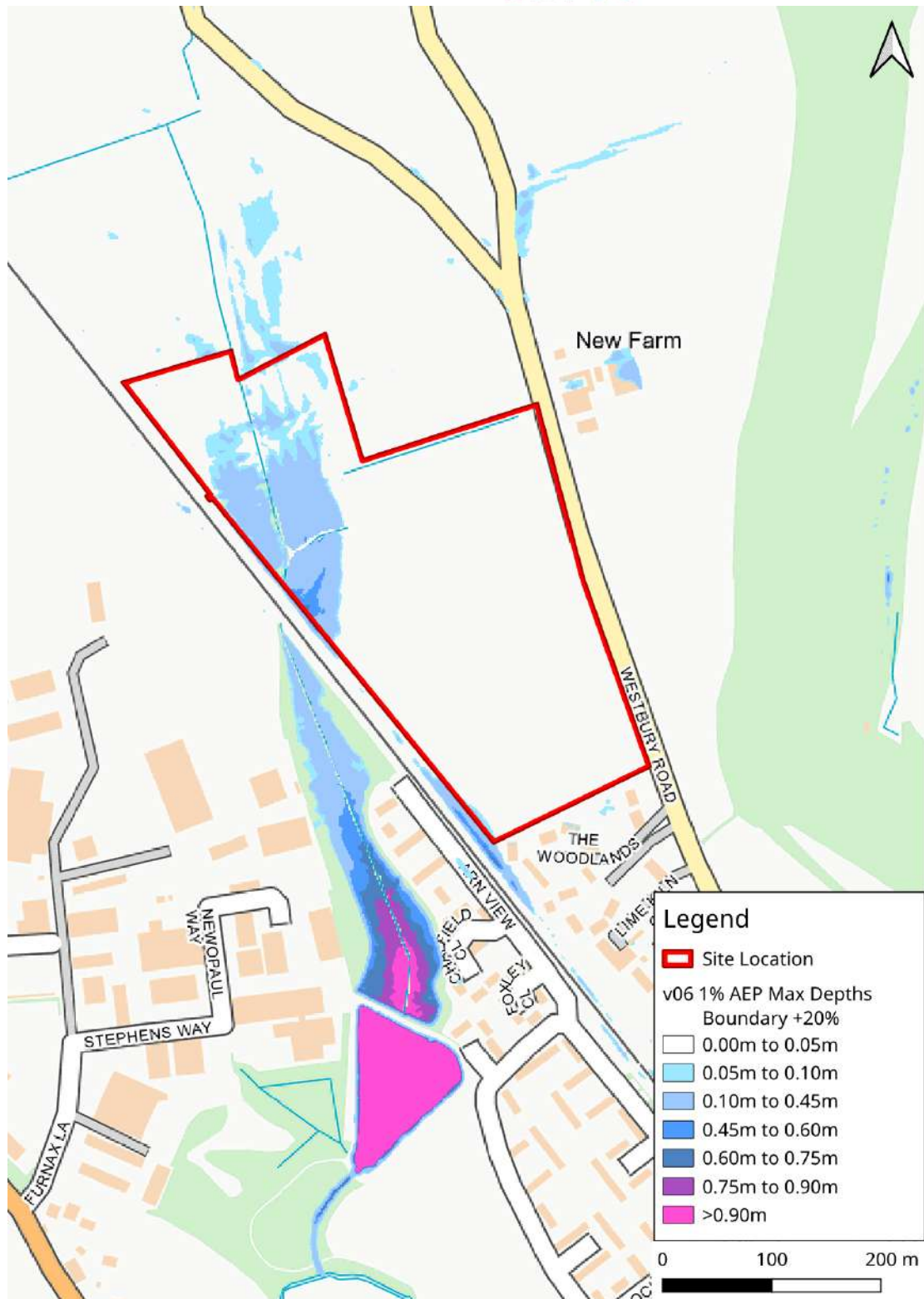


Figure 26: Flood peak depth map for the 1 in 100 year return period (1%AEP) event with a 20% increase in downstream boundary slope

Figure 27 shows the peak depth map for the same event but with a 20% decrease in downstream boundary slope.

