Hydraulic Modelling Report

Land off Patshull Road, Albrighton

Boningale Developments Ltd

SHF.710.011.HY.R.002.A

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Albrighton South

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Executive Summary

This report presents the process undertaken and the findings of a 2D TUFLOW direct rainfall modelling exercise based on 1m DTM LiDAR data and topographical survey data. The model objective is to refine and establish associated baseline flood extents for the proposed development Site.

The model was run for a range of return periods to establish the baseline surface water flood extents and parameters.

A hydrological assessment, inclusive of a desk-based assessment of catchment descriptors, was undertaken, based on the scale of the catchment. It was concluded that ReFH2 was deemed the most appropriate method for the assessment. This method was used to provide hydrological inputs, in the form of hyetographs for use in the hydraulic model.

The baseline model was run for a range of return periods to establish the baseline surface water flood extents and parameters. Up-to-date climate change allowances of +35% and +40% (Upper End estimate) for the Total Potential Change anticipated for the 2070 epoch (2061 - 2125) have also been applied to the 1 in 30-year and 100-year events, respectively, following Environment Agency guidance.

The results from the modelling exercise show a variation in flood extent in the Site when compared to Environment Agency surface water flood mapping.

The model results show that there are two main flow pathways across the Site. The western pathway (Pathway 1) and the central pathway (Pathway 2) have been identified across all return periods for the Site (30-year, 100-year, 1000-year, 30-year +35%CC and 100-year +40%CC). Both pathways are orientated north to south and follow the natural topography of the Site to exit on its southern boundary. Instances of surface water ponding within the Site boundary, will be dealt with by the proposed drainage strategy for the Site.

The inclusion of the proposed surface water control measures means that surface water within the Site can be controlled to ensure flooding of the Site does not impact the proposed development.

The variation between the modelled surface water flood extents and the surface water mapping is likely due to the inclusion of detail such as structure conveyance, representation of the watercourse and disaggregated areas of shallow ponding.

1.0 Introduction

1.1 Background

1.1.1 Enzygo Ltd were commissioned by Boningale Developments Ltd to undertake a direct rainfall modelling exercise to determine the surface water flood extents within the Site and contributing catchment. The area in question is centred at (NGR) 380644, 303313 where a residential development is proposed, with additional uses for a care home and school. This was required to address comments from the Lead Local Flood Authority (Shopshire Council) on the matters of surface water flooding with a requirement to make a detailed assessment of this flooding.

1.1.2 In order to aid the design of the proposed development, and assess modelled parameters against national flood risk guidance, a direct rainfall modelling exercise was undertaken. This hydraulic modelling report has been prepared as a stand-alone report, including methodology and results.

1.1.3 A desk top study identified three unnamed watercourses located within the model domain. Watercourse 1 is a ditch that flows from north to south running parallel to Patshull Road; to the lefthand bank of Watercourse 1. A Ø300mm culvert is present under the access road to Lea Farm, before entering a culvert upstream of Lea Hall Barn (a trash screen is located upstream of the culvert). Watercourse 2 is a ditch that flows from north to south to the west of Lea House before culverting under Holyhead Road and continuing south. Watercourse 3 is a ditch which flows north and then west before entering a Ø675mm culvert.

1.1.4 Pebble Brook, located within the modelled catchment domain which flows north to south is located approximately 300m east of the Site.

1.1.5 The are a number of minor ditches located within the model domain, of which have been reinforced into the model where required.

1.1.6 The location of the development Site and catchment is is provided in Figures 1.1 and 1.2.

Figure 1.1: Map of Watercourses

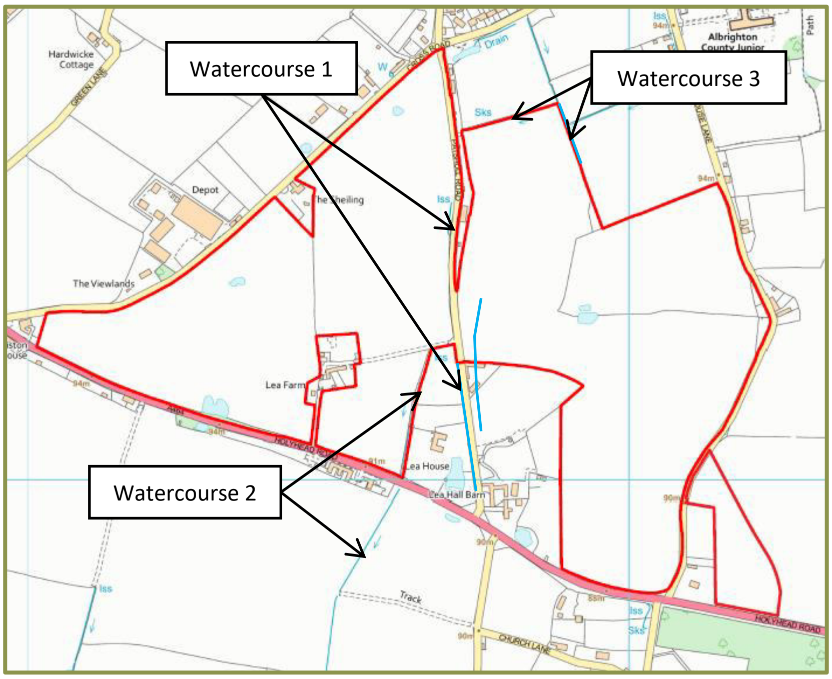
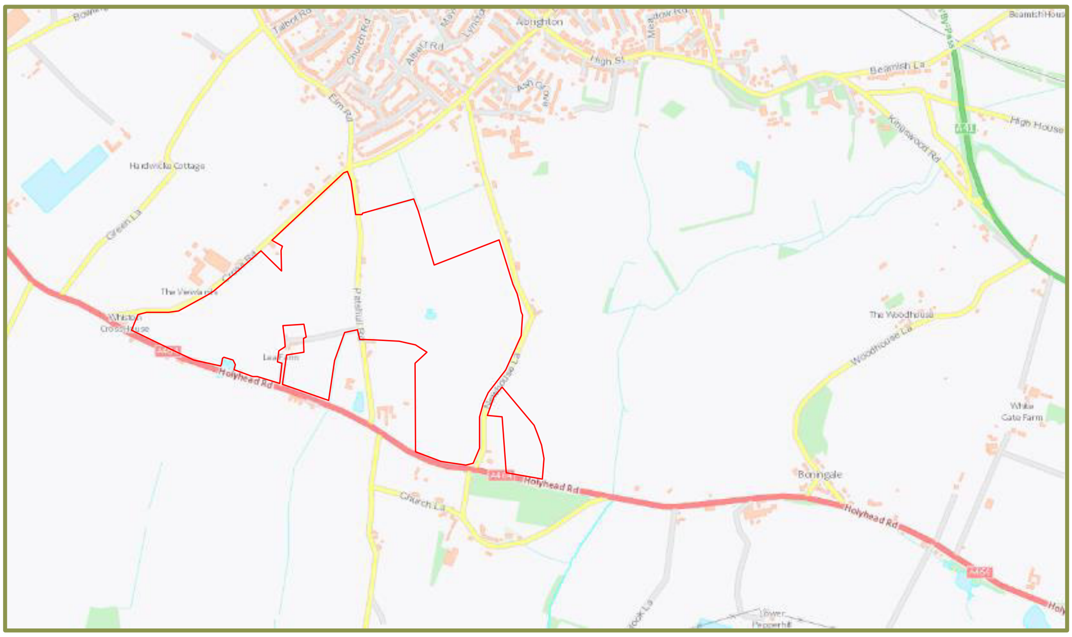


