JBA consulting

Hydraulic Modelling Study at Axmi_07, Axminster

Final Report

July 2024

Prepared for:

East Devon District Council

www.jbaconsulting.com

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Contract

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JBA Project Code	2023s1534

This report describes work commissioned by East Devon District Council, by an instruction dated 26th March 2024. The Client's representative for the contract was Linda Renshaw of East Devon District Council. Rebekah Alford of JBA Consulting carried out this work.

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Abbreviations

1D .... One Dimensional (modelling)

2D .... Two Dimensional (modelling)

AEP .... Annual Exceedance Probability

AOD .... Above Ordnance Datum

dVol .... Change in volume in the TUFLOW model since the previous time (m3)

FRA .... Flood Risk Assessment

HM .... Hydraulic Modelling

HR .... Hydraulic Research, Wallingford

JFLOW .... 2-D hydraulic modelling package developed by JBA

LiDAR .... Light Detection And Ranging

ME .... Mass Error

NGR .... National Grid Reference

OS .... Ordnance Survey

TUFLOW .... Two-dimensional Unsteady FLOW (a hydraulic model)

Executive Summary

JBA Consulting (JBA) were commissioned by East Devon District Council to undertake a hydraulic modelling study of an unnamed watercourses within the vicinity of the strategic developement site (Axmi_07), Axminster.

An unnamed watercourse flows in a westerly direction towards the site and then is culverted underneath. This unnamed watercourse confluences with the River Axe approximately 80m downstream of the site.

The Flood Map for Planning is currently derived from broadscale generalised hydraulic modelling, such as JFLOW. These broadscale models are known to typically have a conservative flood extent and do not explicitly model the channel capacity, or structures within the watercourse. The broadscale modelling is not appropriate for the assessment of flood risk at a site-specific level.

Therefore, a 1D-2D hydraulic model, suitable for a site-specific assessment, was developed using the ESTRY-TUFLOW modelling packages. The model extent included the site and the unnamed watercourse within the vicinity of the site.

In order to create the model, channel survey of the watercourses was collected by Infomap Surveys and Mapping and was used to represent the 1D model extent. Publicly available LiDAR data was used to represent ground levels within the 2D model extent (floodplain).

Hydrographs were derived for 3.3% AEP (1 in 30-year), 1% AEP (1 in 100-year) and 0.1% AEP (1 in 1,000-year) fluvial flood events. These hydrographs were applied directly to the model to provide an assessment of the current flood risk at the site. Further hydrographs were uplifted and applied to represent scenarios of 46% and 61% climate change.

The hydraulic modelling results show that:

- The west of the site is within the 3.3% AEP, 1% AEP and 0.1% AEP modelled fluvial flood extent for the baseline scenario.
- Typical depths across the site are less than 300mm during the 1% AEP plus climate change (61%) event. However, isolated maximum depths of up to 600mm may be observed on the site during this event.
- The 1% AEP plus climate change (61%) event maximum flood levels within the site range between 28.7m AOD and 24.9m AOD.
- The site has a low Hazard-to-People Classification across most of the site due to the shallow depths during the 1% AEP plus climate change (61%) event.

1 Introduction

1.1 Terms of Reference

JBA Consulting (JBA) were commissioned by East Devon District Council to undertake a hydraulic modelling study of an unnamed watercourses within the vicinity of the strategic developement site (Axmi_07) at Axminster (hereafter referred to as 'the site').

1.2 Site Description

The site is located in the south of Axminster, Devon. An unnamed watercourse flows in a westerly direction towards the site and then is culverted underneath. This unnamed watercourse confluences with the River Axe approximately 80m downstream of the site. Further information regarding the site is included in

Table 1-1 and Figure 1-1.

Table 1-1: Summary of Site Details

Site address	Axminster Carpets, Axminster
Site area	5 hectares
Existing land-use	Brownfield
OS-NGR	SY 29286 97952
Country	England
County	Devon

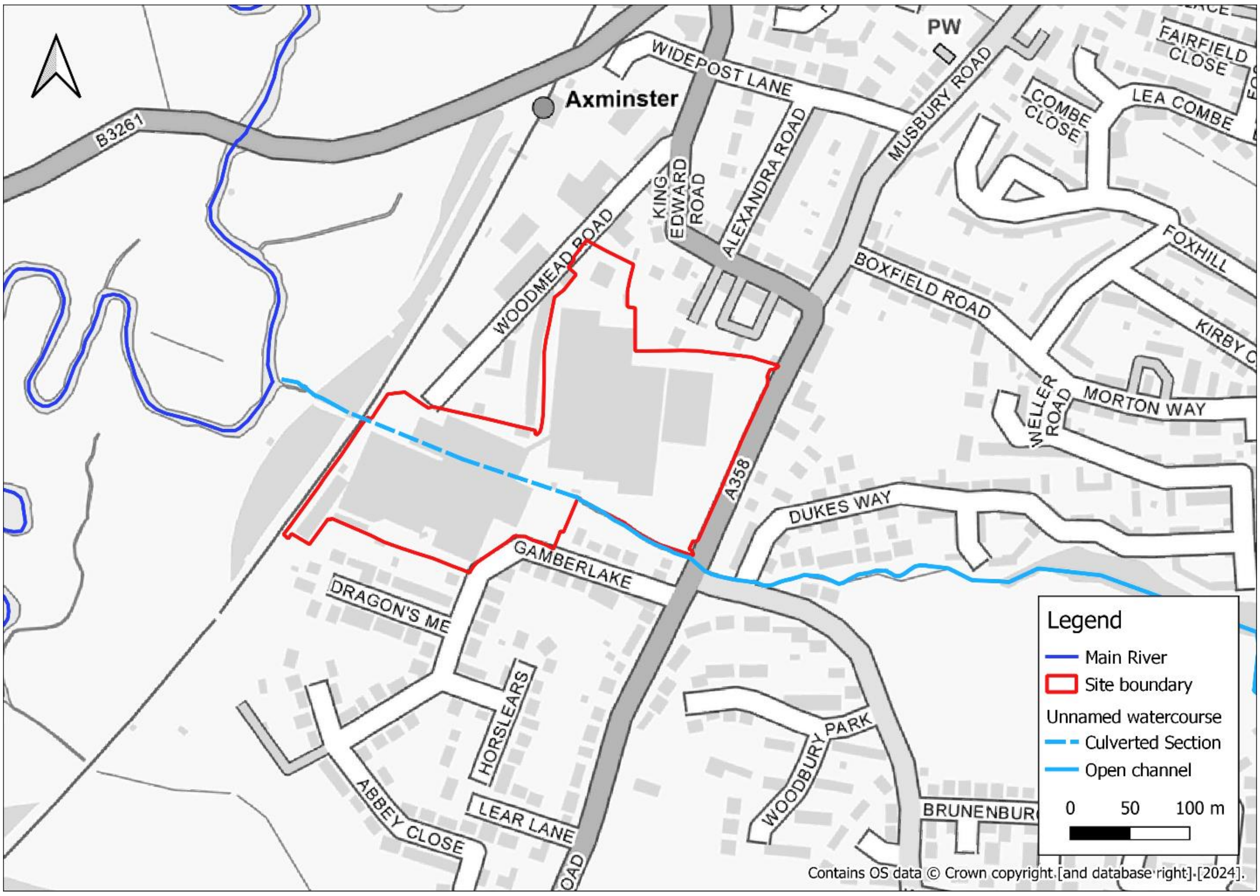

Figure 1-1: Site and watercourses

1.3 General Approach

A 1D-2D hydraulic model was developed using the ESTRY-TUFLOW modelling packages. The model extent included the site and the unnamed watercourse from upstream of the site until it's confluenece with the River Axe, in order to determine the flood mechanisms.

The Flood Map for Planning is currently derived from broadscale generalised hydraulic modelling, such as JFLOW. These broadscale models are known to typically have a conservative flood extent and do not explicitly model the channel capacity, or structures within the watercourse. The broadscale modelling is not appropriate for the assessment of flood risk at a site-specific level.

In order to create a model suitable for a site-specific assessment, channel survey of the watercourses was undertaken by Infomap Surveys and Mapping in April 2024 and was used to represent the 1D model extent. Publicly available LiDAR data was used to represent ground levels within the 2D model extent (floodplain).

Hydrographs were derived for the 3.3% AEP (1 in 30-year), 1% AEP (1 in 100-year), and 0.1% AEP (1 in 1,000-year) fluvial flood events. These hydrographs were applied directly to the model to provide an assessment of the baseline flood risk at the site.

Hydrographs were subsequently uplifted to represent 46% and 61% climate change scenarios.

In line with best practice, the model's sensitivity to roughness, flow and downstream boundary parameters were tested to improve confidence in the model results.

A blockage scenario of 75% has been applied to the long culvert running under the site.

2 Methodology

2.1 Data availability

Infomap Surveys and Mapping collected hard bed channel cross-section data for the watercourses located upstream and downstream of the site in April 2024. In total the survey consisted of 17 cross sections taken at regular intervals along the watercourse and at key hydraulic structures. The survey is included in Appendix A.

Defra LiDAR was obtained from the Open Data website to represent ground levels within the wider flood plain. The LiDAR has a grid resolution of 1m and was last flown in 2022.

2.2 Model extent and build

A 1D-2D ESTRY-TUFLOW model was built to represent the watercourses within the vicinity of the site. The model was simulated using TUFLOW version 2023-03-AE-iSP-w64.

The channel was represented within the 1D domain using ESTRY. Channel cross sections were constructed from the channel survey collected by Infomap Surveys and Mapping in March 2024. The 1D ESTRY model, shown in Figure 2-1 covers approximately 585m of watercourse within the vicinity of the site. Detailed information on the hydraulic structures within the model are provided as part of Appendix B.

Channel cross sections were trimmed to the top of bank and linked to the 2D domain representing the floodplain. The 2D TUFLOW domain has an area of 0.21km^2 and is represented with a 1m grid resolution. LiDAR data was used to inform the model topography across the wider floodplain. Bank levels were represented using a 2D Z line which used survey bank levels from the 1D channel survey and LiDAR data along areas between surveyed cross-sections.

The extents of the 1D and 2D model domains are shown in Figure 2-1 below.