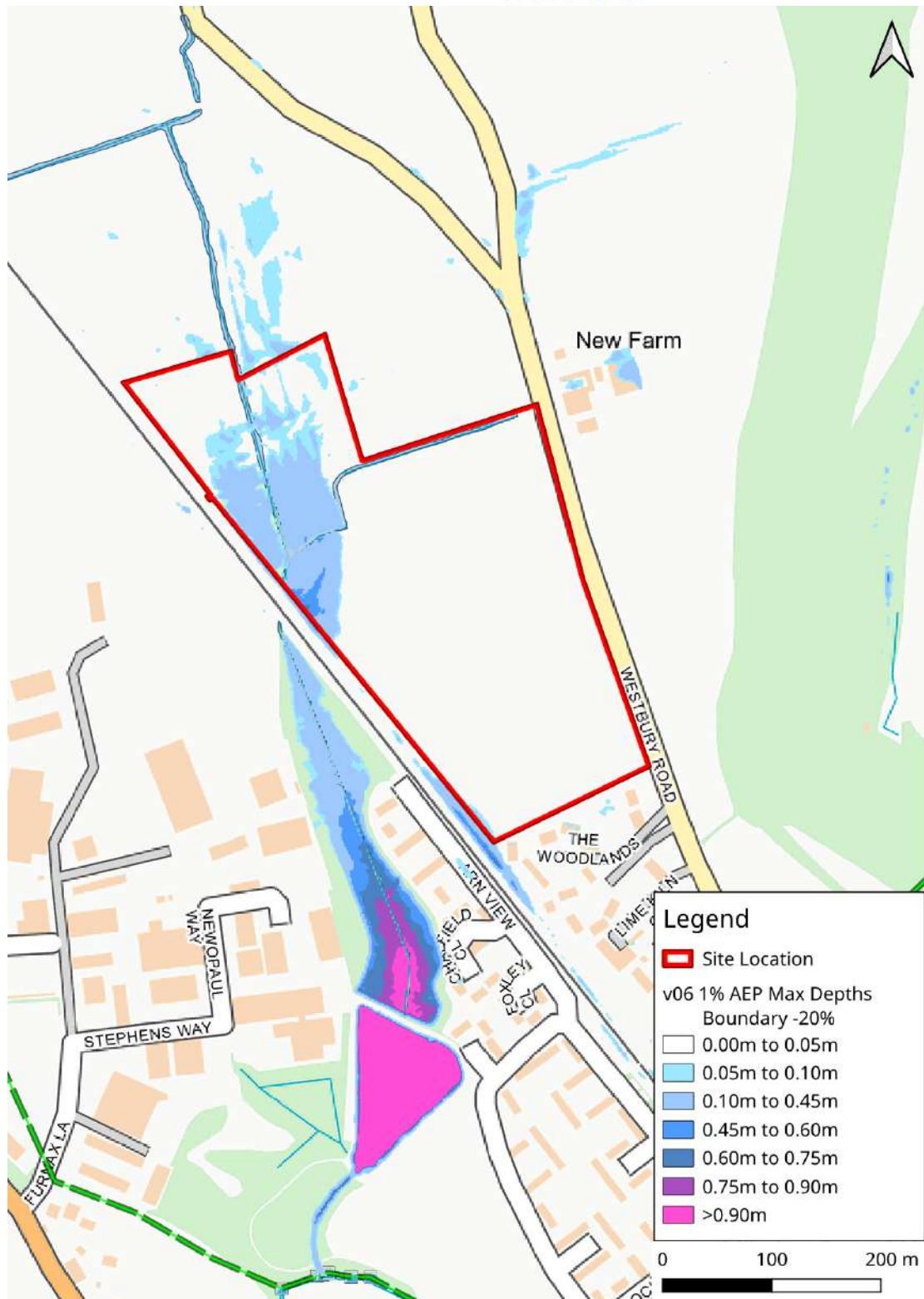


Figure 27: Flood peak depth map for the 1 in 100 year return period (1%AEP) event with a 20% decrease in downstream boundary slope

Comparison of Figures 26 and 27 shows no apparent difference indicating that the modelled peak depths are not at all sensitive to downstream boundary slope.

The fourth and fifth sensitivity tests are to assess the effect of both increasing and decreasing the Manning (hydraulic) roughness by 20%.

Figure 28 shows the peak flood depth map for the 1 in 100 year return period (1%AEP) but with an increase in Manning roughness by 20%.