Figure 1.2: Environment Agency Main River Map



Redline: *Site Boundary*

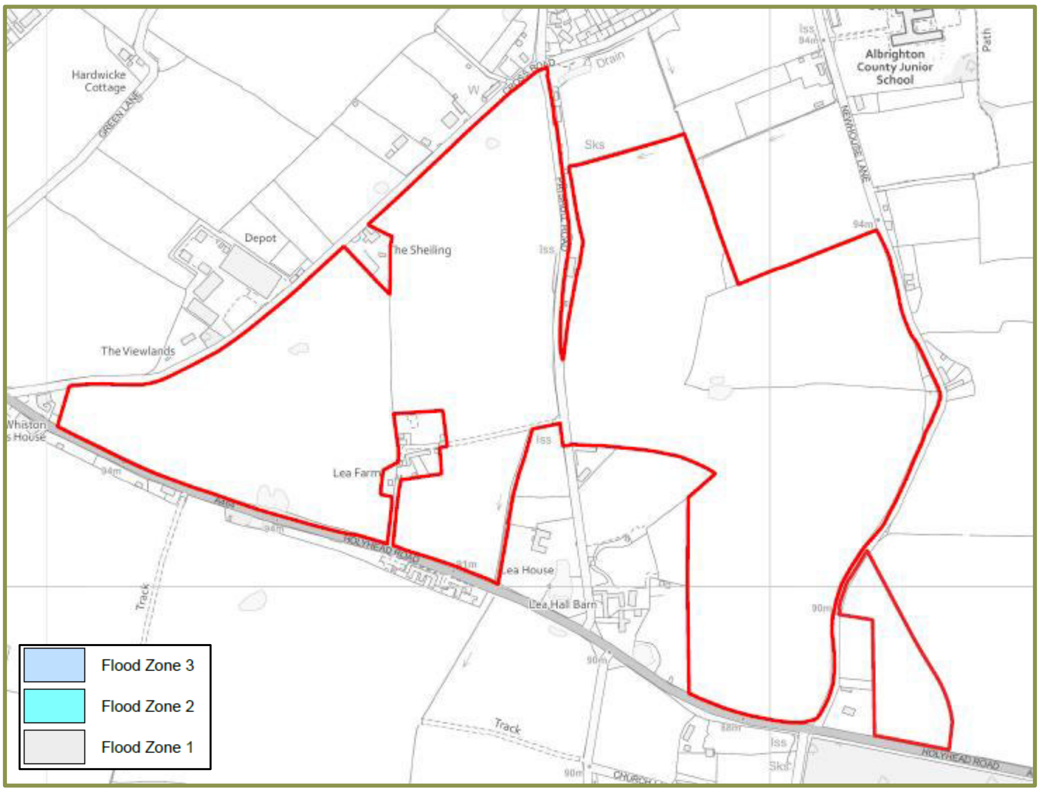
1.1.7 Environment Agency Flood Map for Planning (Figure 1.3) shows that the Site is located in Flood Zone 1, at a low risk of fluvial flooding.

1.1.8 However, Environment Agency long term surface water flood risk mapping shows the Site mapped surface water flooding consisting of high risk ponding and low risk flow pathways. (Figure 1.4).

1.1.9 There are two flow pathway that enter the Site on the northern boundary (Pathway 1 and Pathway 2), with both flowing south and Pathway 1 exiting on the southern boundary of the Site. While Pathway 2 ponds at a topographical low spot within the southern extent of the Site and beyond the Site boundary.

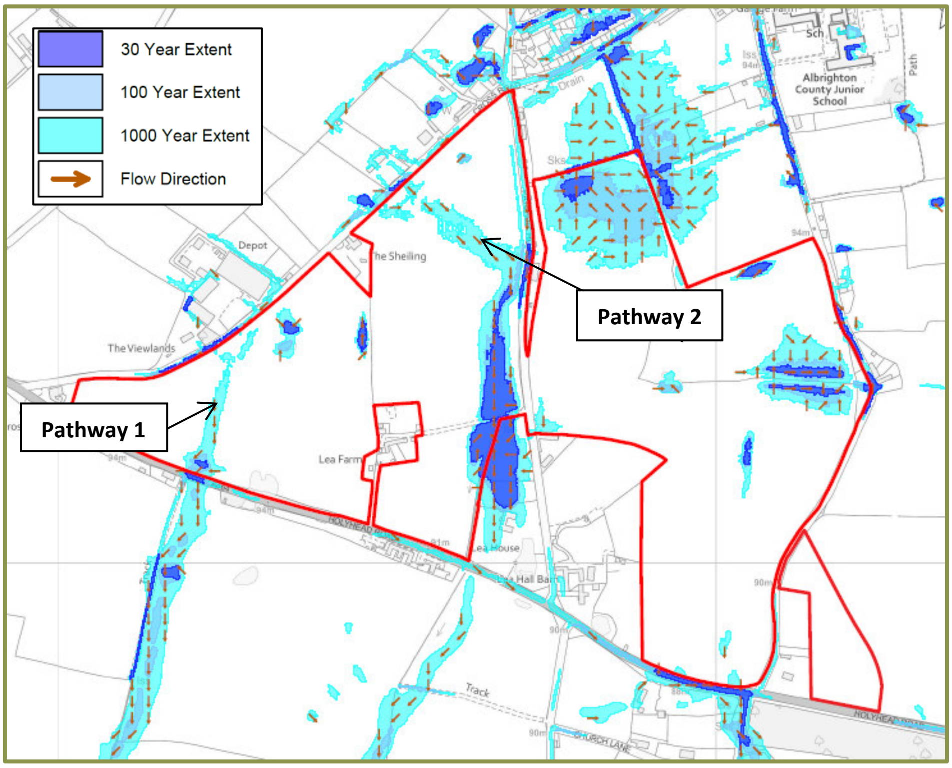
1.1.10 The surface water flood map does not include detail such as detailed channel surveys, in-channel structures, or detailed ground survey. As such, surface water mapping can often result in incorrect flood extents that require refinement through a detailed hydraulic modelling exercise. Therefore, a hydraulic modelling assessment was undertaken based on LiDAR data and topographical survey to confirm and/or refine the surface water flood extents.

Figure 1.3: Environment Agency Flood Map for Planning Map



***Redline:** Site Boundary*

Figure 1.4: Environment Agency Complex Surface Water Mapping



***Redline:** Site Boundary*

1.2 Purpose

1.2.1 The purpose of this Hydraulic Modelling report is to confirm the surface water flood outlines within the Site boundary and the catchment. This is in order to inform the proposed layout for the development Site and associated surface water drainage strategy. This report will:

- Present the methodology to build/run the baseline hydraulic model.
- Report the results in map format.

1.3 Scope

1.3.1 The scope of works includes the following:

- Undertake a hydrological assessment to produce peak flows, which will be used as input boundaries within the new model. A hydrological assessment using ReFH2.3 software has been detailed within this modelling report.
- Build a 2D model using topographical survey/LiDAR data and new hydrological peak flows to provide baseline flood outlines in order to refine existing mapped flood outlines and also allow the modelling of proposed flood risk mitigation measures to inform a development masterplan of the Site.

1.4 Report Structure

1.4.1 This report is structured as follows:

- Section 2 describes the baseline modelling methodology and hydrology derivation method.
- Section 3 includes an analysis of baseline and sensitivity results.
- Section 4 describes the baseline mapping approach.
- Section 5 presents a summary and conclusions.

2.0 Baseline Model Methodology

2.1 Introduction

2.1.1 A 2D model of the catchment, with direct rainfall elements, was constructed, utilising TUFLOW modelling software (version 2023-03-AE-iDP-w64).

2.1.2 The model files and a modelling log, which includes a model file schedule (list of all files used in the modelling), are included in Appendix 1.

2.2 Model Extent

2.2.1 A Site walkover was undertaken in October 2024, which confirmed existing watercourses within the Site boundary and identified additional watercourses not covered by the Site topographic survey (April 2024). These additional watercourses have been reinforced into the model in the 2D domain.

2.2.2 A copy of the topographical survey is included in Appendix 2.

2.2.3 The overall model extent extends from (NGR) 380555, 304098 and 382559, 303792 to (NGR) 380463, 302528 and 381292, 302371, which covers the catchments for the Site. The model reach comprises of a 2D channel, informed from LiDAR and topographical survey data with culverts represented in the 1D domain within the catchment.

2.2.4 The topographical survey contains information in relation to the topography of the Site.

2.2.5 A summary of the Site boundary and model extent is included in Figure 2.1.

Figure 2.1: Model Boundary

Pink: *Model Boundary* ***Red****: Site boundary*

2.3 Cross-Sections

2.3.1 As the model is a TUFLOW (2D domain only model), there are no cross-sections represented in the 1D domain. A '1d_nwke_ALB_001' layer has been used, in order to add the culverts to the model domain which represent conveyance features under Kingswood Road, Holyhead Road and a crossing point in a field parcel. Manning's 'n' roughness values associated with the culverts in the model have been entered via the attributes table in the 1D network layer.