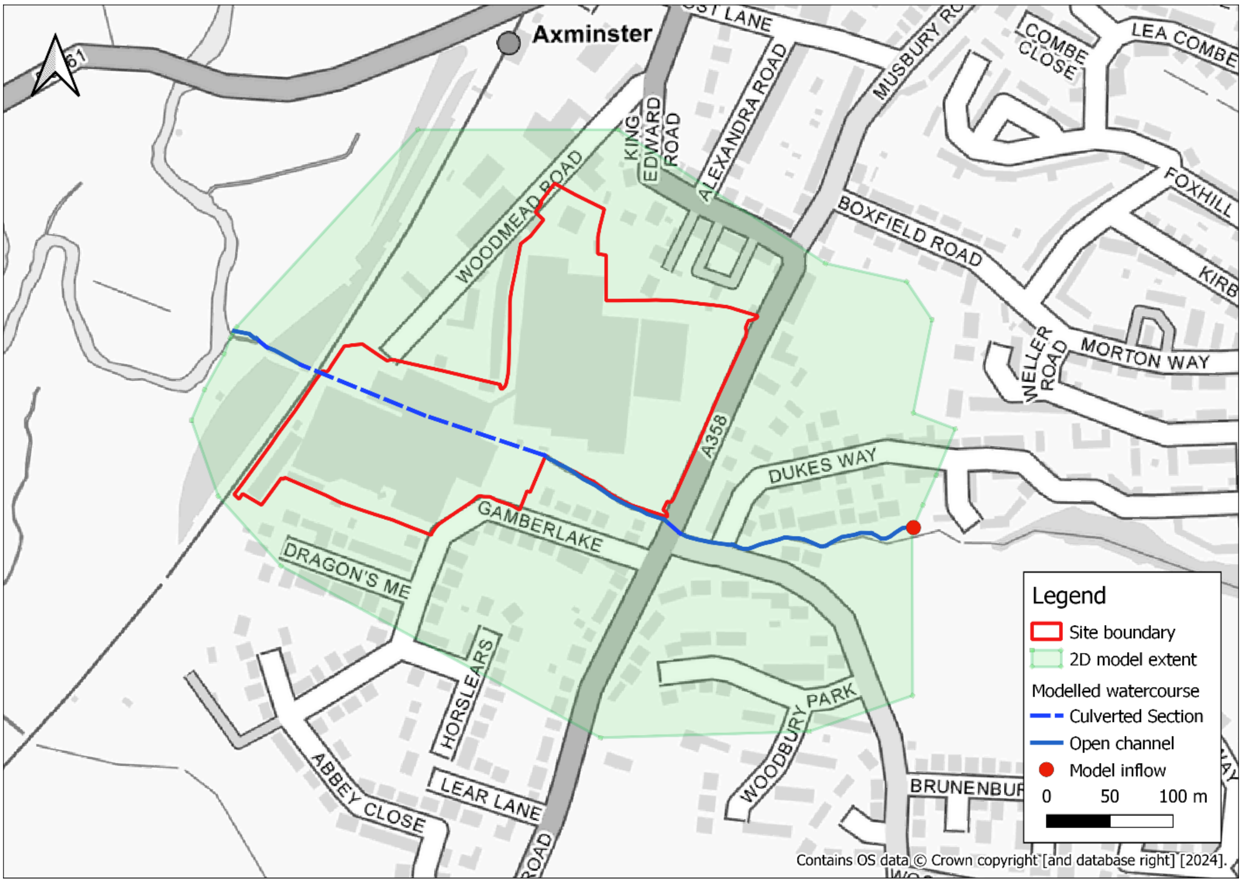

Figure 2-1: Modelled 1D and 2D domains

Figure 2-2 shows the topography shown within the LiDAR data. It shows that, within the 2D domain, ground levels fall from approximately 48mAOD in the south and 41mAOD to in the north to 23mAOD to the west of the site.

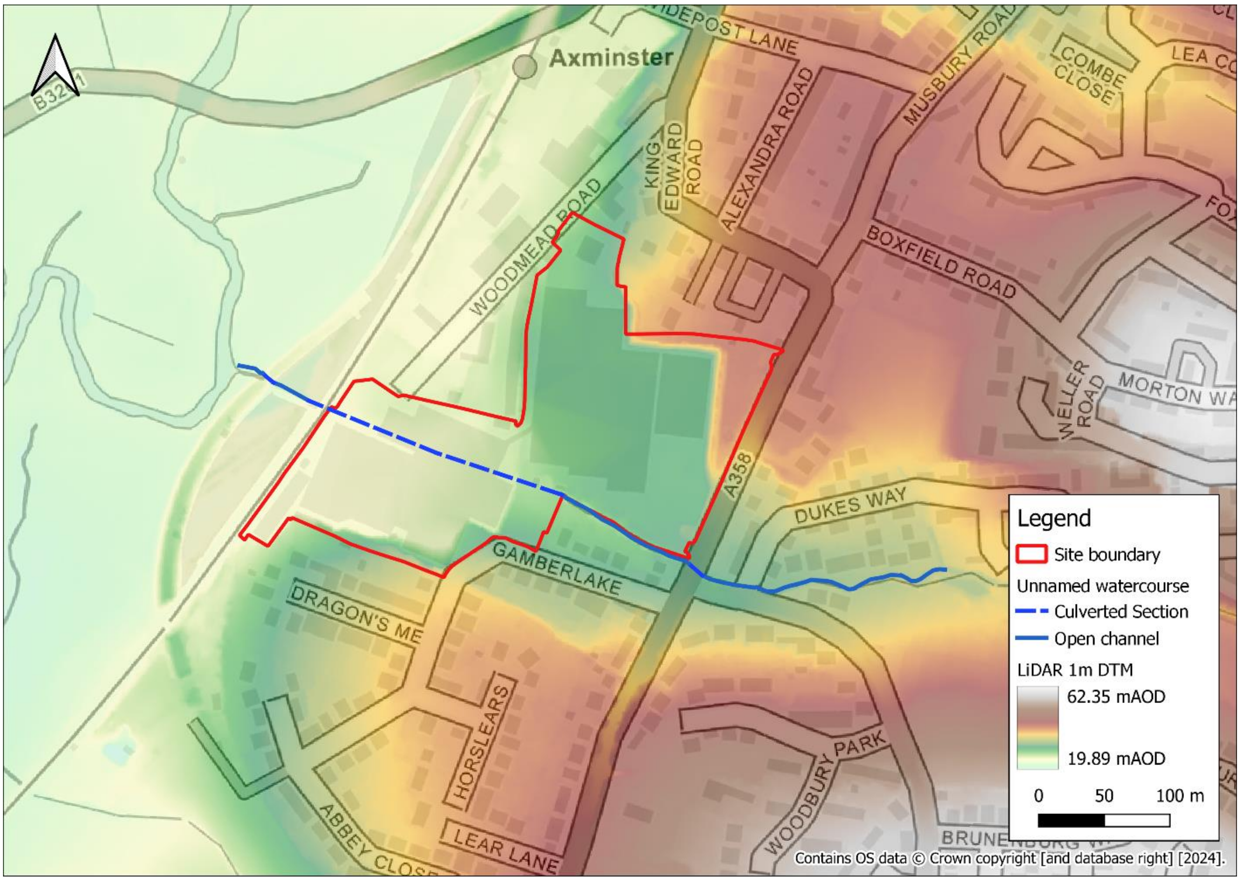

Figure 2-2: Model ground levels (m AOD)

2.3 Model boundary conditions

2.3.1 Model inflows

A hydrological assessment was carried out in order to derive the peak flow estimates for the unnamed watercourse and tributaries.

The full hydrological assessment is included in Appendix C. Flow-time hydrographs were estimated for the 3.3% AEP (1 in 30-year), 1% AEP (1 in 100-year), 1% AEP plus climate change, and 0.1% AEP (1 in 1,000-year) fluvial flood events.

Climate change allowances were applied in line with the latest 2021 Environment Agency Guidance with all flows uplifted by 46% and 61% (ref: Central and higher allowances for the 2080's epoch, East Devon Management Catchment).

The flow from the watercourse has been represented as a point inflows into the hydraulic model.

2.3.2 Downstream boundary conditions

The downstream boundary of the model is located approximately 80m west of the site, at the confluence with the River Axe. The downstream boundary of the 1D domain has been represented using a Water Level (Head) versus Flow (m) (HQ) boundaries, with the slope calculated from the riverbed and water level taken from the Infomap Surveys and Mapping channel survey collected in April 2024. Sensitivity testing has been undertaken to consider the impact of levels from the River Axe on the tributary. This was found not to have an impact on the flood levels on the site. Results can be seen in Appendix D.2.

Water Level (Head) versus Flow (m) (HQ) boundaries have been applied to the downstream boundary of the floodplain within the 2D domain, with the slope determined using the 1m LIDAR DTM.

2.4 Model roughness

Manning's "n" values were used to represent the roughness within both the 1D channel and 2D floodplain.

The values of the 1D roughness were based on photographs provided by Infomap Surveys and Mapping within the channel survey document. Manning's 'n' values in the floodplain (2D) were set to represent different land uses within the model extent. Land uses were defined using OS mapping. The range of Manning's "n" values used is shown in Table 2-1

Table 2-1: Manning's 'n' range within the hydraulic model

Features	Manning's 'n' value assigned
Buildings	0.3
Road and Tracks	0.025
General surface	0.05
Woodland / Vegetation	0.07
Channel roughness	0.02 to 0.07

2.5 Calibration and model performance

2.5.1 Calibration

There is no hydrometric information available for the watercourse, and the catchment upstream is ungauged. Therefore, no data specific to the catchment was available to assist with the preparation of the design hydrology or model verification/calibration. An internet search of the historical flood records for the site was undertaken but no site-specific records were found.

2.5.2 Model performance

During the model simulations the maximum cumulative mass error was -0.26% during the 0.1% AEP event as shown in Figure 2-3. This is within the acceptable range of +/-1%.