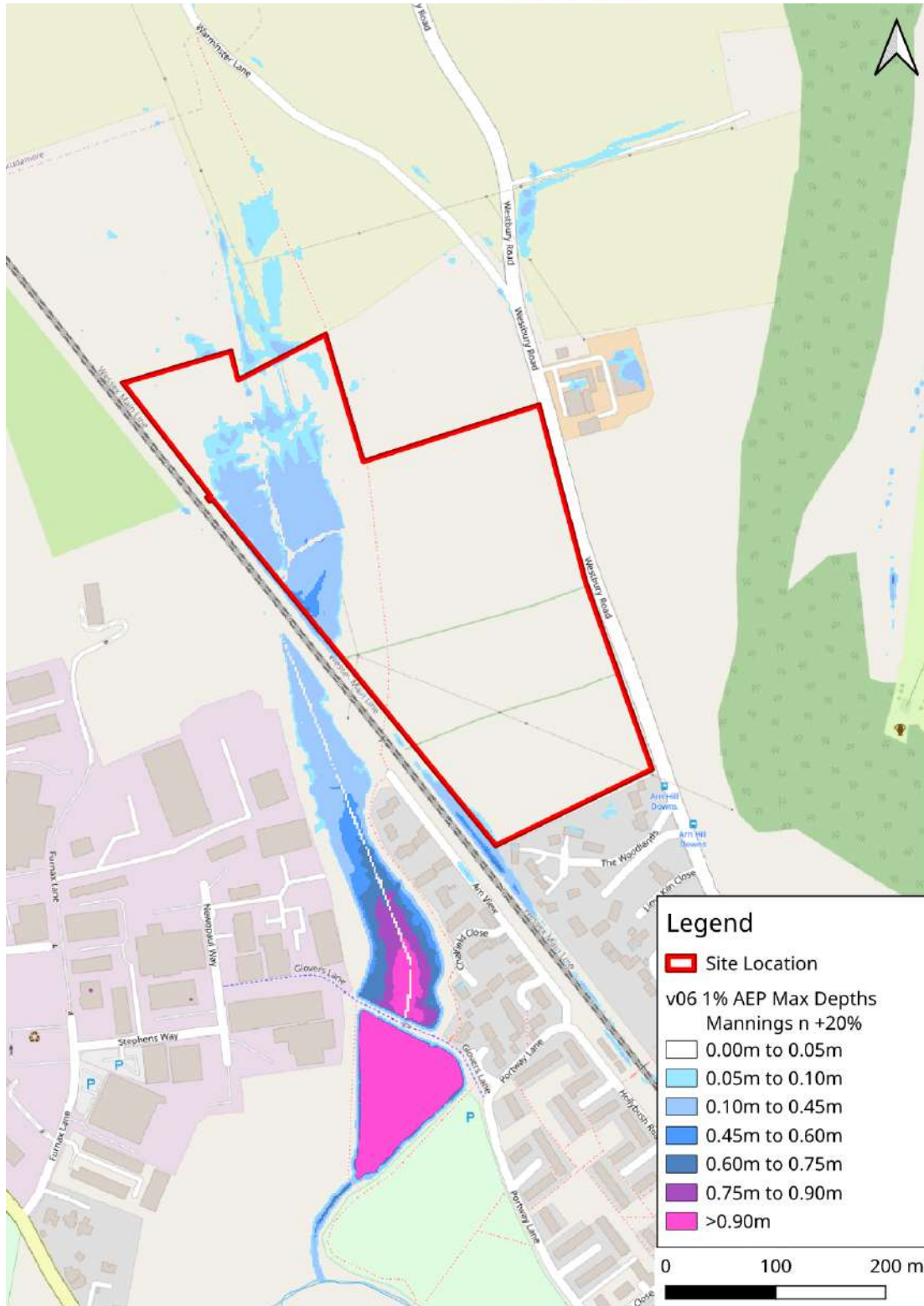


Figure 28: Peak flood depth map for the 100 year return period (1%AEP) flood event with an increase to Manning roughness of 20%

The effect of a 20% decrease in hydraulic roughness is shown in Figure 29, also applied to the 1 in 100 year return period (1%AEP) flood event.