2.4 Structures

2.4.1 The identified structures comprise of four structures (rectangular and circular culverts), the details of which are summarised in Table 2.1. It should be noted that nominal orifice sizes were included in the model, in lieu of structure details for all structures.

2.4.2 A Ø600mm culvert inlet was observed at the downstream extent of Watercourse 3. At the time model was run a CCTV survey of the asset to identify its route had been scheduled but no results received. It is assumed that flows from this asset flow south outside of the catchment.

Table 2.1: In-channel Structure Descriptions

Structure 1 (Kingswood R)
• Modelled as an 'R' (Rectangular culvert) with overtopping modelled in the 2D domain • Inlet/exit losses: default as per the TUFLOW manual • Opening Dimensions: Height - 2.00m, Width - 2.00m • u/s invert: 99.79AOD (informed from bounding cross sections) • d/s invert: 97.783mAOD (informed from bounding cross sections) • Length: 25.14m • Manning's: 0.012 (representative of concrete, cement - finished).
Structure 2 (Holyhead R)
• Modelled as an 'R' (Rectangular culvert) with overtopping modelled in the 2D domain • Losses: default as per the TUFLOW manual • Opening Dimensions: Height - 1.5m, Width - 1.5m (x2) • u/s invert: 81.277mAOD (informed from bounding cross sections) • d/s invert: 81.087mAOD (informed from bounding cross sections) • Length: 19.32m • Manning's: 0.012 (representative of concrete, cement - finished). A survey of the culvert located under Holyhead Road was commissioned, though not received upon completion of the modelling exercise and submission of this modelling report.

Structure 3 (Holyhead C)
• Modelled as an 'C' (Circular culvert) with overtopping modelled in the 2D domain • Losses: default as per the TUFLOW manual • Opening Dimensions: Ø300mm • u/s invert: 90.30mAOD (informed from bounding cross sections) • d/s invert: 90.30mAOD (informed from bounding cross sections) • Length: 18.41m • Manning's: 0.012 (representative of concrete, cement - finished).
Structure 4 (Field C)
• Modelled as an 'C' (Circular culvert) with overtopping modelled in the 2D domain • Losses: default as per the TUFLOW manual • Opening Dimensions: Ø300mm • u/s invert: 88.60mAOD (informed from bounding cross sections) • d/s invert: 88.60mAOD (informed from bounding cross sections) • Length: 11.51m • Manning's: 0.012 (representative of concrete, cement - finished).

2.5 Hydrology Inflow Boundaries

Catchment Boundary

2.5.1 The FEH Web Service was used to identify the contributing catchments for the Site. It was established that the Site is split into two catchments. As such, the catchment boundaries at NGR 381250, 302400 (East Catchment) and NGR 380500, 302550 (West Catchment) which encompass the Site and wider catchment area were obtained (Figures 2.2, 2.3 and 2.4).

2.5.2 The FEH Webservice catchment boundary has been checked against 1m DTM LiDAR data (as this is more detailed that the 50m grid resolution from the Integrated Hydrological Digital Terrain Model (IHDTM) used for the calculation of the FEH web service catchment boundaries), aerial imagery and OS mapping. It should always be ensured that the catchment area from the FEH Webservice be checked and adjusted accordingly to provide the most accurate assessment of catchment hydrology.

East Catchment

2.5.3 The East Catchment area of 5.447km^2 was identified for the Site (hereafter the 'adjusted catchment' of 2.270km^2) (Figures 2.2, 2.3 and 2.4) based on a review of aerial imagery, OS mapping and 1m DTM LiDAR Data.

West Catchment

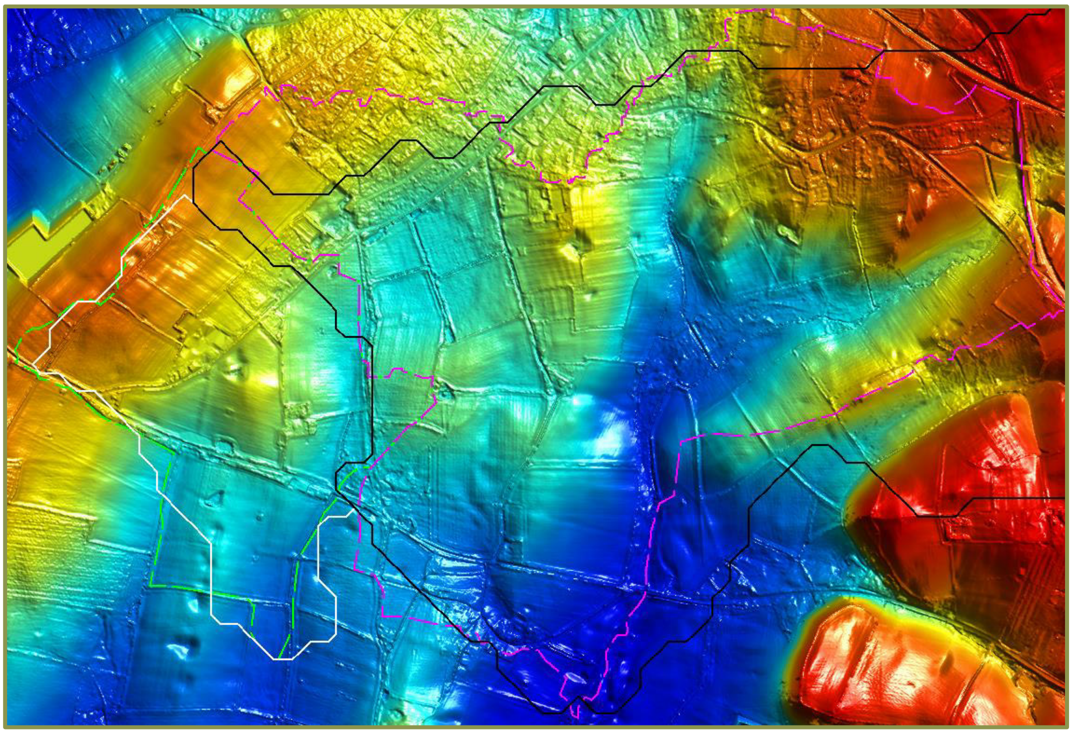
2.5.4 The West Catchment area of 0.640km^2 was identified for the Site (hereafter the 'adjusted catchment' of 0.731km^2) (Figures 2.2, 2.3 and 2.4) based on a review of aerial imagery, OS mapping and 1m DTM LiDAR Data.

2.5.5 The adjusted catchments will be used to derive input hydrology for the catchment, specifically, with the focus on deriving the surface water flood extents within the Site.

Figure 2.2: Catchment Boundaries

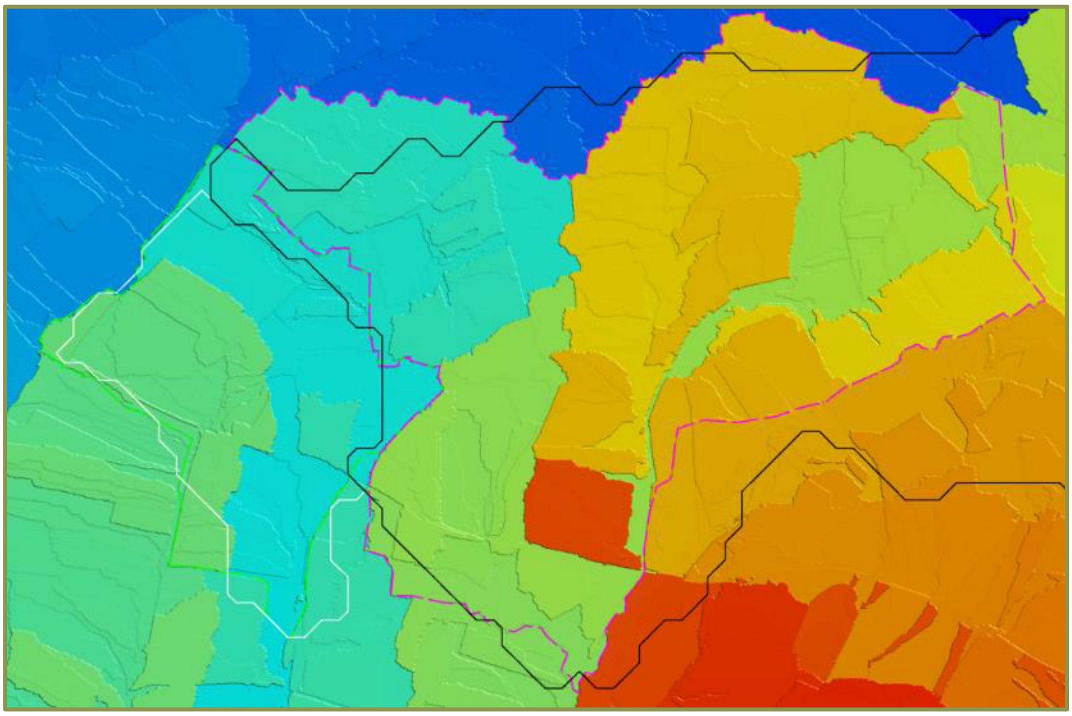
White: *FEH Webservice Catchment* ***Green Dashed:*** *Adjusted Western Catchment* ***Black:*** *FEH Webservice Catchment* ***Pink Dashed:*** *Adjusted Eastern Catchment*