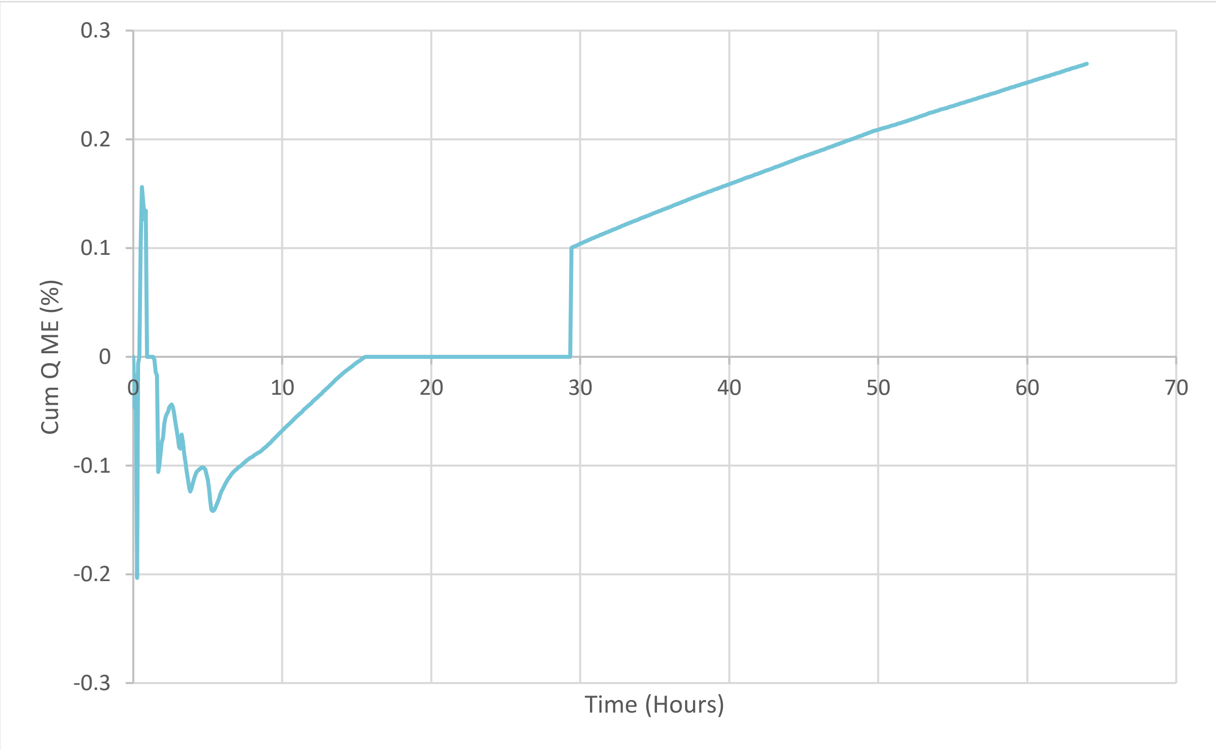

Figure 2-3: 0.1% AEP baseline cumulative ME (%)

A series of other stability checks have been conducted for the hydraulic model. The change in volume (dVol) results in Figure 2-4 show the dVol peaks at approximately 3 hours with a value of approximately 289m³. This is within an acceptable range and suggests the model is stable.

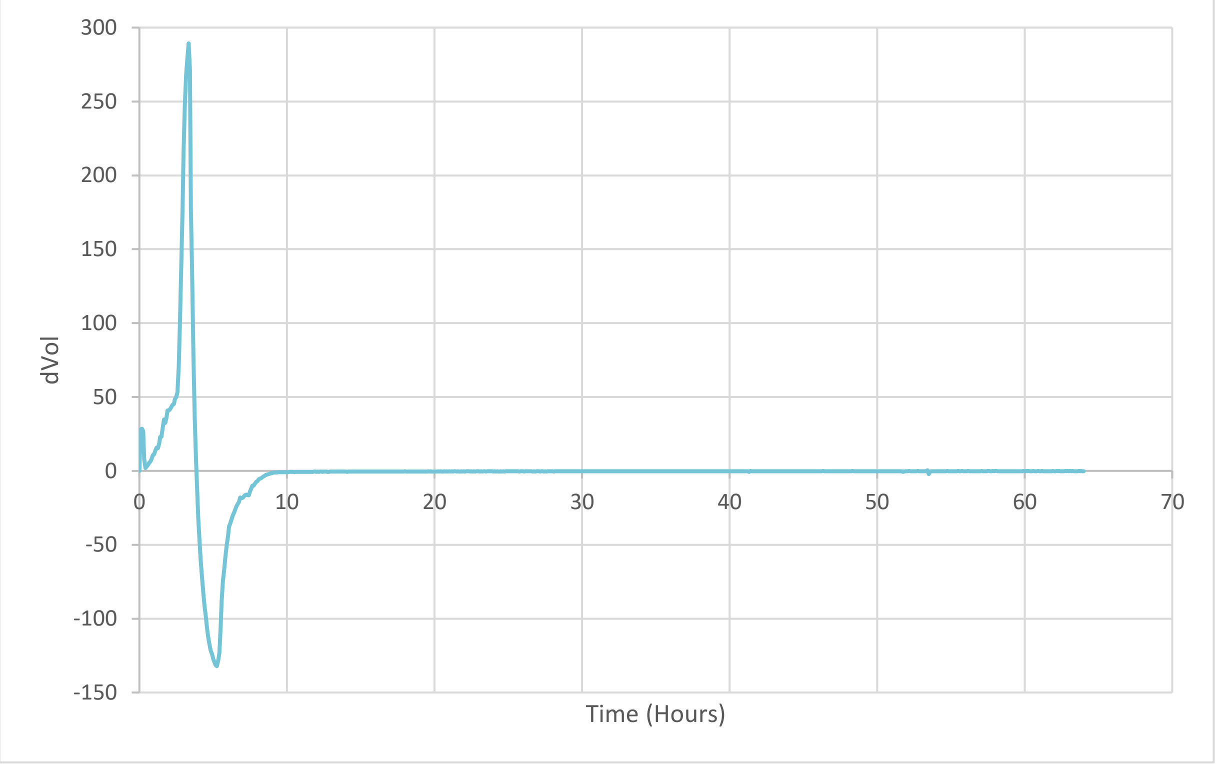

Figure 2-4: 0.1% AEP baseline dVol plot

2.6 Sensitivity analysis

A review into the model's sensitivity to changes in flow, roughness and downstream boundary parameters has been undertaken in line with best practices. The model is sensitive to increases in roughness and flow but insensitive to changes in downstream boundary conditions. The roughness parameters and inflows have been checked and follow best practice and are therefore considered to be appropriate for the modelling. This sensitivity analysis provides confidence in the results of the modelling. Further details of the sensitivity analysis can be found in Appendix D.

2.7 Model runs

The following scenarios and events were simulated using the hydraulic model:

- [Existing condition] - 3.3% AEP (1 in 30-year) event
- [Existing condition] - 1% AEP (1 in 100-year) event
- [Existing condition] - 0.1% AEP (1 in 1000-year) event
- [2080 central allowance] - 3.3% AEP plus 46% climate change (1 in 30-year) event
- [2080 central allowance] - 1% AEP plus 46% climate change (1 in 100-year) event
- [2080 central allowance] - 0.1% AEP plus 46% climate change (1 in 1000-year) event
- [2080 higher allowance] - 3.3% AEP plus 61% climate change (1 in 30-year) event
- [2080 higher allowance] - 1% AEP plus 61% climate change (1 in 100-year) event
- [2080 higher allowance] - 0.1% AEP plus 61% climate change (1 in 1000-year) event
- [Sensitivity Analysis] –1% AEP event with [+ 20%] increase in roughness
- [Sensitivity Analysis] – 1% AEP event with HT boundary and increase in water level at model boundary to represent level of River Axe.
- [Sensitivity Analysis] – 1% AEP event with [+20%] increase in flow

3 Baseline Model Results

3.1 Baseline flood extents

Baseline flood extents for the 3.3% AEP (1 in 30-year), 1% AEP (1 in 100-year) and 0.1% AEP (1 in 1000-year) fluvial events are shown in Figure 3-1. This shows that the west of the site is within the 3.3% AEP, 1% AEP and 0.1% AEP modelled events for the baseline scenario.

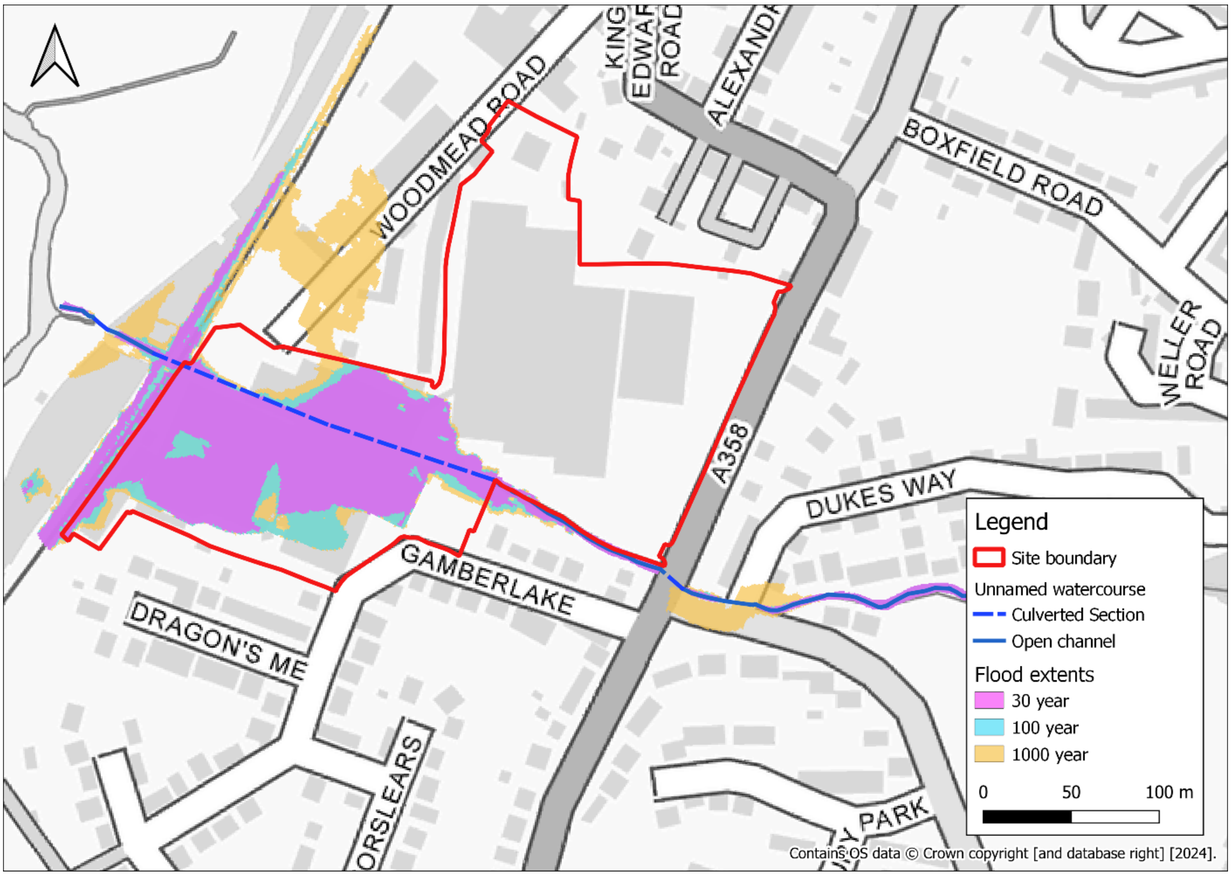

Figure 3-1: Baseline flood extents - 3.3% AEP (1 in 30-year), 1% AEP (1 in 100-year) and 0.1% AEP (1 in 1000-year)

The 1% AEP plus climate change (61%) peak modelled flood extent is shown in Figure 3-2. This shows that the north-east of the site is within the 1% AEP plus climate change (61%) flood extent.