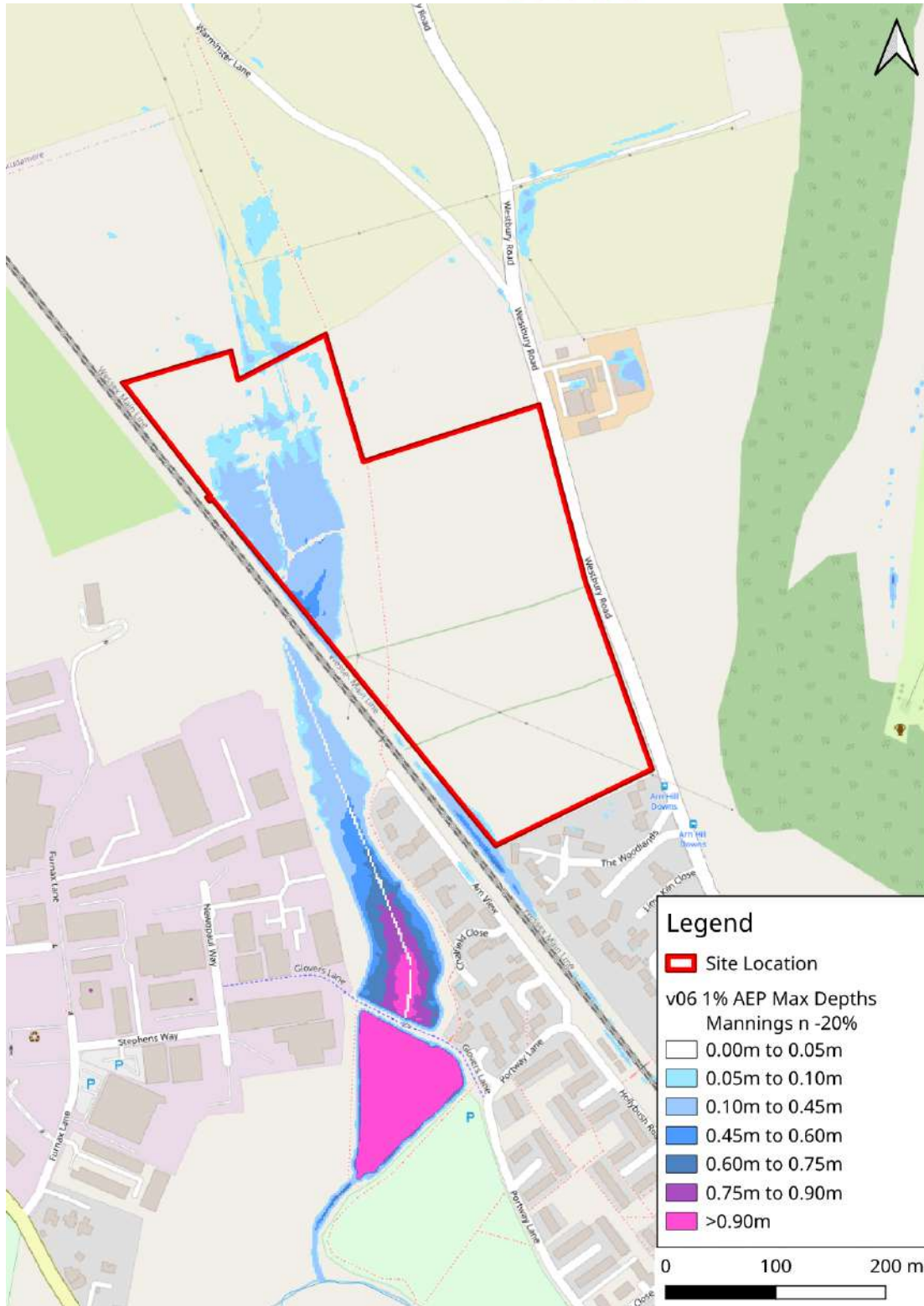


Figure 29: Peak flood depth map for the 100 year return period (1%AEP) flood event with an increase to Manning roughness of 20%

Comparison of Figures 28 and 29 indicates that there is a small impact on peak flood depths due to increasing and decreasing the baseline Manning roughness values by 20% as would be expected.

The peak flood levels in mAOD for each of the five sensitivity tests for each ESTRY 1D Node are shown below in Table 9. For ease of reference, the peak levels for the 100 year return period (1%AEP) are also included.

Table 9: Results of sensitivity testing on peak flood level (mAOD) at each Estry node

Node	100 Year RP (1%AEP)	+20% increase in Manning Roughness	-20% decrease in Manning Roughness	50% Blockage at Glovers Lane Footbridge	20% increase in downstream boundary slope	20% decrease in downstream boundary slope
CatchD.1	119.311	119.313	119.308	119.311	119.311	119.311
CatchD.2	118.475	118.479	118.469	118.475	118.475	118.475
E0137.1	114.757	114.759	114.753	114.757	114.757	114.757
E0137.2	114.744	114.747	114.738	114.744	114.744	114.744
E01a.1	119.184	119.184	119.175	119.184	119.184	119.184
E01a.2	118.575	118.576	118.583	118.575	118.575	118.575
E01b.2	117.930	117.931	117.919	117.930	117.930	117.930
E01c.2	117.209	117.210	117.217	117.209	117.209	117.209
E01d.2	116.343	116.344	116.330	116.343	116.343	116.343
E01e.2	115.583	115.584	115.595	115.583	115.583	115.583
E01f.2	115.117	115.118	115.102	115.117	115.117	115.117
E01g.2	114.824	114.825	114.840	114.824	114.824	114.824
E02a.2	114.671	114.669	114.678	114.671	114.671	114.671
E02b.2	114.504	114.511	114.490	114.504	114.504	114.504
E02c.2	114.239	114.232	114.253	114.239	114.239	114.239
E02d.2	114.213	114.204	114.211	114.213	114.213	114.213
E02e.2	114.211	114.204	114.209	114.211	114.211	114.211