Figure 2.3: Catchment Boundary - LiDAR Comparison



White: *FEH Webservice Catchment* ***Green Dashed:*** *Adjusted Western Catchment* ***Black:*** *FEH Webservice Catchment* ***Pink Dashed:*** *Adjusted Eastern Catchment*

Figure 2.4: Catchment Boundary – Watershed Catchment Comparison



White: *FEH Webservice Catchment* ***Green Dashed:*** *Adjusted Western Catchment* ***Black:*** *FEH Webservice Catchment* ***Pink Dashed:*** *Adjusted Eastern Catchment*

Catchment Descriptors

2.5.6 Analysis of the FEH Webservice Catchment Descriptors for the 2.270km^2 (Table 2.2 - East Catchment) and 0.731km^2 (Table 2.3 – West Catchment) adjusted catchments were undertaken.

2.5.7 A discussion of the Catchment Descriptors downloaded from the FEH Webservice (Tables 2.2 and 2.3), and how key Catchment Descriptors have been checked/edited through a desktop study is provided below.

Table 2.2: FEH Catchment Descriptors - East Catchment

Catchment Descriptor	Value	Catchment Descriptor	Value
AREA	5.4475 **(2.270)**	SPRHOST	35.84
ALTBAR	110	URBCONC1990	0.591
ASPBAR	241	URBEXT1990	0.031
ASPVAR	0.38	URBLOC1990	0.581
BFIHOST	0.461	URBCONC2000	0.857
BFIHOST19	0.46	URBEXT2000	0.022
DPLBAR	2.5	URBLOC2000	0.866
DPSBAR	2.8.7	C	-0.03233
FARL	0.995	D1	0.3431
FPEXT	0.0711	D2	0.3072
FPDBAR	0.525	D3	0.36872
FPLOC	0.714	E	0.31655
LDP	5.11	F	2.38506
PROPWET	0.31	C(1 km)	-0.032

Catchment Descriptor	Value	Catchment Descriptor	Value
RMED-1H	10.5	D1(1 km)	0.334
RMED-1D	29.1	D2(1 km)	0.306
RMED-2D	35.9	D3(1 km)	0.372
SAAR	690	E(1 km)	0.312
SAAR4170	700	F(1 km)	2.379

Adjusted values are included in red ***bold****.*

Table 2.3: FEH Catchment Descriptors - West Catchment

Catchment Descriptor	Value	Catchment Descriptor	Value
AREA	0.640 **(0.731)**	SPRHOST	32.90
ALTBAR	96	URBCONC1990	-999999
ASPBAR	148	URBEXT1990	0.002
ASPVAR	0.79	URBLOC1990	-999999
BFIHOST	0.521	URBCONC2000	-999999
BFIHOST19	0.495	URBEXT2000	0
DPLBAR	0.85	URBLOC2000	-999999
DPSBAR	15.4	C	-0.0318
FARL	1	D1	0.3292
FPEXT	0.0938	D2	0.30577
FPDBAR	0.57	D3	0.3698
FPLOC	0.484	E	0.31097
LDP	1.63	F	2.38334
PROPWET	0.31	C(1 km)	-0.031
RMED-1H	10.5	D1(1 km)	0.33
RMED-1D	28.2	D2(1 km)	0.304
RMED-2D	34.8	D3(1 km)	0.369
SAAR	682	E(1 km)	0.311
SAAR4170	698	F(1 km)	2.379

Adjusted values are included in red ***bold****.*

i. BFIHOST

2.5.8 BFIHOST is the baseflow index developed using the Hydrology of Soil Types (HOST) classification and is the baseflow proportion of the flow on average. It is estimated based on daily mean flow data. Baseflow comprises water entering the watercourse through shallow subsurface flow and groundwater flow (mechanisms other than direct surface runoff); hence permeable soils and geology tend to yield a higher baseflow.

2.5.9 A new catchment descriptor called BFIHOST19 is now available in FEH Webservice datasets. BFIHOST19 addresses a number of issues associated with the original BFIHOST descriptor[1].

2.5.10 BFIHOST19 includes revised regression methods used to estimate BFIHOST and also has improved classification of rare soil types.

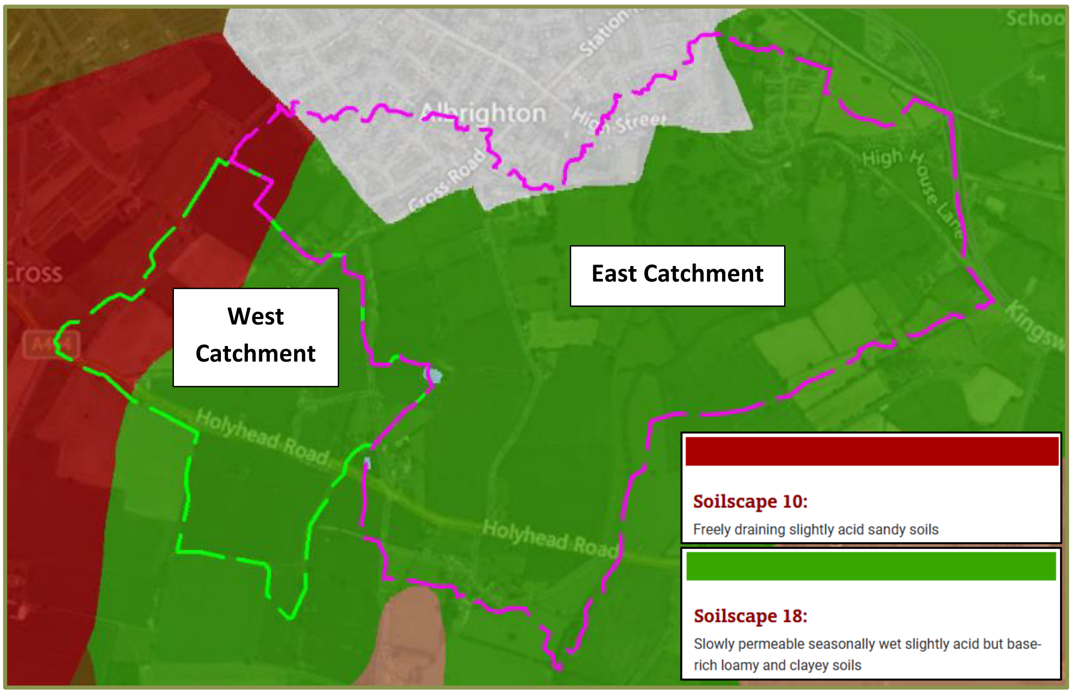
2.5.11 The Soilscapes online soils map viewer[2] (Figure 2.5) shows that the catchments are underlain by freely draining, slightly acid sandy soils and slowly permeable, seasonally wet, slightly acid but base-rich loamy and clayey soils.

[1] https://fehweb.ceh.ac.uk/News/Article/bfihost19nowavailable
[2] http://www.landis.org.uk/soilscapes/

2.5.12 The Geology of Britain online map viewer[3] (Figure 2.6) shows the bedrock beneath the adjusted catchments is the Helsby Sandstone Formation - Pebbly (gravelly) sandstone, Helsby Sandstone Formation - Mudstone, Mercia Mudstone Group - Mudstone/Halite-Stone and Mercia Mudstone Group - Sandstone.