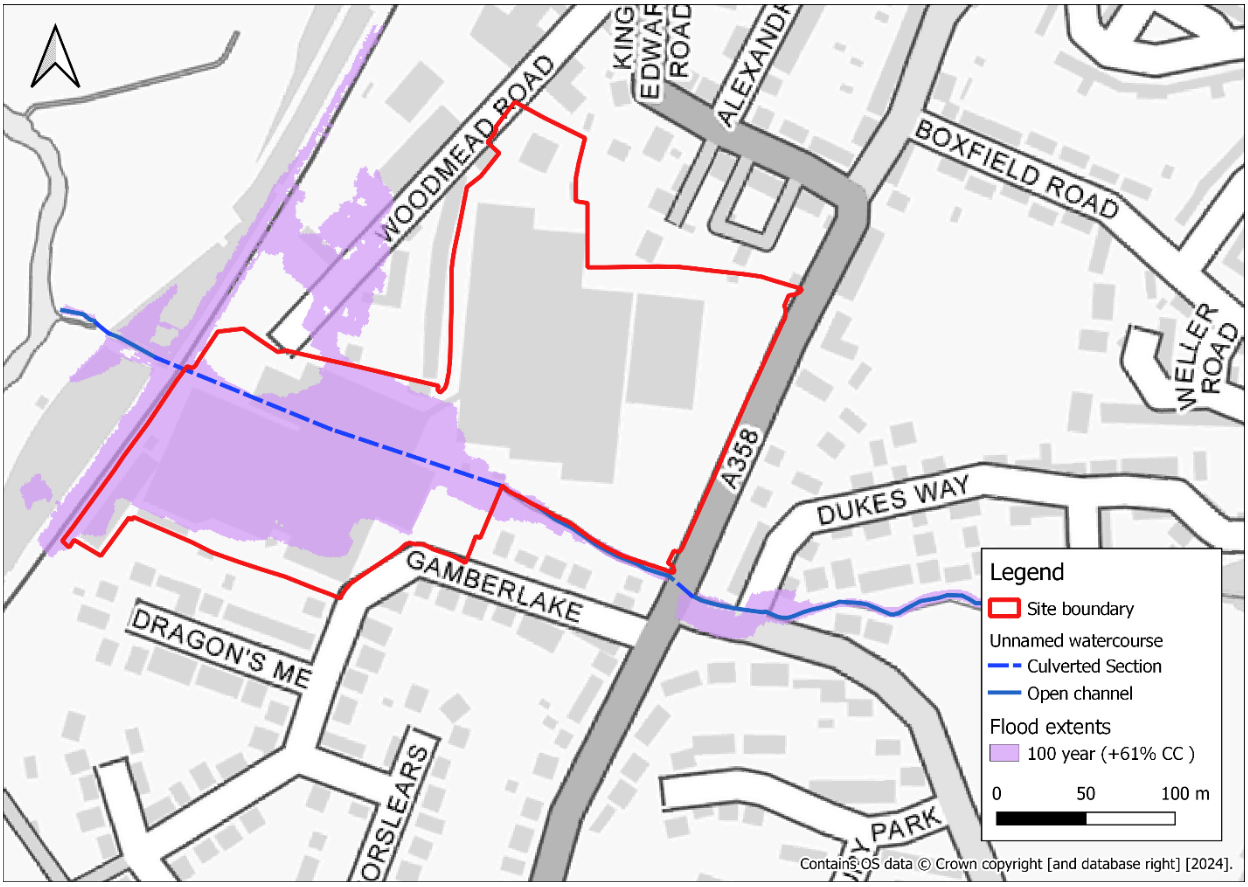

Figure 3-2: 1% AEP plus climate change (61%) flood extent

3.1.1 Peak modelled flood depths

The peak modelled flood depths during the 1% AEP plus climate change (61%) flood event are shown in Figure 3-3.

This indicates that typical depths across the site are less than 300mm during this event. However, isolated flood depths of up to 600mm may be observed within the site boundary. Flood depths are expected to be deeper along the bank of the tributary flowing south to north through the site and upstream of the A358 culvert and the disused railway culvert.

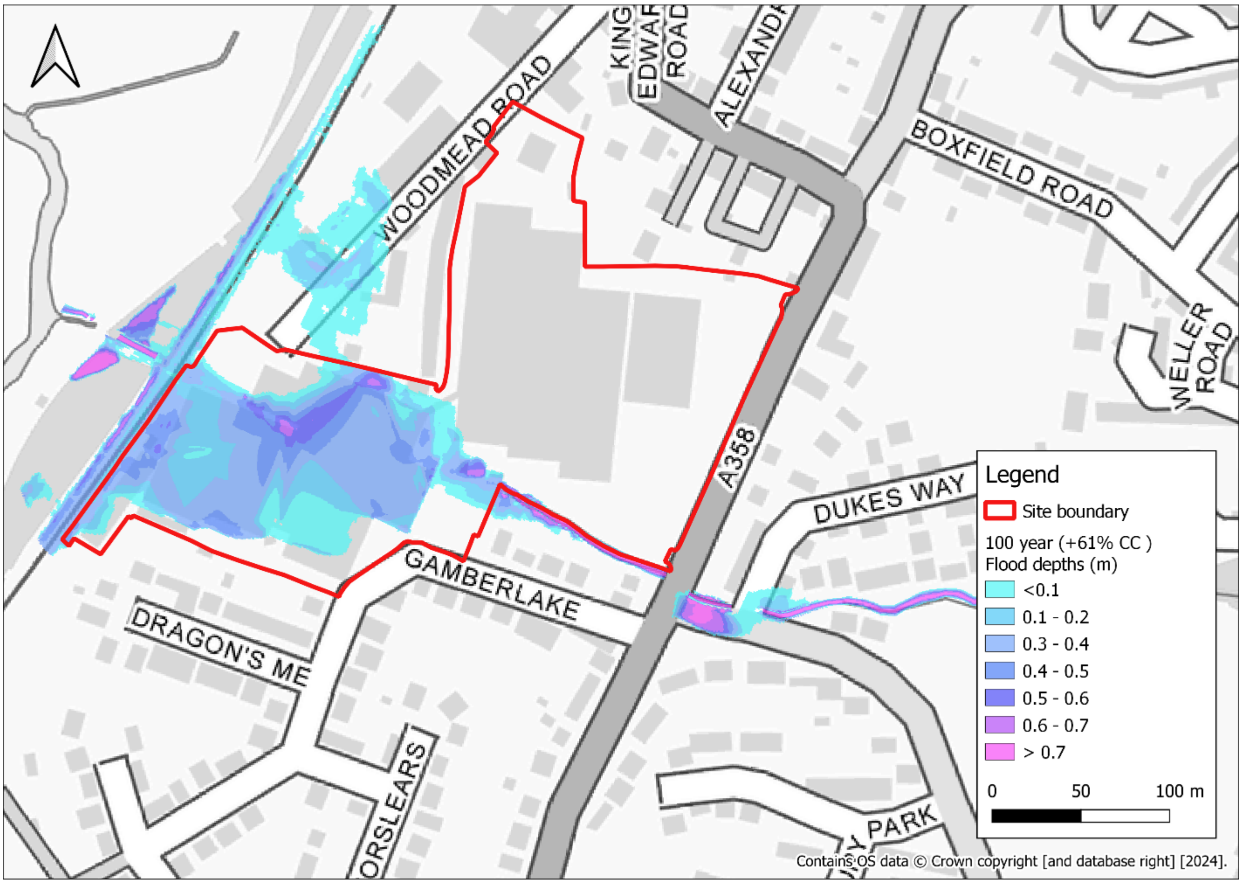

Figure 3-3: 1% AEP plus climate change (61%) maximum flood depths

3.1.2 Peak modelled flood levels

The peak modelled flood levels during the 1% AEP plus climate change (61%) flood event are shown in Figure 3-4. This shows that the 1% AEP plus climate change (61%) maximum flood levels within the site range between 28.7m AOD and 24.9m AOD.

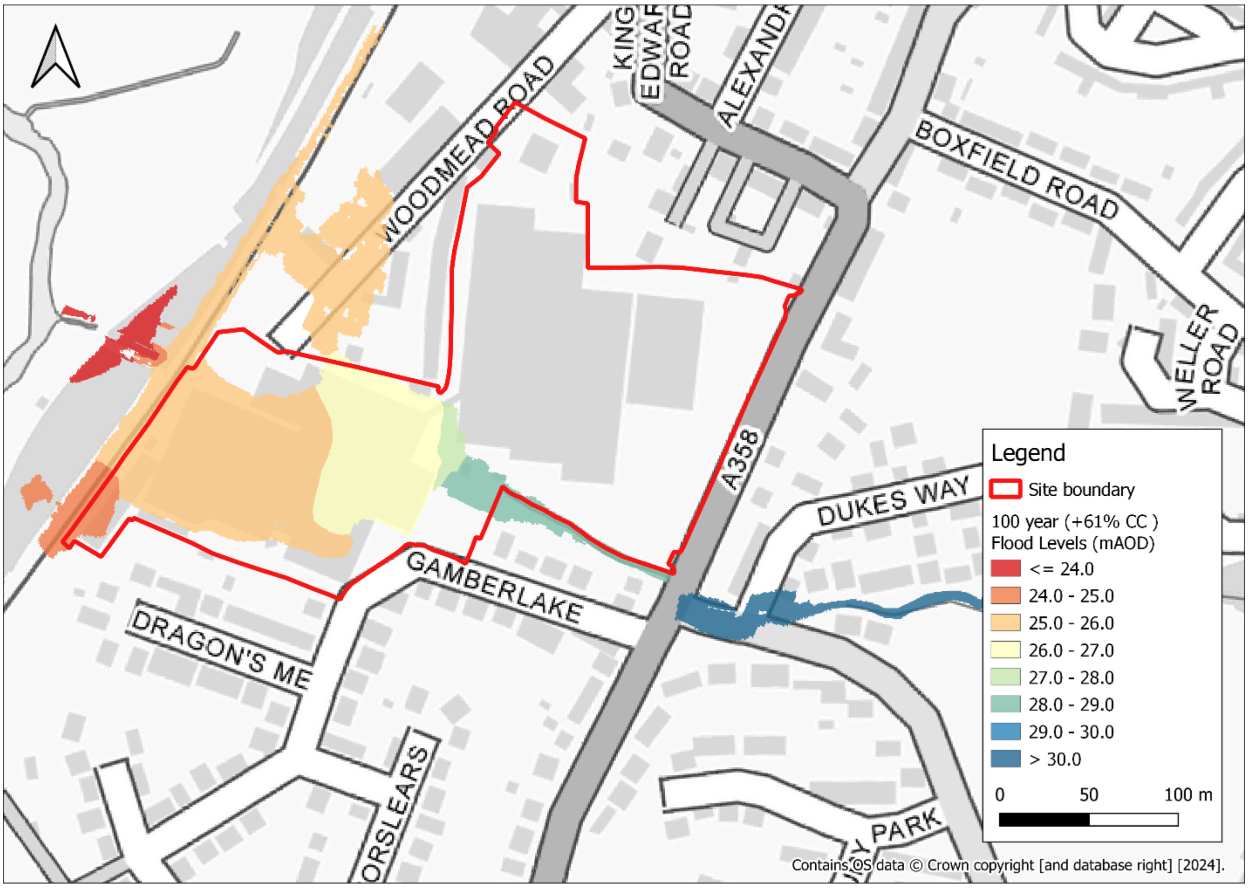

Figure 3-4: 1% AEP plus climate change (61%) flood levels

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3.1.3 Hazard-to-People Classification

The fluvial Hazard-to-People Classification during the 1% AEP plus climate change 61%) flood event has been mapped using the formula as suggested in Defra's FD2321/TR2 "Flood Risk to People". The different hazard categories are shown in Table 3-1 and the Hazard Classification at the site during the 1% AEP plus climate change (61%) flood event is shown in Figure 3-5.