E03a.2	114.210	114.204	114.208	114.210	114.210	114.210
E03b.2	114.210	114.203	114.207	114.210	114.210	114.210
M01a.1	115.432	115.490	115.390	115.432	115.432	115.432
M01a.2	115.322	115.382	115.257	115.322	115.322	115.322

M01b.2	115.225	115.286	115.160	115.225	115.225	115.225
M02a.2	115.135	115.196	115.080	115.135	115.135	115.135
M02b.2	115.069	115.133	115.024	115.069	115.069	115.069
M02c.1	115.035	115.106	114.935	115.035	115.035	115.035
M02c.2	114.994	115.065	114.892	114.994	114.994	114.994
M02d.2	114.971	115.042	114.870	114.971	114.971	114.971
M02e.2	114.931	115.001	114.831	114.931	114.931	114.931
M03a.2	114.884	114.953	114.787	114.884	114.884	114.884
M03b.2	114.822	114.889	114.729	114.822	114.822	114.822
M03c.2	114.756	114.820	114.667	114.756	114.756	114.756
M03d.2	114.660	114.720	114.579	114.660	114.660	114.660
M03e.2	114.547	114.599	114.480	114.547	114.547	114.547
M04a.2	114.485	114.529	114.430	114.485	114.485	114.485
M04b.2	114.425	114.456	114.386	114.425	114.425	114.425
M04c.2	114.389	114.410	114.361	114.389	114.389	114.389
M04d.2	114.368	114.384	114.348	114.368	114.368	114.368
M04e.2	114.357	114.368	114.340	114.357	114.357	114.357
M04f.2	114.352	114.362	114.337	114.352	114.352	114.352
M05a.1	114.249	114.259	114.234	114.249	114.249	114.249
M05a.2	114.244	114.253	114.231	114.244	114.244	114.244
M05b.2	114.234	114.238	114.223	114.234	114.234	114.234
M05c.2	114.223	114.224	114.216	114.223	114.223	114.223
M06a.2	114.212	114.207	114.209	114.212	114.212	114.212
M06b.2	114.211	114.205	114.208	114.211	114.211	114.211
M06d.2	114.209	114.202	114.206	114.209	114.209	114.209
M06e.2	114.207	114.200	114.205	114.207	114.207	114.207
M07a.1	113.733	113.785	113.663	113.735	113.733	113.733
M07a.2	113.653	113.694	113.593	113.657	113.653	113.653
M07b.2	113.533	113.562	113.484	113.568	113.533	113.533
M07c.2	113.444	113.475	113.397	113.553	113.444	113.444