2.5.13 Soils are indicative of high infiltration potential over permeable geology with variable infiltration potential.

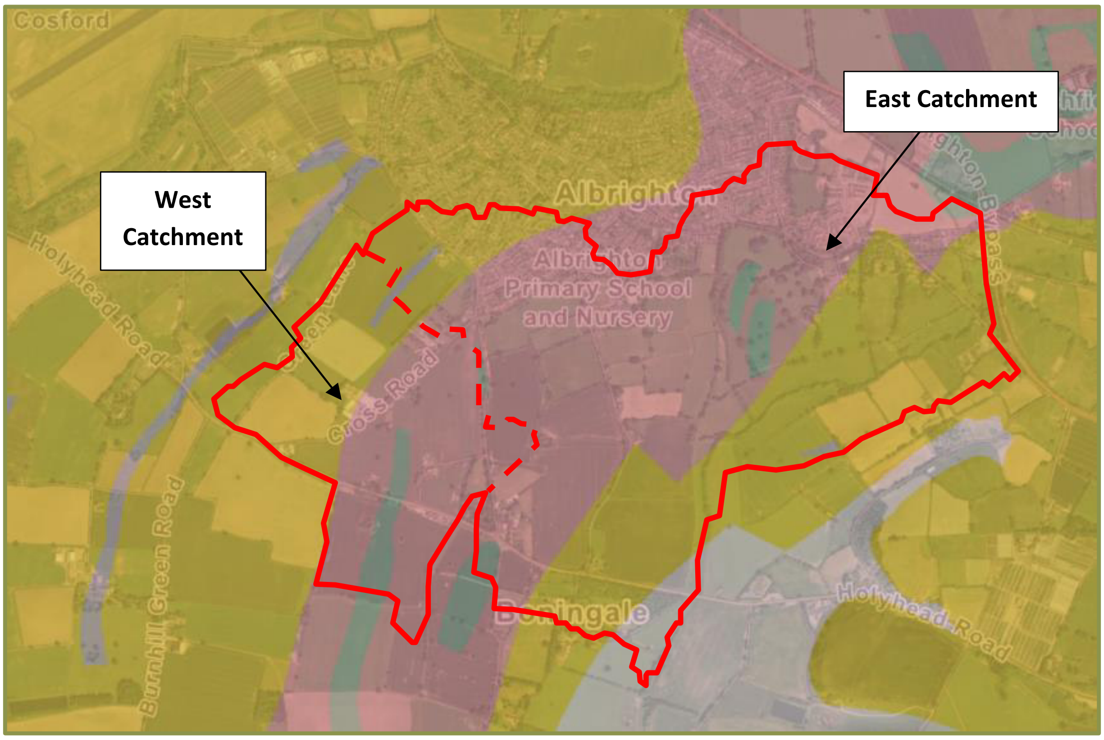
Figure 2.5: Soils Mapping



Soils Data © Cranfield University (NSRI) and for the Controller of HMSO [2024].

[3] http://mapapps.bgs.ac.uk/geologyofbritain3d/

Figure 2.6: Geology Mapping (Bedrock)



Helsby Sandstone Formation - Sandstone, pebbly (gravelly). Sedimentary bedrock formed between 247.1 and 241.5 million years ago during the Triassic period.

Helsby Sandstone Formation - Mudstone. Sedimentary bedrock formed between 247.1 and 241.5 million years ago during the Triassic period.

Mercia Mudstone Group - Mudstone and halite-stone. Sedimentary bedrock formed between 252.2 and 201.3 million years ago during the Triassic period.

Mercia Mudstone Group - Sandstone. Sedimentary bedrock formed between 252.2 and 201.3 million years ago during the Triassic period.

Contains British Geological Survey materials © NERC [2024].

2.5.14 As such, the FEH webservice BFIHOST/BFIHOST19 values of 0.461/0.460 (East Catchment) and 0.521/0.495 (West Catchment) are deemed representative of the catchments and will be carried forward in this assessment.

ii. SPRHOST

2.5.15 The SPRHOST parameter reflects the amount of surface runoff in a catchment and is also based on the HOST soils classifications. The SPRHOST values of 35.84 (East Catchment) and 32.90 (West Catchment) will be carried forward in this assessment.

iii. PROPWET

2.5.16 PROPWET describes the proportion of time that soils are wet. PROPWET values for the UK range from approximately 0.80 in Northern Scotland where there is high annual rainfall, to 0.20 in East Anglia where annual rainfall is much lower.

2.5.17 Low PROPWET values tend to inhibit flooding, as the catchment is not saturated prior to a flood event and there is higher capacity for infiltration, the opposite is true for catchments with higher PROPWET values. The PROPWET values of 0.31 (for both catchments) for the adjusted catchments is low, and may be explained by the following factors:

- Wet spells only occur at a moderate frequency and tend to be of a relatively short duration (supported by the SAAR figures below).
- The adjusted catchment is in the south-east where rainfall levels are lower when compared to the north of England.

2.5.18 The PROPWET values taken from the FEH Webservice (0.31) are considered representative of the adjusted catchments.

iv. FARL

2.5.19 The FARL value is a measure of flow attenuation caused by reservoirs and lakes, and ranges from 0 (total attenuation) to 1.0 (no discernible attenuation).

2.5.20 The East Catchment has a FARL of 0.995, which as per the FEH Webservice account for the ponds located within the land between Patshull Road and Newhouse Lane. The West Catchment has a FARL value of 1 indicates no attenuation due to reservoirs or lakes.

2.5.21 The FARL values of 0.995 and 1 taken from the FEH Webservice data are therefore considered representative of the adjusted catchments.

v. URBEXT

East Catchment

2.5.22 The Urban Extent URBEXT1990 output for the catchment of 0.031 indicates an 'Slightly Urbanised' catchment. The FEH catchment descriptor URBEXT2000 was calculated to be 0.022, which also indicates an 'Essentially Rural' catchment and shows a small decrease in urbanisation has occurred during the intervening 10-year period, however, the change is minor/negligible.

2.5.23 The urban extents from URBEXT2000 are similar to the extents shown on up-to-date OS mapping and aerial photography with no significant variations between the two datasets. There has been no development since the year 2000 and therefore an adjustment to the year 2024 is not considered necessary for the catchment.

West Catchment

2.5.24 The Urban Extent URBEXT1990 output for the catchment of 0.002 indicates an 'Essentially Rural' catchment. The FEH catchment descriptor URBEXT2000 was calculated to be 0.000, which also indicates an 'Essentially Rural' catchment and shows a small decrease in urbanisation has occurred during the intervening 10-year period, however, the change is minor/negligible.

2.5.25 The urban extents from URBEXT2000 are similar to the extents shown on up-to-date OS mapping and aerial photography with no significant variations between the two datasets. There has been no development since the year 2000 and therefore an adjustment to the year 2024 is not considered necessary for the catchment.

vi. SAAR

2.5.26 SAAR values within the FEH represent standard average annual rainfall data for the standard period 1961-1990.

2.5.27 A SAAR value of 690mm (East Catchment) and 682mm (West Catchment) indicates a moderately dry catchment. Given the catchment location in the west of England, the SAAR values taken from the FEH Webservice are considered acceptable and will be carried forward in this assessment.

vii. DPSBAR

2.5.28 The Drainage Path Slope (DPSBAR) shows a value of 28.7 (East Catchment) and 15.4 (West Catchment), which indicates a flat catchment. This is supported by a review of OS mapping and LiDAR. The DPSBAR value taken from the FEH Webservice is considered representative of the adjusted catchment.

2.6 ReFH2 Method

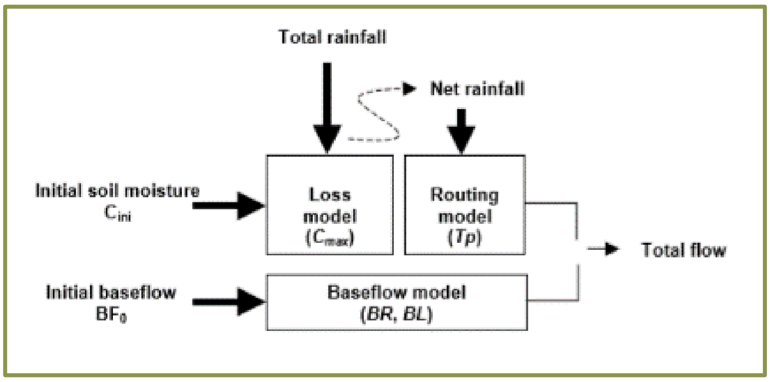
Introduction

2.6.1 The Revitalised Rainfall-runoff (ReFH) model was first published in 2005 as an update to the previous FEH rainfall-runoff method, the FSR/FEH rainfall-runoff method. ReFH was based on robust hydrological modelling techniques and was an improvement over the FEH/FSR Rainfall Runoff method (FEH), as described in the FEH. The method uses Catchment Descriptors from the FEH Webservice, to generate design flood events of specific return periods.