Figure 3 5 shows that the site has a low Hazard-to-People Classification across most of the site during the 1% AEP plus climate change (4%) event. A moderate and significant Hazard-to-People Classification is present in isolated areas across the site, presenting a 'danger for some' risk and 'danger for most' risk.

Table 3-1: Defra's FD2321/TR2 "Flood Risks to People" Classification

Flood hazard rating depth x (velocity+0.5) +DF	Level of Flood Hazard Description	Class label
<0.75	Low	Caution "Flood zone with shallow flowing water or deep standing water"
0.75 to 1.25	Moderate	Dangerous for some (i.e. Children) "Danger: flood zone with deep or fast flowing water"
1.25 to 2.00	Significant	Dangerous for most "Danger: flood zone with deep fast flowing water"
>2.00	Extreme	Dangerous for all "Extreme danger: flood zone with deep fast flowing water"
Using the hazard equation HR = d*(v+0.5) + DF Where d = depth of flooding (m), v = velocity of floodwaters (m/s), DF = debris factor		

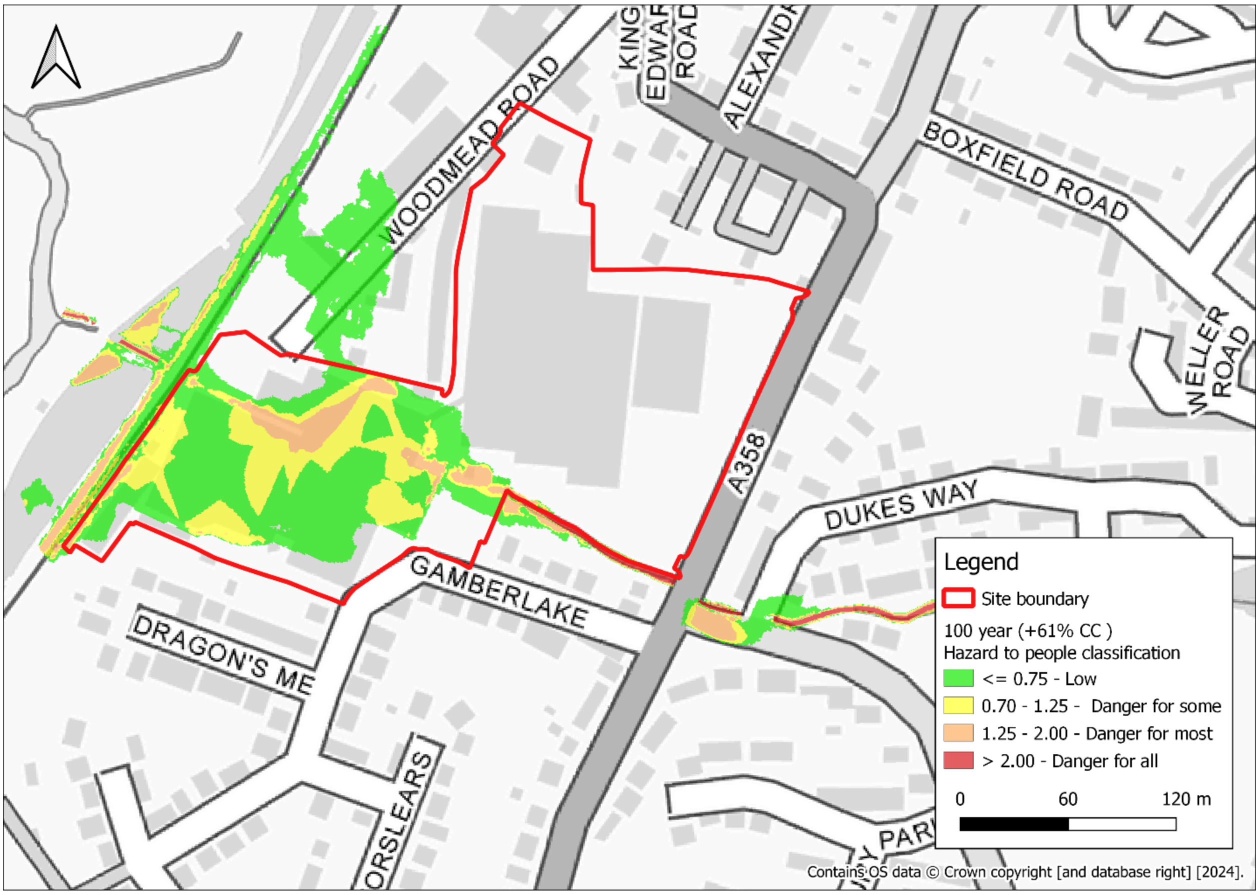


Figure 3-5: 1% AEP plus climate change (61%) Hazard-to-People Classification

4 Conclusion

4.1 Conclusion

- JBA Consulting (JBA) were commissioned by East Devon District Council to undertake a hydraulic modelling study of an unnamed watercourses within the vicinity of the strategic developement site (Axmi_07), Axminster.
- A 1D-2D hydraulic model was developed using the ESTRY-TUFLOW modelling packages. The model extent included the Site and the unnamed watercourses within the vicinity of the Site.
- In order to create the model, channel survey of the watercourses was collected by Infomap Surveys and Mapping and was used to represent the 1D model extent. Publicly available LiDAR data was used to represent ground levels within the 2D model extent (floodplain).
- Hydrographs were derived for the 3.3% AEP (1 in 30-year), 1% AEP (1 in 100-year) and 0.1% AEP (1 in 1,000-year) fluvial flood events. These hydrographs were applied directly to the model to provide an assessment of the baseline flood risk of the site. Further uplifted hydrographs to represent the 46% and 61% climate change scenarios were also apllied.
- The hydraulic modelling results show that:
    - The west of the site is within the 3.3% AEP, 1% AEP and 0.1% AEP modelled fluvial flood extent for the baseline scenario.
    - Typical depths across the site are less than 300mm during the 1% AEP plus climate change (61%) event. However, isolated maximum depths of up to 600mm may be observed on the site during this event.
    - The 1% AEP plus climate change (61%) event maximum flood levels within the site range between 28.7m AOD and 24.9m AOD.
    - The site has a low Hazard-to-People Classification across most of the site due to the shallow depths during the 1% AEP plus climate change (61%) event.

A Survey

A.1 Channel survey

B Key Hydraulic Structures and non-standard channel representation

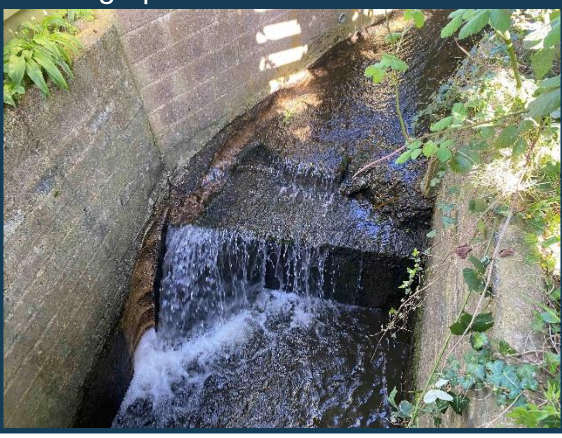
B.1 Wier

Included in model?	Yes
Model label:	AXEW_513w
Type:	Wier
How has structure been modelled?	The structure was modelled as weir unit using ESTRY. Channel geometry is represented using an XZ table. The following modelling parameters were used:

ID	AXEW_513w
Type	WW
Ignore	F
UCS	T
Len_or_ANA	NULL
n_nF_Cd	1.00000
US_Invert	30.08000
DS_Invert	28.88000
Form_Loss	NULL
pBlockage	NULL
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	NULL
Height_or_	NULL
Number_of	NULL
HConF_or_W	NULL
WConF_or_W	NULL
EntryC_or_	NULL
ExitC_or_W	NULL
eS1	NULL
eS2	NULL
eN1	NULL
eN2	NULL
eN3	NULL
eN4	NULL
eN5	NULL
eN6	NULL
eN7	NULL
eN8	NULL

AXEW_433w.csv	
X	Z
0	31.27
0.03	30.12
1.68	30.08
1.68	31.28
1.76	31.31

Looking upstream from :



B.2 Dukes way culvert

Included in model?	Yes
Model label:	AXEW_433r
Type:	Rectangular culvert
How has structure been modelled?	The structure was modelled as a rectangular culvert unit using ESTRY. Overtopping of the structure is modelled in the 2D domain. Bridge deck elevations are picked up in LIDAR with a z shape used to ammend with a MAX NO MERGE function to raise any points lower than the bridge deck height form the channel survey. There is a pipe crossing within the culvert which has been represented using a 9% blockage. The following modelling parameters were used:

ID	AXEW_433r
Type	R
Ignore	F
UCS	T
Len_or_ANA	15.90000
n_nF_Cd	0.02
US_Invert	28.83000
DS_Invert	29.21000
Form_Loss	NULL
pBlockage	NULL
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	1.61000
Height_or_	2.01000
Number_of	1
HConF_or_W	0.6
WConF_or_W	0.9
EntryC_or_	0.5
ExitC_or_W	1.00000
eS1	NULL
eS2	NULL
eN1	NULL
eN2	NULL
eN3	NULL
eN4	NULL
eN5	NULL
eN6	NULL
eN7	NULL
eN8	NULL

Upstream face, looking downstream:

Downstream face, looking upstream:

B.3 A358 Culvert

Included in model?	Yes
Model label:	AXEW_392 and AXEW_392w
Type:	Irregular culvert
How has structure been modelled?	The structure was modelled as an irregular culvert unit using ESTRY. A separate wier unit was included immediately downstream to represent the wier within the culvert. The opening geometry is specified in an HW table. The culvert geometry changes midway through but only the culvert entrance and exit were available so the culvert exit has been used as the geometry for the whole culvert as this was the most constraining. There is a pipe crossing within the culvert but this has not been modelled. Overtopping of the structure is modelled in the 2D domain. Bridge deck elevations are picked up in LIDAR with a z shape used to ammend with a MAX NO MERGE function to raise any points lower than the bridge deck height from the channel survey. The following modelling parameters were used:

ID	AXEW_392
Type	I
Ignore	F
UCS	T
Len_or_ANA	14.29000
n_nF_Cd	0.02
US_Invert	28.84000
DS_Invert	28.82000
Form_Loss	NULL
pBlockage	NULL
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	NULL
Height_or_	NULL
Number_of	1
HConF_or_W	0
WConF_or_W	1.00000
EntryC_or_	0.5
ExitC_or_W	1.00000
eS1	NULL
eS2	NULL
eN1	NULL
eN2	NULL
eN3	NULL
eN4	NULL
eN5	NULL
eN6	NULL
eN7	NULL
eN8	NULL

ID	AXEW_392w
Type	WW
Ignore	F
UCS	T
Len_or_ANA	1.00000
n_nF_Cd	NULL
US_Invert	28.82000
DS_Invert	28.06000
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WConF_or_W	NULL
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ExitC_or_W	NULL
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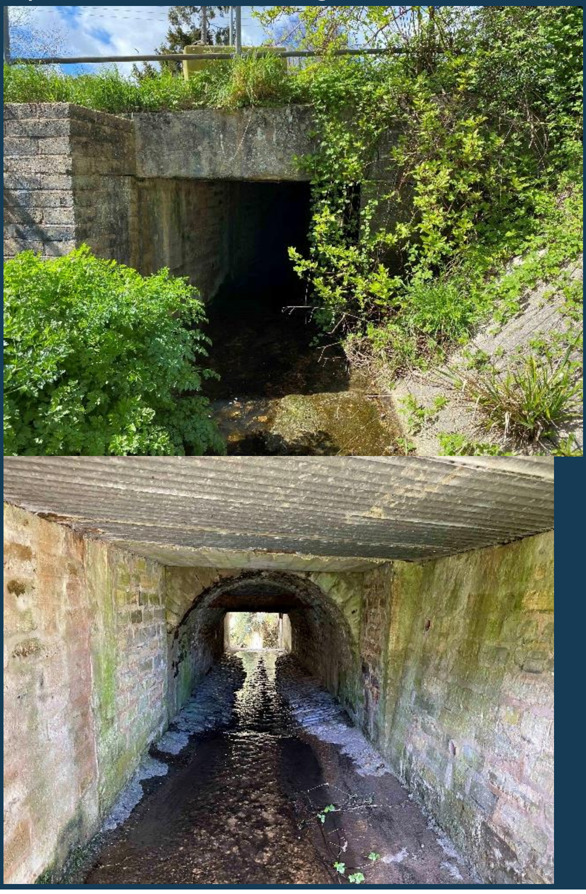
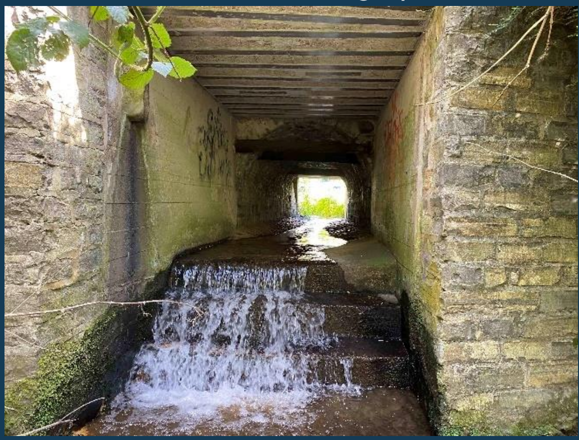
eS2	NULL
eN1	NULL
eN2	NULL
eN3	NULL
eN4	NULL
eN5	NULL
eN6	NULL
eN7	NULL
eN8	NULL

AXEW_392i.csv

H	W
28.84	0
28.9	0.39
29	1.9
29.1	1.9
29.2	1.9
29.3	1.9
29.4	1.9
29.5	1.9
29.6	1.9
29.7	1.9
29.8	1.87
29.9	1.81
30	1.73
30.1	1.62
30.2	1.47
30.3	1.28
30.4	1.01
30.5	0.58
30.55	0

Upstream face, looking downstream:	Downstream face, looking upstream:
	

B.4 Footbridge

Included in model?	Yes
Model label:	AXEW_277b and AXEW_277
Type:	BBW bridge and SN channel section
How has structure been modelled?	The structure was modelled as BBW bridge unit using ESTRY. Opening geometry is represented using an XZ table. Overtopping has been modelled in the 1D domain using a ‘BBW’ weir unit. The channel section immediately downstream had a high slope for it's length and was causing 1D negative depths when modelled as an oopen channel (S unit), so this was ammended to an SN unit to remove negative depths.The following modelling parameters were used for AXEW_277b:

ID	AXEW_277b
Type	BBW
Ignore	F
UCS	T
Len_or_ANA	1.20000
n_nF_Cd	NULL
US_Invert	-99999.00000
DS_Invert	-99999.00000
Form_Loss	0.001
pBlockage	NULL
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	NULL
Height_or_	NULL
Number_of	NULL
HConF_or_W	NULL
WConF_or_W	NULL
EntryC_or_	NULL
ExitC_or_W	NULL
eS1	NULL
eS2	NULL
eN1	2.15000
eN2	0.2
eN3	1.00000
eN4	2.00000
eN5	0.88
eN6	NULL
eN7	NULL
eN8	NULL

AXEW_277b.csv	
X	Z
0	28.34
0	26.8
0.9	26.82
1.35	26.81
2.15	26.93
2.15	28.34

Upstream face, looking downstream:

Downstream face, looking upstream:
N/A

B.5 Footbridge

Included in model?	Yes
Model label:	AXEW_274b
Type:	BBW bridge
How has structure been modelled?	The structure was modelled as BBW bridge unit using ESTRY. Opening geometry is represented using an XZ table. The trash sceen has not been modelled. Overtopping has been modelled in the 1D domain using a 'BBW' weir unit. The following modelling parameters were used:

ID	AXEW_274b
Type	BBW
Ignore	F
UCS	T
Len_or_ANA	1.25000
n_nF_Cd	NULL
US_Invert	-99999.00000
DS_Invert	-99999.00000
Form_Loss	0.001
pBlockage	NULL
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	NULL
Height_or_	NULL
Number_of	NULL
HConF_or_W	NULL
WConF_or_W	NULL
EntryC_or_	NULL
ExitC_or_W	NULL
eS1	NULL
eS2	NULL
eN1	2.02000
eN2	0.2
eN3	1.02000
eN4	2.00000
eN5	0.88
eN6	NULL
eN7	NULL
eN8	NULL

AXEW_274b.csv

X	Z
0	28.08
0	26.71
0.69	26.71
1.22	26.78
1.64	26.68
2.02	26.59
2.02	28.08

Upstream face, looking downstream:

Downstream face, looking upstream: N/A

B.6 Culvert under site

Included in model?	Yes
Model label:	AXEW_268
Type:	Circular culvert changing to Irregular Culvert
How has structure been modelled?	The structure was modelled with a circular culvert unit opening and a irregular culvert unit exit using ESTRY. The trash screen was modelled as a 1m section of culvert opening with a blockage of 10%. The culvert outfall geometry is specified in an HW table. The overtopping of the structure is modelled in the 2D domain. Bridge deck elevations are picked up in LIDAR. The following modelling parameters were used:

ID	AXEW_268ii
Type	I
Ignore	F
UCS	T
Len_or_ANA	103.00000
n_nF_Cd	0.02
US_Invert	-99999.00000
DS_Invert	22.43000
Form_Loss	NULL
pBlockage	NULL
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	NULL
Height_or_	NULL
Number_of	1
HConF_or_W	0
WConF_or_W	1.00000
EntryC_or_	0
ExitC_or_W	1.00000
eS1	NULL
eS2	NULL
eN1	NULL
eN2	NULL
eN3	NULL
eN4	NULL
eN5	NULL
eN6	NULL
eN7	NULL
eN8	NULL

ID	AXEW_268
Type	C
Ignore	F
UCS	T
Len_or_ANA	1.00000
n_nF_Cd	0.02
US_Invert	26.47000
DS_Invert	26.47000
Form_Loss	NULL
pBlockage	10.00000
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	0.9
Height_or_	NULL
Number_of	1
HConF_or_W	0
WConF_or_W	1.00000
EntryC_or_	0.5
ExitC_or_W	0
eS1	NULL
eS2	NULL
eN1	NULL
eN2	NULL
eN3	NULL
eN4	NULL
eN5	NULL
eN6	NULL
eN7	NULL
eN8	NULL

ID	AXEW_268i
Type	C
Ignore	F
UCS	T
Len_or_ANA	102.78000
n_nF_Cd	0.02
US_Invert	26.47000
DS_Invert	-99999.00000
Form_Loss	NULL
pBlockage	NULL
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	0.9
Height_or_	NULL
Number_of	1
HConF_or_W	0
WConF_or_W	1.00000
EntryC_or_	0
ExitC_or_W	1.00000
eS1	NULL
eS2	NULL
eN1	NULL
eN2	NULL
eN3	NULL
eN4	NULL
eN5	NULL
eN6	NULL
eN7	NULL
eN8	NULL

AXEW_268i.csv

H	W
22.43	0
22.5	1.27
22.6	1.5
22.7	1.5
22.8	1.5
22.9	1.5
23	1.47
23.1	1.44
23.2	1.35
23.3	1.25
23.4	1.09
23.5	0.85
23.6	0.46
23.64	0

A 75% blockage scenario was undertaken for this culvert. A pBlockage factor of 77.5 was applied to take into account the 10% blockage already applied due to the trash screen. The maximum flood depths can be seen in Appendix E.