M07d.2	113.339	113.360	113.312	113.548	113.339	113.339
M07e.2	113.309	113.325	113.288	113.548	113.309	113.309
M07f.2	113.299	113.314	113.279	113.547	113.299	113.299
M08a.2	113.295	113.309	113.275	113.547	113.295	113.295
M08b.2	113.293	113.306	113.274	113.547	113.293	113.293
M08c.2	113.292	113.305	113.273	113.546	113.292	113.292
M08d.2	113.292	113.305	113.273	113.546	113.292	113.292
M08e.2	113.291	113.304	113.273	113.546	113.291	113.292
M08f.2	113.291	113.304	113.273	113.546	113.291	113.291
M08g.2	113.291	113.304	113.273	113.546	113.291	113.291
M08h.2	113.291	113.304	113.273	113.546	113.291	113.291
M08i.2	113.291	113.303	113.272	113.546	113.291	113.291
S_00002.1	115.599	115.596	115.558	115.599	115.599	115.599
S_00002.2	115.365	115.421	115.306	115.365	115.365	115.365
S_00111.1	113.062	113.075	113.045	113.037	113.062	113.062
S_00111.2	113.061	113.074	113.044	113.036	113.061	113.061
S_00255_1.2	113.079	113.079	113.079	113.079	113.079	113.079
S_00255_2.2	113.062	113.075	113.045	113.037	113.062	113.062
S_00283.1	119.843	119.843	119.843	119.843	119.843	119.843
S_00346.1	115.457	115.516	115.609	115.457	115.457	115.457
S_00668_1.2	114.192	114.184	114.190	114.192	114.192	114.192
S_202.1	113.061	113.074	113.044	113.036	113.061	113.061
S_202.2	112.992	113.007	112.972	112.966	112.992	112.992
W01a.2	115.257	115.316	115.193	115.257	115.257	115.257
W01b.2	115.157	115.219	115.087	115.157	115.157	115.157
W01c.2	115.051	115.118	114.966	115.051	115.051	115.051
W01d.2	115.003	115.073	114.908	115.003	115.003	115.003
W01e.2	114.980	115.051	114.880	114.980	114.980	114.980

7. Model Calibration, Stability & Limitations

7.1 Calibration

No historical information from the Environment Agency was available to calibrate the new Portway Stream model between the northern (upstream) railway culvert and the River Were confluence.

Photographs from local residents indicating ponding of rainwater on the proposed development site immediately upstream of the southern culvert were provided by Phoenix Design Partnership.

The most useful is presented below with credit permission from John Tulloch. It was taken in December 2023 from Arn Hill Down. This was a flood event of note in the River Were catchment.



Figure 30: Floodwater ponding upstream of southern railway culvert in December 2023

Analysis of level data from the Environment Agency's George Street flow gauge in Warminster indicates that this flood event gave rise to the third highest peak level in the 20 year record at this gauge. Figure 31 shows the complete level plot at this gauge illustrating this point.

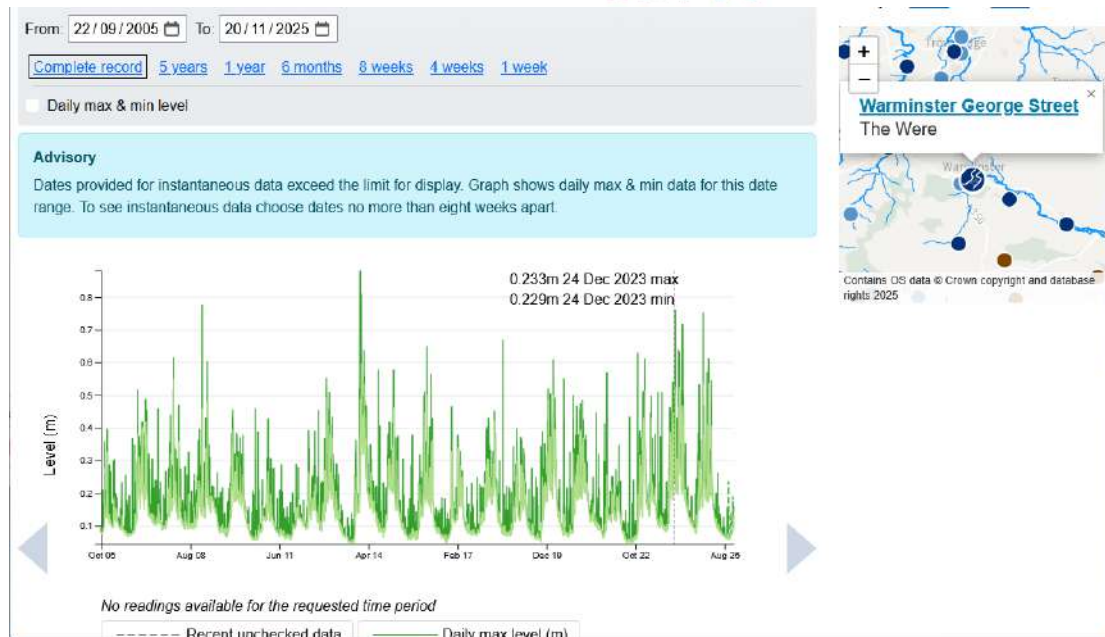


Figure 31: Complete level record from Environment Agency flow gauge on the River Were at George Street in Warminster

Figure 31 was taken from the Environment Agency's Hydrology Data Explorer

Comparison with the modelled flood extent for the 1 in 30 year return period (3.33%AEP) shown in Figure 18 indicates good qualitative agreement between modelled flood extents and the locations where ponding is shown in Figure 30.