2.6.2 ReFH2 was released in early 2015, with a significant update (Version 2.1), published in November 2015. ReFH2 includes an extension of the ReFH model to represent urban catchments and is compatible with FEH2022 rainfall frequency statistics.

2.6.3 The ReFH model has three components: a loss model (Cmax), a routing model (Tp) and a base flow model (BR, BL) (Table 2.4). The loss model uses a soil moisture accounting approach to define the amount of rainfall occurring over the catchment that is converted to direct runoff. The rainfall losses are derived as the event unfolds, rather than being defined by a fixed value of percentage runoff. The routing component of ReFH uses the unit hydrograph concept, adopting a 'kinked' triangle as the standard shape. Finally, the base flow model is based on the linear reservoir concept with its characteristic recession defined by an exponential decay controlled by the recession constant termed base flow lag (Figure 2.7).

Figure 2.7: Schematic Representation of the ReFH Model



Source: *Wallingford HydroSolutions Ltd 2016. The Revitalised Flood Hydrograph Model ReFH2.2: Technical Guidance.*

Table 2.4: Summary of the Six ReFH Model Parameters

Name	Parameter or Initial Condition	Description
T_p	Model parameter	Unit hydrograph time to peak (hours)
B_L	Model parameter	Baseflow recession constant or lag (hours)
B_R	Model parameter	Baseflow recharge
C_{Max}	Model parameter	Maximum soil moisture capacity (mm)
C_{ini}	Initial condition	Initial moisture content (mm)
BF_0	Initial condition	Initial baseflow (m^3s^{-1})

Source: *Wallingford HydroSolutions Ltd 2016. The Revitalised Flood Hydrograph Model ReFH2.2: Technical Guidance.*

2.6.4 The ReFH2 calculations were undertaken within the ReFH2 standalone software to calculate peak flow estimates from catchment descriptors as provided in Tables 2.2 and 2.3.

Storm Duration Estimation

i. East Catchment

2.6.5 The default rainfall parameters derived by ReFH2 from the FEH2022 rainfall model were applied. A storm duration of 7.50-hours and a timestep of 0.50-hours were used. A Seasonal Correction Factor (SCF) of 0.70 and Areal Reduction Factor (ARF) of 0.98 were also applied.

ii. West Catchment

2.6.6 The default rainfall parameters derived by ReFH2 from the FEH2022 rainfall model were applied. A storm duration of 1.50-hours and a timestep of 0.50-hours were used. A Seasonal Correction Factor (SCF) of 0.67 and Areal Reduction Factor (ARF) of 0.98 were also applied.

Peak Flow Estimation

2.6.7 In line with ReFH2 Method guidance, a winter seasonality (default storm profile) was selected, and flows were estimated for each required return period.

2.6.8 The model parameters for the ReFH2 method should ideally be based on actual flood event data comprising rainfall and flow records rather than catchment descriptors alone. However, due to the lack of available flow data for the catchment, the ReFH2 design standards have been adopted in this instance based on the technical guidance.

2.6.9 The key ReFH2 model parameter values are provided in Tables 2.5 (East Catchment) and 2.6 (West Catchment).

2.6.10 The peak flows calculated using the ReFH2 Method are summarised in Table 2.7. Calculation extracts are included in Appendix 3.

Table 2.5: ReFH2 Parameters - East Catchment

Parameter	Unit	Default Value	Adjusted Value
T_p	Hours (hrs)	4.24	-
B_L	Hours (hrs)	40.39	-
B_R	-	1.66	-
C_{Max}	Millimetres (mm)	375.40	-
C_{ini}	Millimetres (mm)	107.24	-
BF_0	m^3/s	0.07	-

Table 2.6: ReFH2 Parameters - West Catchment

Parameter	Unit	Default Value	Adjusted Value
T_p	Hours (hrs)	2.78	-
B_L	Hours (hrs)	33.37	-
B_R	-	2.16	-
C_{Max}	Millimetres (mm)	411.13	-
C_{ini}	Millimetres (mm)	101.05	-
BF_0	m^3/s	0.02	-

2.6.11 A climate change allowance of 35% has been added to the 1 in 30-year and 40% to the 1 in 100-year flow estimate representing the 'Upper End' estimate for the 2070 epoch (2061 to 2125) for the Severn Middle Worcestershire Management Catchment[4].

Table 2.7: ReFH2 Method Peak Flows (Winter Profile)

Return Period	East Catchment - Direct Rainfall (mm/h)	West Catchment - Direct Rainfall (mm/h)
30	2.05	2.32
100	2.66	3.01
1000	4.42	5.00
*30 + (35%CC)	2.90	3.27
*100 + (40%CC)	3.98	4.49

*Climate Change Peak flow allowances for Severn Middle Worcestershire Management Catchment: Upper End (2061 – 2125).

Peak Flow Components

2.6.12 Peak flows as shown in Table 2.7 are calculated from, and comprise of, a number of components as derived by ReFH2 software (Figures 2.8 and 2.9). The components are:

- Design rainfall (mm) - represents the total rainfall falling in the catchment
- Total net rainfall (mm) - represents the rainfall (after losses) that contributes to direct runoff.
- Direct runoff (m^3/s) - Direct (Overland/surface water) runoff
- Baseflow (m^3/s) - Baseflow representing the emergence of infiltrated rainfall volumes.

[4] https://environment.data.gov.uk/hydrology/climate-change-allowances/rainfall

Figure 2.8: ReFH2 Output components (1000-year event) - East Catchment

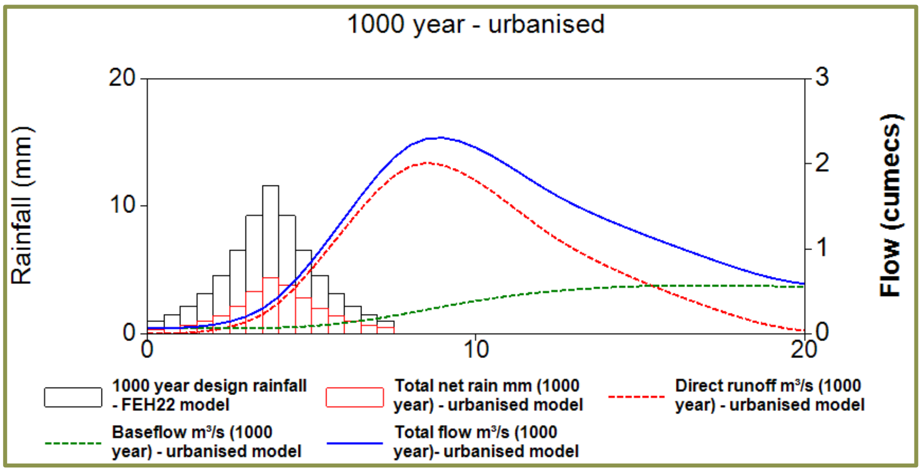
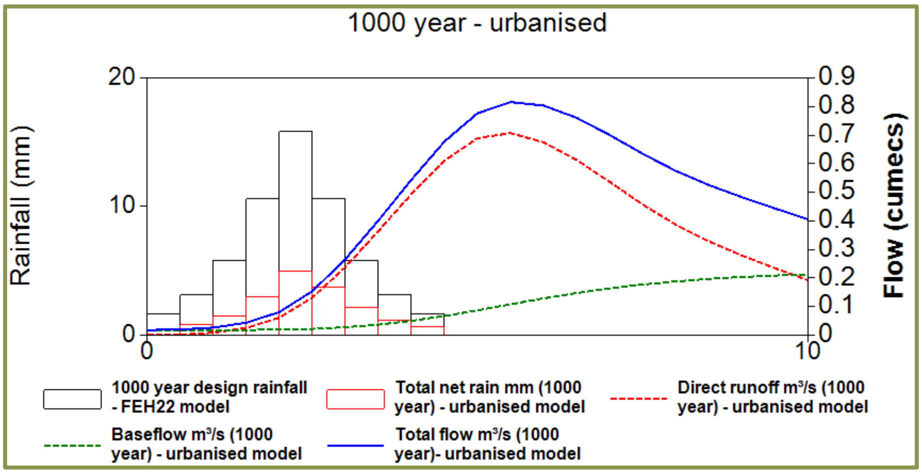


Figure 2.9: ReFH2 Output components (1000-year event) - West Catchment



2.6.13 The net rainfall as shown in Figures 2.8 and 2.9 have formed the rainfall input to the direct rainfall model.

2.7 Inflow Boundaries

2.7.1 Based on the hydrological assessment that has been undertaken, the flow input has been created at one location, representative of: the rainfall on the model domain. It has been added to the model using the following layer '2d_RF_ALB_001'. The flows have been inputted as an 'RF' input (Rainfall versus Time [mm]) (Figure 2.10).