Upstream face, looking downstream:

Downstream face, looking upstream:

B.7 Railway Culvert

Included in model?	Yes
Model label:	AXEW_032
Type:	Irregular culvert
How has structure been modelled?	The structure was modelled as an irregular culvert unit using ESTRY. The opening geometry is specified in an HW table. Overtopping of the structure is modelled in the 2D domain. There is a pipe crossing the middle of the culvert which has not been modelled. The following modelling parameters were used:

ID	AXEW_032
Type	I
Ignore	F
UCS	T
Len_or_ANA	11.07000
n_nF_Cd	0.02
US_Invert	22.06000
DS_Invert	22.03000
Form_Loss	NULL
pBlockage	NULL
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	NULL
Height_or_	NULL
Number_of	1
HConF_or_W	0
WConF_or_W	1.00000
EntryC_or_	0.5
ExitC_or_W	1.00000
eS1	NULL
eS2	NULL
eN1	NULL
eN2	NULL
eN3	NULL
eN4	NULL
eN5	NULL
eN6	NULL
eN7	NULL
eN8	NULL

AXEW_032i.csv

H	W
22.06	0
22.1	1.5
22.2	1.5
22.3	1.5
22.4	1.5
22.5	1.5
22.6	1.5
22.7	1.5
22.8	1.39
22.9	1.05
23	0.42
23.02	0.04

Upstream face, looking downstream:

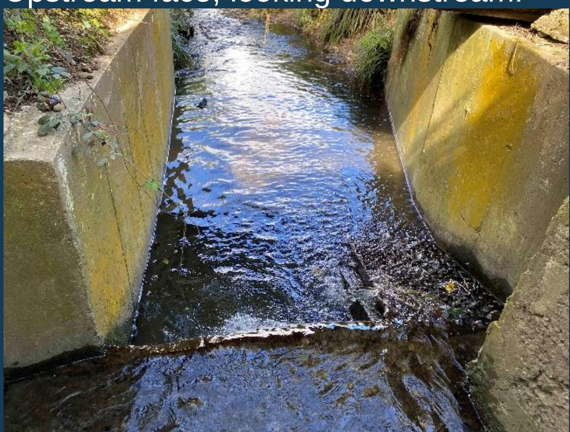
Downstream face, looking upstream:

B.8 Wier

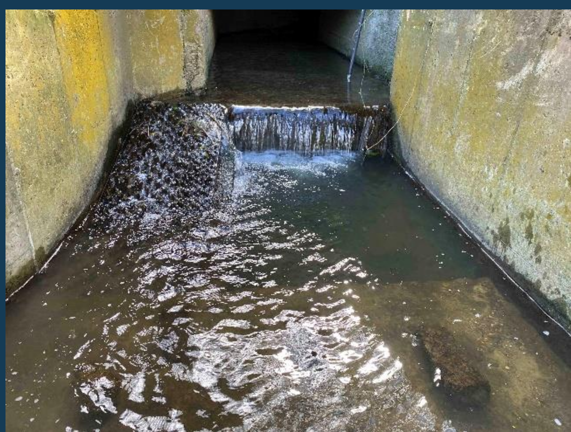
Included in model?	Yes
Model label:	AXEW_019w
Type:	Irregular culvert
How has structure been modelled?	The structure was modelled as weir unit using ESTRY. Channel geometry is represented from the upstream and downstream cross sections. The following modelling parameters were used:

ID	AXEW_019w
Type	WW
Ignore	F
UCS	T
Len_or_ANA	NULL
n_nF_Cd	NULL
US_Invert	22.04000
DS_Invert	21.26000
Form_Loss	NULL
pBlockage	NULL
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	1.63000
Height_or_	NULL
Number_of	NULL
HConF_or_W	NULL
WConF_or_W	NULL
EntryC_or_	NULL
ExitC_or_W	NULL
eS1	NULL
eS2	NULL
eN1	NULL
eN2	NULL
eN3	NULL
eN4	NULL
eN5	NULL
eN6	NULL
eN7	NULL
eN8	NULL

Upstream face, looking downstream:



Downstream face, looking upstream:



B.9 Access culvert

Included in model?	Yes
Model label:	AXEW_017b
Type:	BBW Bridge unit
How has structure been modelled?	The structure was modelled as BBW bridge unit using ESTRY. Opening geometry is represented using an XZ table. Overtopping has been modelled in the 1D domain using a 'BBW' weir unit. The following modelling parameters were used:

ID	AXEW_017b
Type	BBW
Ignore	F
UCS	T
Len_or_ANA	NULL
n_nF_Cd	NULL
US_Invert	-99999.00000
DS_Invert	-99999.00000
Form_Loss	0.001
pBlockage	NULL
Inlet_Type	NULL
Conn_1D_2D	NULL
Conn_No	NULL
Width_or_D	NULL
Height_or_	NULL
Number_of	NULL
HConF_or_W	NULL
WConF_or_W	NULL
EntryC_or_	NULL
ExitC_or_W	NULL
eS1	NULL
eS2	NULL
eN1	3.35000
eN2	0.548
eN3	1.17000
eN4	35.00000
eN5	0.69
eN6	NULL
eN7	NULL
eN8	NULL

AXEW_017b.csv

X	Z
0.28	23.04
0.69	22.84
0.94	21.3
1.97	21.18
2.12	21.68
2.19	21.7
2.23	21.76
2.7	21.86
2.79	23.01
3	23.06

Upstream face, looking downstream:

Downstream face, looking upstream:
N/A

C Hydrology Report

D Sensitivity Analysis

D.1 Sensitivity to roughness

Figure 4-1 shows the impact in peak water level when 1D and 2D roughness is adjusted by +20% during the 100-year event. This shows the model is sensitive to changes in roughness, the greatest impact of 0.32m is found at AXEW_268i.2. However, the roughness values used within the modelling are based on photographical evidence in the 1D and mapping in the 2D and are considered to be appropriate.

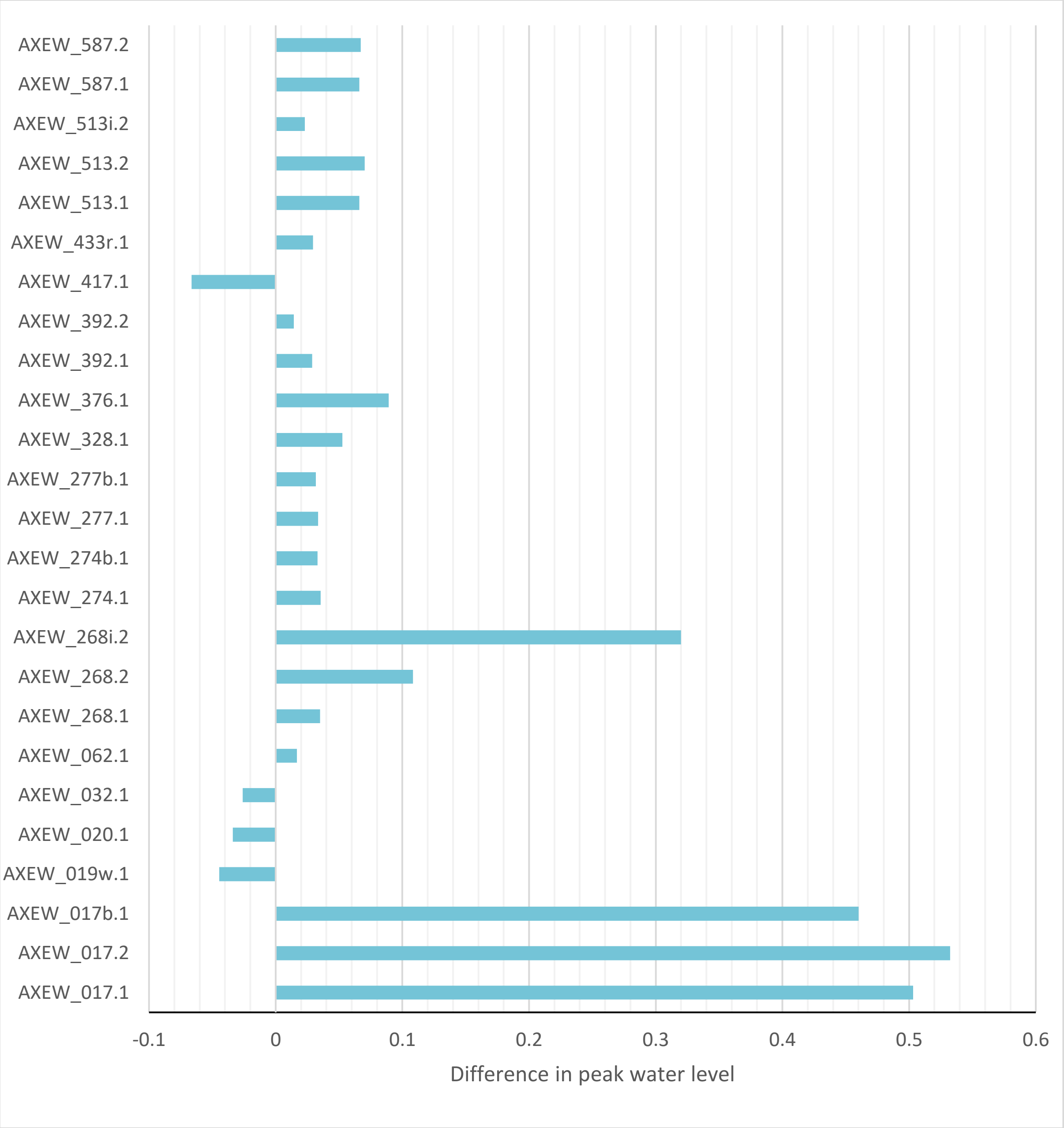


Figure 4-1: Sensitivity analysis for +20% roughness

D.2 Sensitivity to downstream boundary conditions

Figure 4-2 shows the impact in peak water level when a HT boundary with a bankful level (22.96mAOD) is applied to the 1D downstream boundary during the 100-year event to represent the levels from the River Axe at the confluence (approximately 23mAOD). This proportional impact shows that the model is not particularly sensitive to changes in this parameter. The greatest impact is 0.453m and is found at AXEW_017.2, close to the downstream model extent. The graph shows that the water levels at the culvert inlet (AXEW_062.1) and (AXEW_268i.2) are moderately affected but no node further upstream at the site are affected and therefore the site is not affected by the water level of the River Axe.