The flood depth mapping model for the 1 in 1000 year return period (0.1%AEP) flood event from the new model is similar to but of lesser extent than the Environment Agency's existing flood zone mapping, particularly on the proposed development site. The new model shows a markedly less amount of flooding to the north and south of the proposed development site

7.2 Stability

The model is considered healthy and stable.

The timestep values were within the recommended range in the TUFLOW manual with a minimum value of 0.445 seconds. It is recommended that the minimum timestep values should not be less than one tenth of the cell size, which would be 0.2 seconds.

The Courant Number Nu and Diffusion Number Nd are both within recommended values (Nu <1.0, Nd <0.3) as shown in Figures 32 and 33.

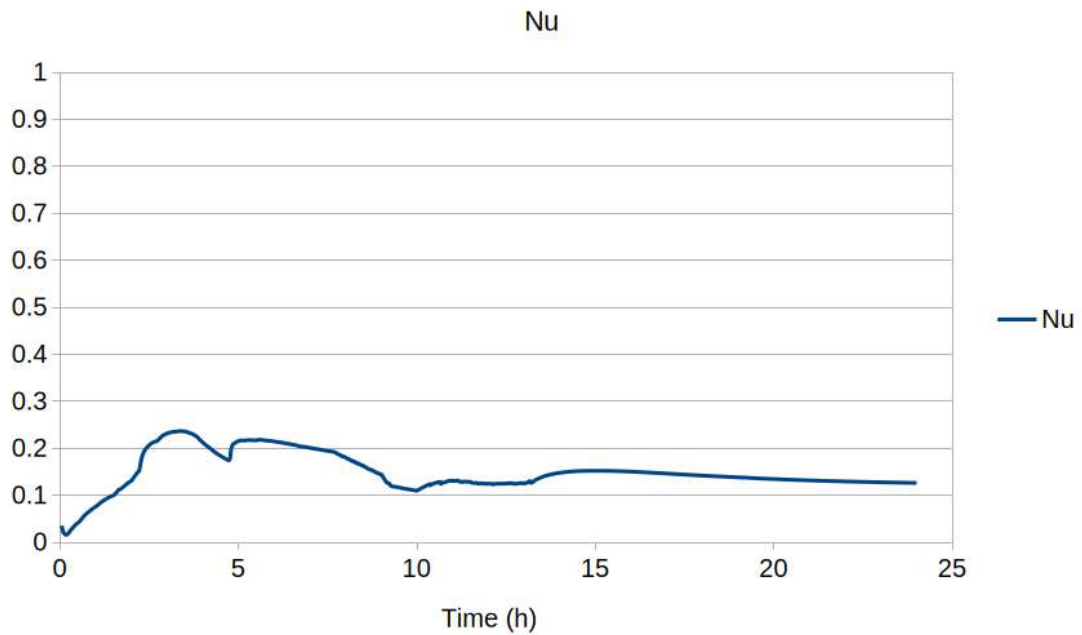


Figure 32: Variation of Nu throughout the baseline model duration

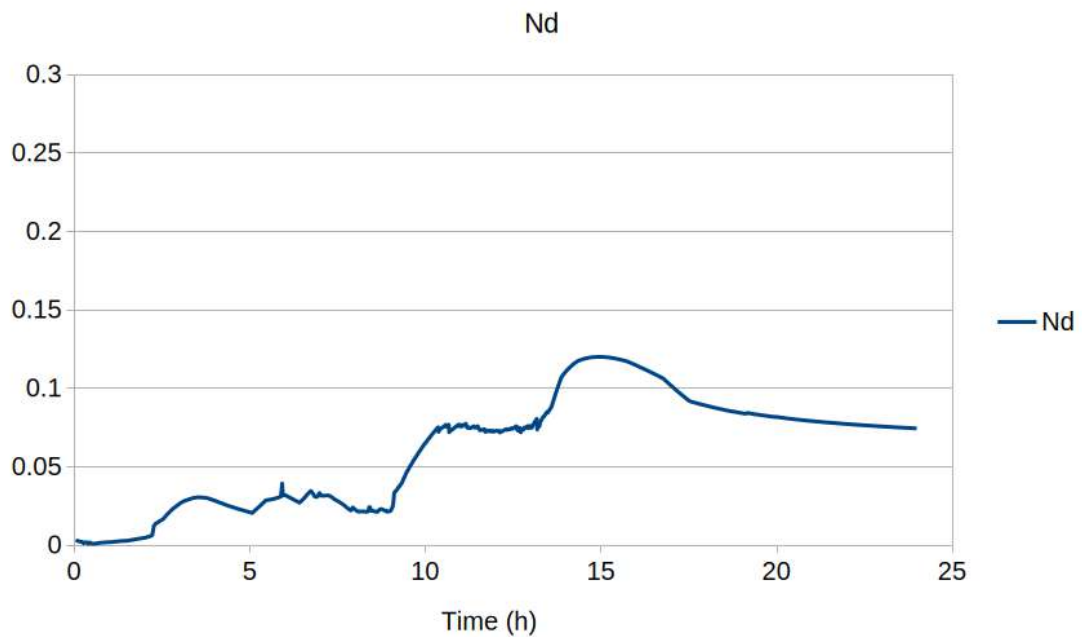


Figure 33: Variation of Nd throughout the baseline model duration

The Shallow Wave Celerity Number Nc shows slight fluctuation between 7.7 hours and 10 hours that exceeds recommended values in the manual as shown in Figure 34.

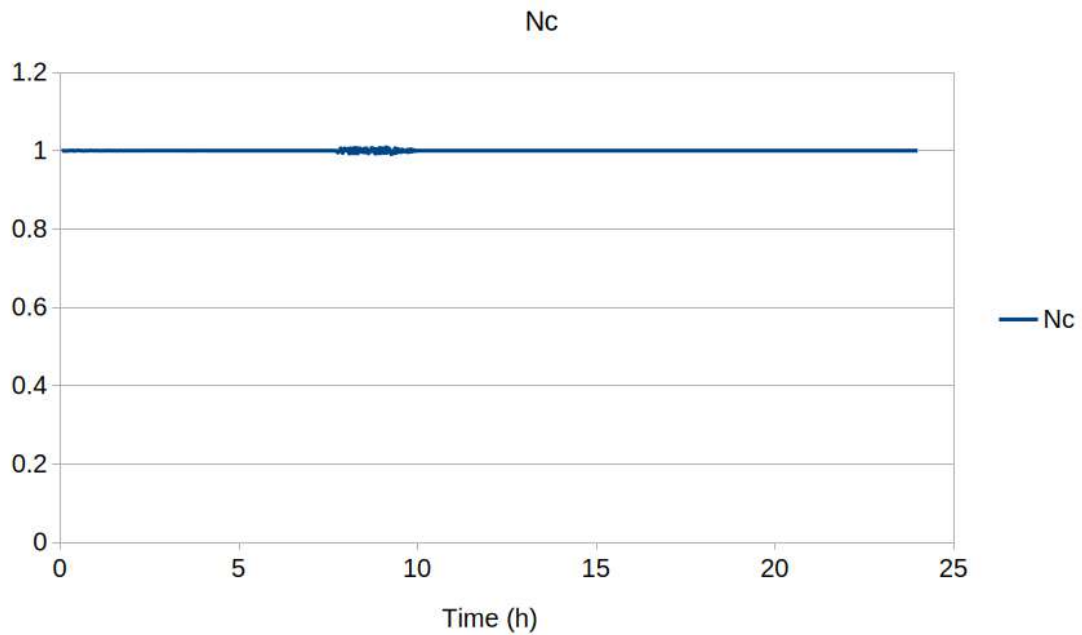


Figure 34: Variation of Nc throughout the baseline model duration

Review of the mapped timestep outputs confirmed this to be due to the deep water circulation in the Portway Pond which is downstream of the primary hydraulic control (Glovers Lane footbridge at the pond inlet). There are no stability issues that continue upstream beyond this point and therefore it has no impact on the peak flood level results at the site.

There are no mass balance issues in the 1D Estry component.

The final cumulative mass error for the majority of simulations was between -0.01% and 0.04% as shown in Figure 35. This is regarded as well within the expected bounds for a good model. The downstream boundary sensitivity tests experienced a higher cumulative mass error, most likely due to the significantly higher water levels at the boundary in the 2D domain, downstream of Glovers Lane. These will not have impacted the peak level results at the site.