2.7.2 The 'RF input (Rainfall) represents total net rainfall as shown in Figure 2.10 and Table 2.7.

Figure 2.10: Peak Flow Calculation and Input Locations

2.8 Downstream Boundary

2.8.1 The model boundary is defined through the layer '2d_bc_ALB_BNDY_001' to allow overland flow to freely exit the 2D model domain without glass walling (Figure 2.10).

2.9 Hydraulic Roughness

2.9.1 Hydraulic roughness represents the conveyance capacity of, vegetation growth, bed and bank material, channel sinuosity and structures and land use within the floodplain. Within ESTRY-TUFLOW, the hydraulic roughness is defined using the Manning's 'n' roughness coefficient values.

2.9.2 Manning's 'n' roughness values were assigned from survey and photographs, modelling judgement and through industry standard literature including Chow, Hicks & Mason and USGS. Chow (1959) contains reference tables to match the structure materials with a value for Manning's 'n'. These reference tables are the most widely used method in 1D modelling.

2.9.3 Manning's roughness values have been input to the 1d 'nwke' layer and tmf (ALB_001.tmf). Use of this method allows application of varying Manning's values to represent in changes in roughness for structures within the model and materials layers.

2.9.4 Scrutiny of the model extent using OS mapping and aerial photographs showed that significant areas were grassed. As such, a base value of 0.045 representing 'General Surface Natural' was utilised within the model. Further layers representing roughness for various identified land uses have been added, namely:

- 2d_MAT_ALB_ Trees_and_Shrubs_001 (Manning's value of 0.10)
- 2d_MAT_ALB_Roads_Tracks_Hardstanding_001 (Manning's value of 0.025)

- 2d_MAT_ALB_Gardens_001 (Manning's value of 0.05)
- 2d_MAT_ALB_Buildings_001 (Manning's value of 0.05)

2.10 Topographic Changes

2.10.1 Layer '2d_ztin_ALB_Site_001', '2d_ztin_KNE_Site_002', '2d_ztin_KNE_Site_003', '2d_ztin_KNE_Site_004', '2d_ztin_KNE_Site_005', '2d_ztin_KNE_Site_006', '2d_ztin_KNE_Site_007', '2d_ztin_KNE_Site_008', and '2d_ztin_KNE_Site_009' define the topography of the Site, with this being represented in the 2D domain. These layers apply spot height levels from the topographical survey.

2.10.2 Layer '2d_zsh_ALB_Decks_001' has been used to reinforce the bridge decks located in the model. This layer applies a known deck level for the bridge rather than using filtered 1m DTM LiDAR.

2.10.3 Layer '2d_zsh_ALB_Channels_001' has been used to reinforce the bed level and gradients of ditches within the model domain.

2.10.4 Layer '2d_zsh_ALB_Ponds_001' has been used to reinforce pond bed levels within the model domain.

2.11 Model layers

2.11.1 Layers used within the model are detailed below.

1D Model Layers

- 1d_nwke_ALB_001; defines in-channel culverts (rectangular and circular culverts)

2D Model Layers

- 2d_bc_hx_ALB_001; defines 1D2D linking cells
- 2d_code_ALB_001; defines model extent
- 2d_bc_ALB_BNDY_001; defines floodplain boundaries to prevent glass walling
- 2d_po_ALB_001; defines a line used as an aid to inform flows across the 2D domain in the model
- 2d_sa_ALB_001; defines a baseflow that is applied directly to the base grid created when the model is run
- 2d_RF_ALB_001; applies a rainfall hyetograph to polygons within the model domain
- 2D_IWL_ALB_001; applies an initial water level to the ponds located within the model domain, which are present from the initiation of the model

2D Topographical Layers

- 2d_ztin_ALB_Site_001; defines the site levels from topographic survey (Parcel 1)
- 2d_ztin_ALB_Site_002; defines the site levels from topographic survey (Parcel 2)
- 2d_ztin_ALB_Site_003; defines the site levels from topographic survey (Parcel 3)
- 2d_ztin_ALB_Site_004; defines the site levels from topographic survey (Parcel 4)
- 2d_ztin_ALB_Site_005; defines the site levels from topographic survey (Parcel 5)

- 2d_ztin_ALB_Site_006; defines the site levels from topographic survey (Parcel 6)
- 2d_ztin_ALB_Site_007; defines the site levels from topographic survey (Parcel 7)
- 2d_ztin_ALB_Site_008; defines the site levels from topographic survey (Parcel 8)
- 2d_ztin_ALB_Site_009; defines the site levels from topographic survey (Parcel 9)
- 2d_zsh_ALB_Decks_001; defines the deck level of bridges in the model
- 2d_zsh_ALB_Channels_001; reinforces the bed level and width of channels in the model domain
- 2d_zsh_ALB_ponds_001; reinforces the bed level of ponds within the model domain
- 2d_MAT_ALB_Trees_and_Shrubs_001; defines 2D roughness for wooded areas
- 2d_MAT_ALB_Roads_Tracks_Hardstanding 001; defines 2D roughness for roads, tracks and car parks
- 2d_MAT_ALB_Gardens_001; defines roughness for gardens
- 2d_MAT_ALB_Buildings_001; defines roughness for buildings
- 2d_MAT_ALB_Water_001; defines roughness for water

2.12 Model Runs

2.12.1 The 2D TUFLOW direct rainfall hydraulic model was run for a range of return periods, using peak flows, which are summarised in Table 2.8.

Table 2.8: Peak Rainfall (mm/hr) Used in the Modelling Study

Return Period	East Catchment - Direct Rainfall (mm/h)	West Catchment - Direct Rainfall (mm/h)
30	2.05	2.32
100	2.66	3.01
1000	4.42	5.00
*30 + (35%CC)	2.90	3.27
*100 + (40%CC)	3.98	4.49

*Climate Change Peak flow allowances for Severn Middle Worcestershire Management Catchment: Upper End (2061 – 2125).

2.12.2 The model was run for the following return periods; 30-year, 100-year and 1000-year.

2.12.3 The model also was run with a 35% for climate change allowance for the 1 in 30-year event and 40% for the 1 in 100-year event, representative of the Upper End estimate for the Severn Middle Worcestershire Management Catchment (2061 - 2125).

2.12.4 Table 2.9 and the modelling log (Appendix 1) provide a summary of all model runs undertaken.

Table 2.9: Run Identifiers and Description (Baseline)

Model Run ID	Scenario Description
~e~_001	Existing free-flowing structures (Baseline)

3.0 Analysis of Results

3.1 Summary of Model Outputs

3.1.1 As this is a 2D direct rainfall model, it should be noted that there are disaggregated/isolated areas of flooding. This is the result of a filtering process undertaken on the raw model outputs whereby all flood depths ≤0.02m have been removed to highlight areas of flooding and remove areas that are 'wet' due to the direct rainfall approach.

3.1.2 Dry islands and polygons smaller than 200m^2 were also removed from the outlines to remove 'noise' from the surface water flood outlines.