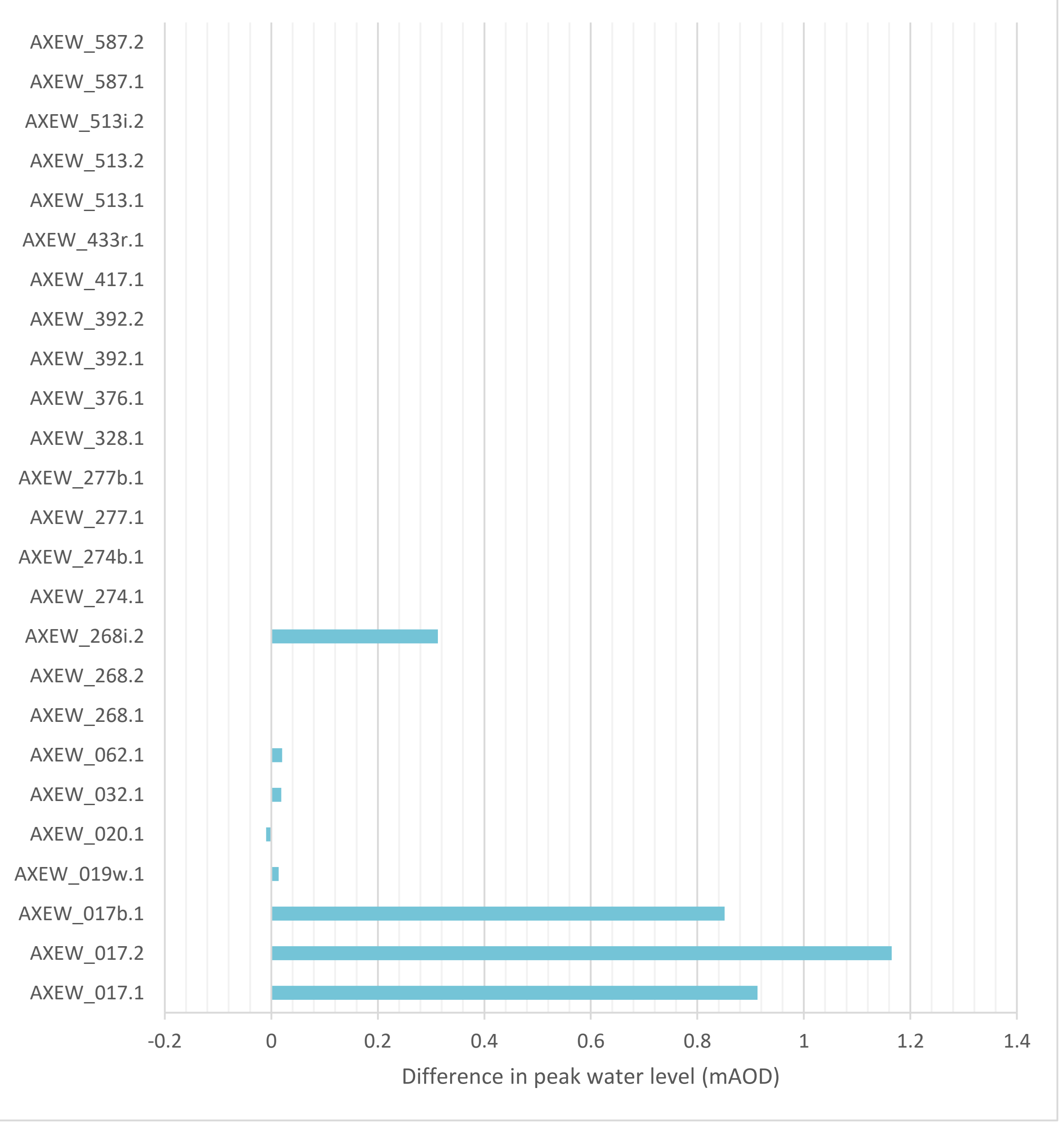


Figure 4-2: Sensitivity analysis for River Axe levels at the downstream boundary

D.3 Sensitivity to flow

Figure 4-3 shows the impact in peak water level when 1D flow is adjusted by +20% during the 100-year event. The greatest impact of 0.35m is found at node AXEW_268i.2. This shows the model is sensitive to changes in flow as the impact is proportionate. However, the hydrology used within the model follows best practice and is therefore considered to be appropriate.

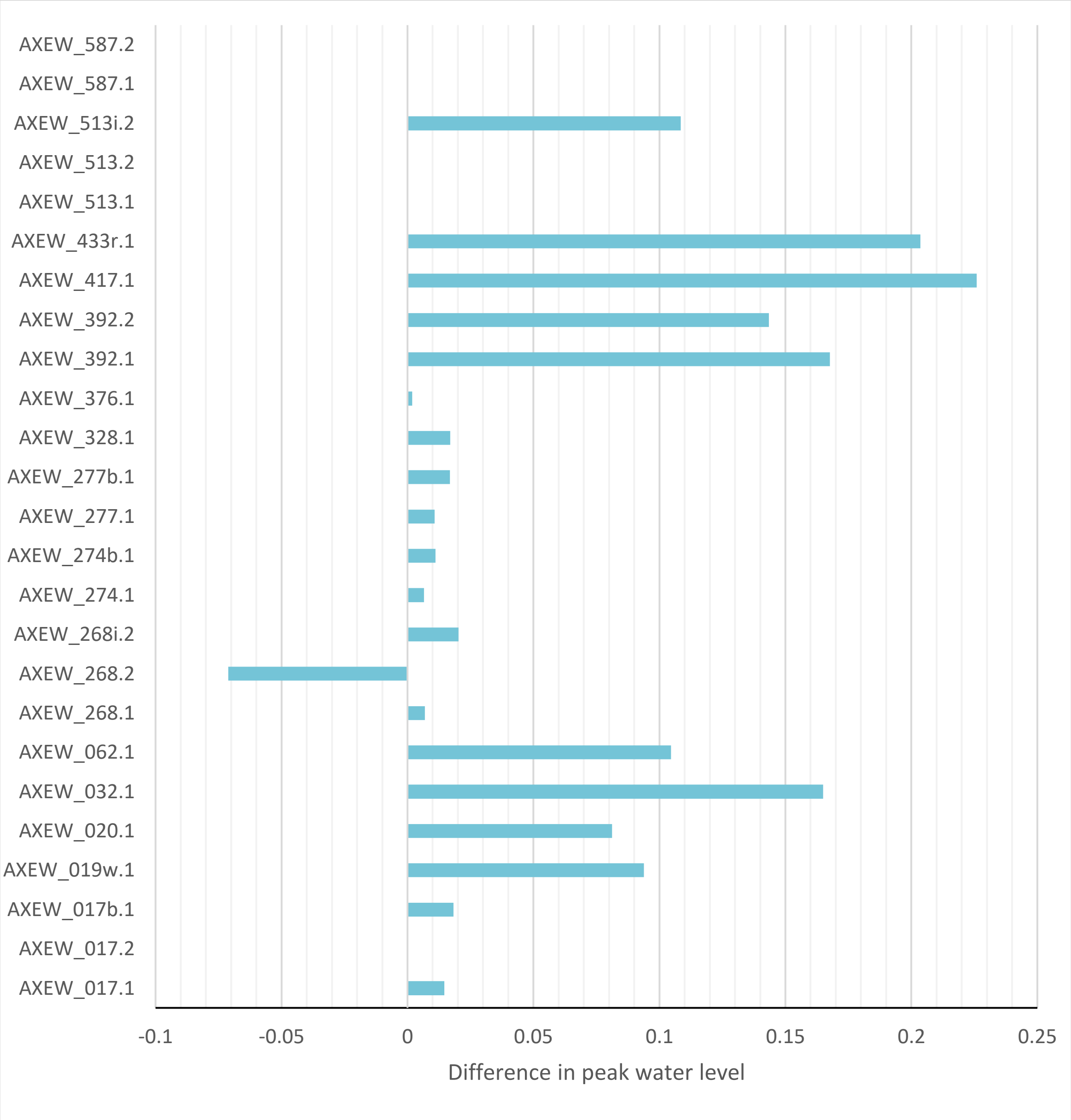


Figure 4-3: Sensitivity analysis for +20% flow

E Residual Flood Risk

The peak modelled flood depths during the 1% AEP plus climate change (61%) flood event with a 75% blockage applied to the culvert are shown in Figure 3-3.

This indicates that the flood extent is not significantly changed but the flood depths across the sites have increased by approximately 100mm.

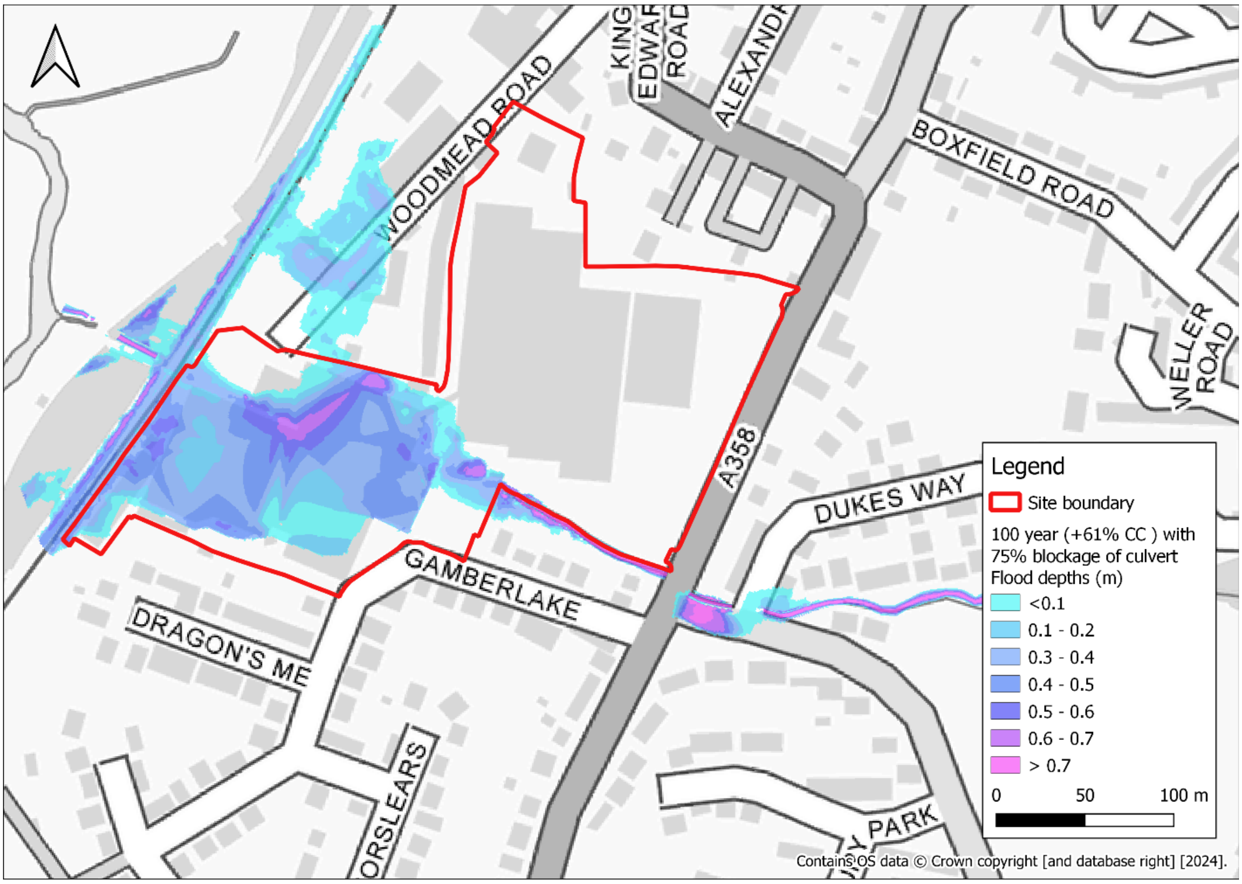


Figure 4-4: 1% AEP plus climate change (61%) with 75% blockage on culvert maximum flood depths

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