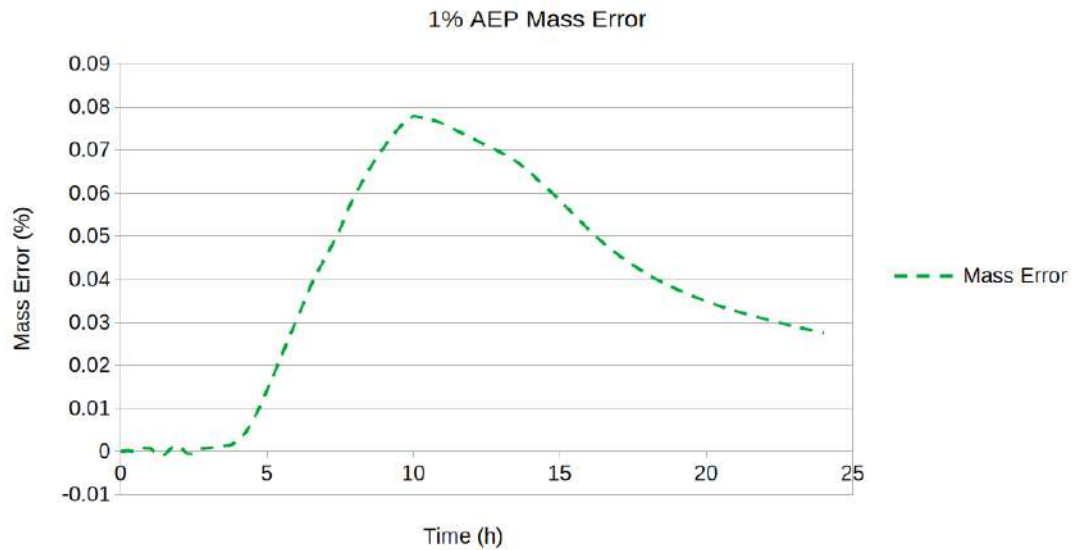


Figure 35: Variation of Mass Error throughout the baseline model duration

Likewise Figure 36 shows the variation in volume through the baseline model simulation.

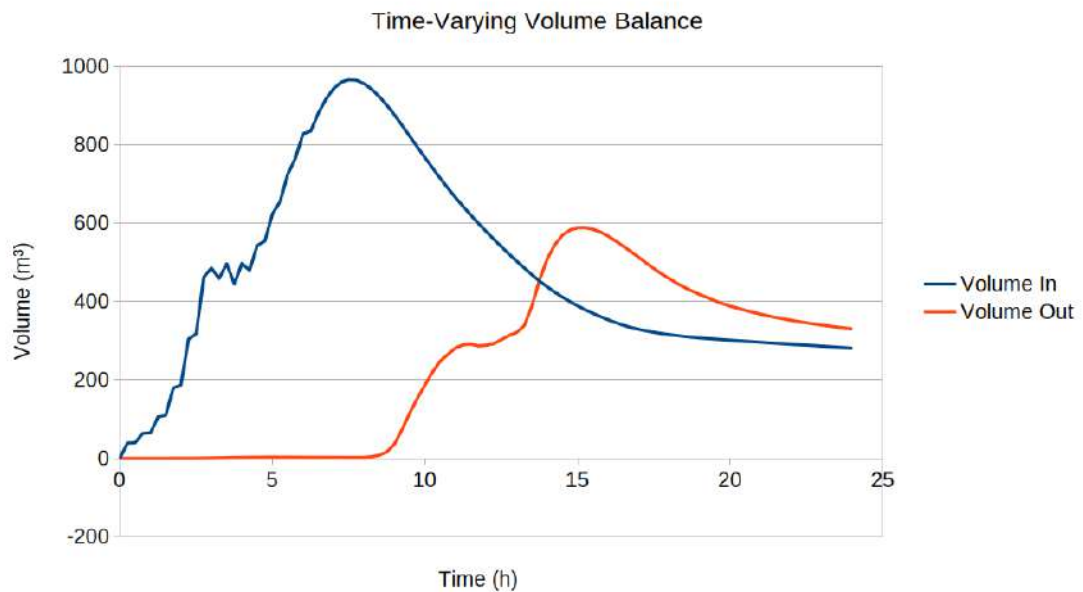


Figure 36: Variation of volume throughout the baseline model duration

The discrepancy in the volume balance is due to water being retained in Portway Pond and discharged very slowly.

7.3 Limitations

The modelling exercise has made best use of the available data at the time of model construction and simulations. There are no EA hydrometric gauges in the Portway Stream catchment and the baseline model results and sensitivity testing results are consistent with the out of bank flooding during the December 2023 flood event that has been photographed by residents on the proposed development site.

It produces similar but lesser flood extents when compared with the existing Environment Agency flood zone mapping on the proposed development site.

8. Conclusions

A new hydraulic model has been developed for the Portway Stream between the northern railway culvert and the River Were confluence, incorporating drainage ditches from the A350 and New Farm.

This new model has been developed by inclusion of 20 new surveyed cross sections and nine new structures, including the Govers Lane footbridge and the control and outlet structures on the Portway Pond.

The new model is a 1D/2D hydraulic model which uses the ESTRY software for the 1D component and TUFLOW for the floodplain areas. This conforms to Environment Agency best practice for hydraulic modelling.

In order to best represent flood risk from Arn Hill Down and on the development catchment itself, it makes use of a direct rainfall component for these areas.

It employs a fine scale 2m grid resolution for the floodplain areas.

The new model includes the latest 2022 Environment Agency LiDAR data.

The new model has also benefitted from detailed hydrological analysis, developed in accordance with the latest 2025 Environment Agency hydrological guidance.

Mapping results from the new model are qualitatively consistent with but of lesser extent than the current Environment Agency flood zones on the proposed development site.

The new model results show considerably reduced flood extent than the Environment Agency flood zones both upstream of the proposed development site and between the southern railway culvert and the River Were confluence.

The modeled flood extents for the 30 year return period (3.33%AEP) were compared with photographs of floodwater ponding upstream of the southern railway culvert and appeared to show good qualitative agreement.

9. Recommendations

The results from the new model could be used to update the current (November 2025) Environment Agency fluvial mapping for the Portway Stream catchment as they include additional cross section and survey data as well as being of fine grid resolution and making use of the latest (2022) Environment Agency LiDAR data.

Appendix A: Survey Drawings

Appendix B: FEH Calculation Record