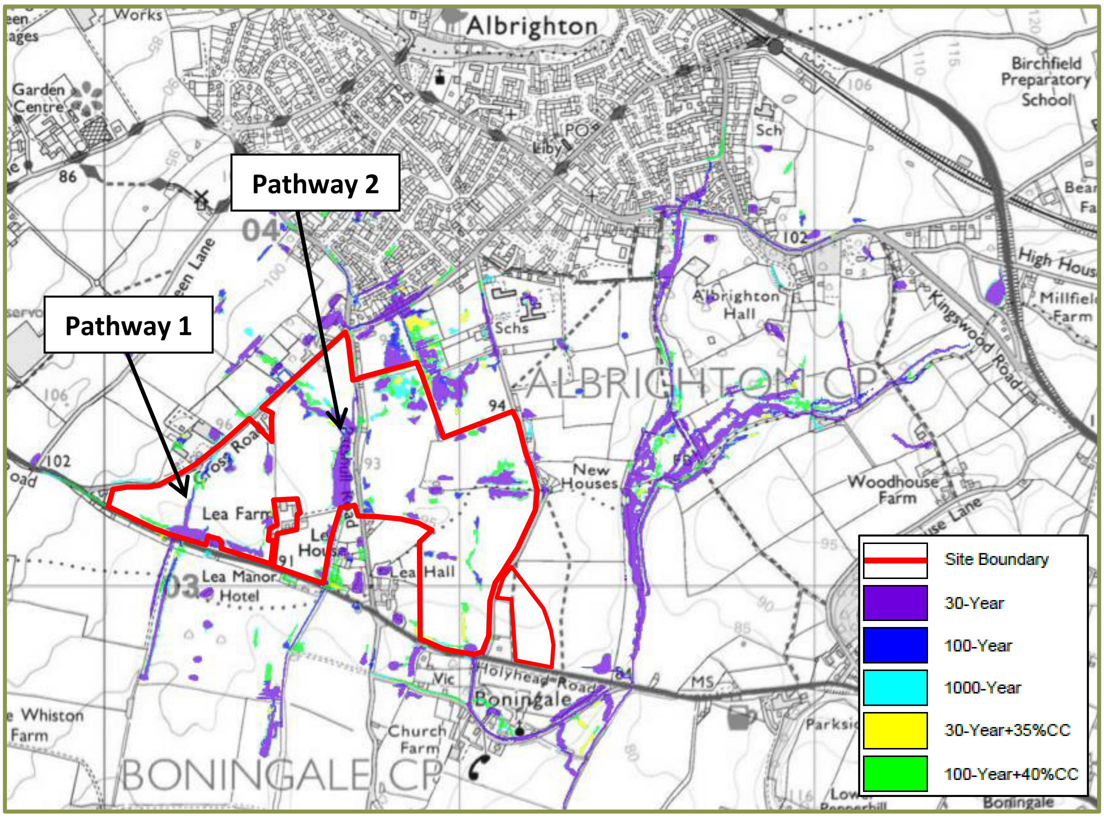
Baseline Scenario (Run 001)

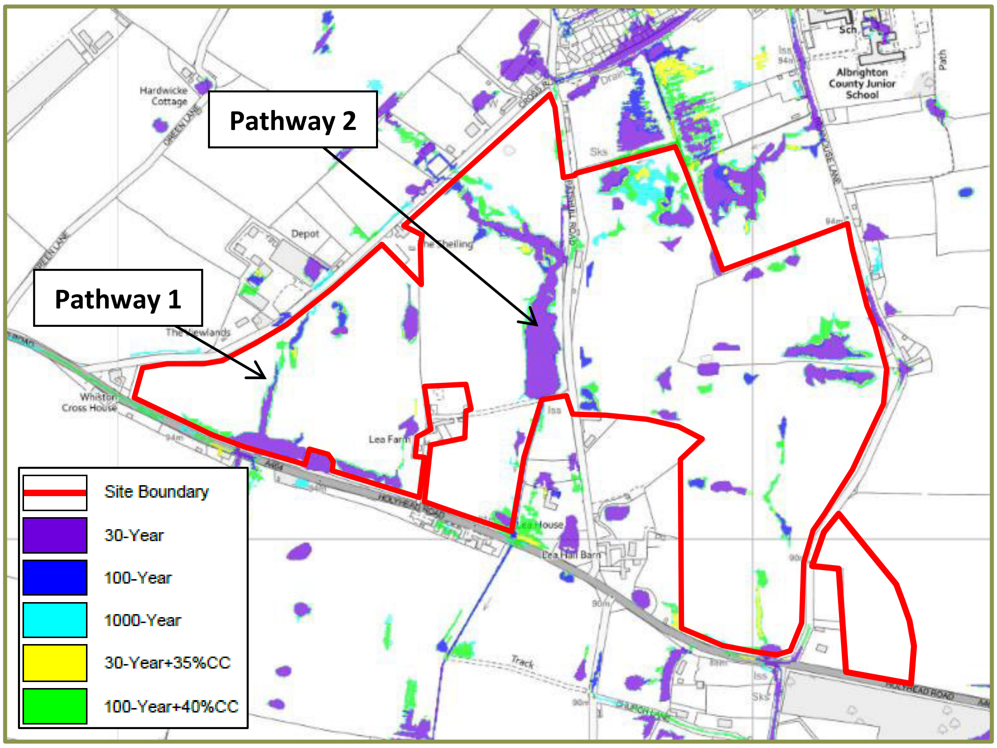
3.1.3 Figure 3.1 shows the maximum flood extents for the whole model domain. The baseline flood extents for Run 001 are also provided as Drawing 001.

3.1.4 The model results show that there are two main flow pathways across the Site. The western pathway (Pathway 1) and the central pathway (Pathway 2) have been identified across all return periods for the Site (30-year, 100-year, 1000-year, 30-year +35%CC and 100-year +40%CC). Both pathways are orientated north to south and follow the natural topography of the Site to exit on its southern boundary (Figure 3.1).

3.1.5 Instances of surface water ponding within the Site boundary, will be dealt with by the proposed drainage strategy for the Site.

Figure 3.1: Baseline Flood Outlines (Run 001)



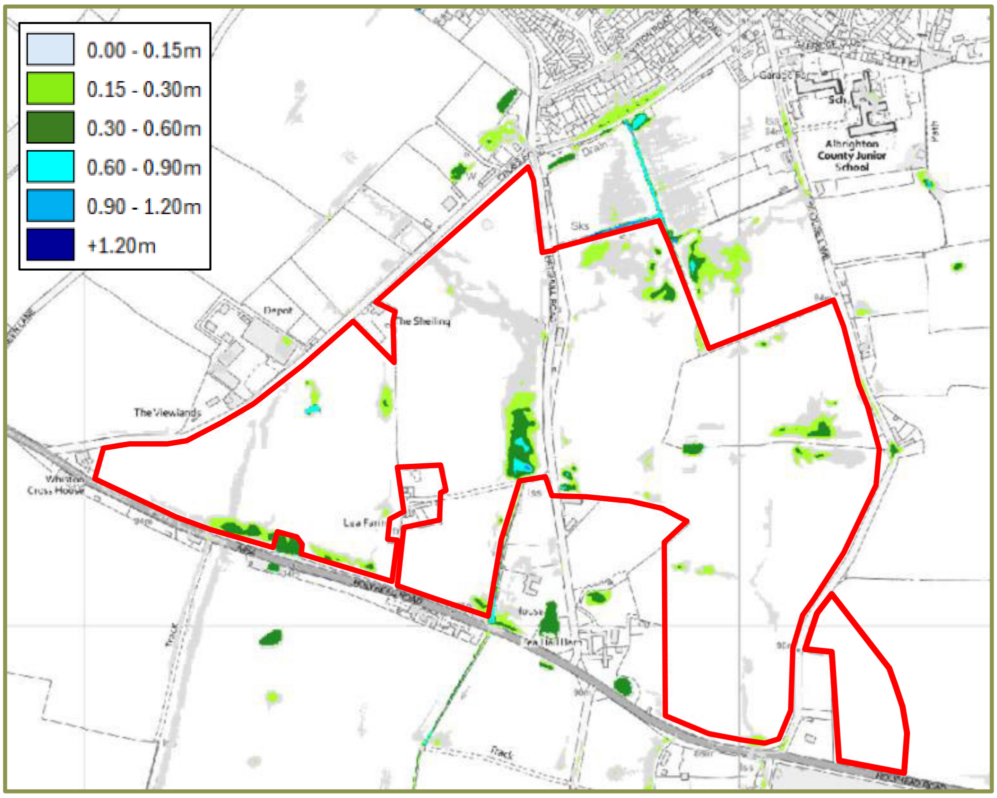


Top: *Wider Catchment View* ***Bottom:*** *Site View*

Flood Depth

3.1.6 Figure 3.2 shows that the flood depth within the Site for Pathway 1 is between 0.00 and 0.60m, while the flood depths for Pathway 2 is between 0.00 and 1.20m.

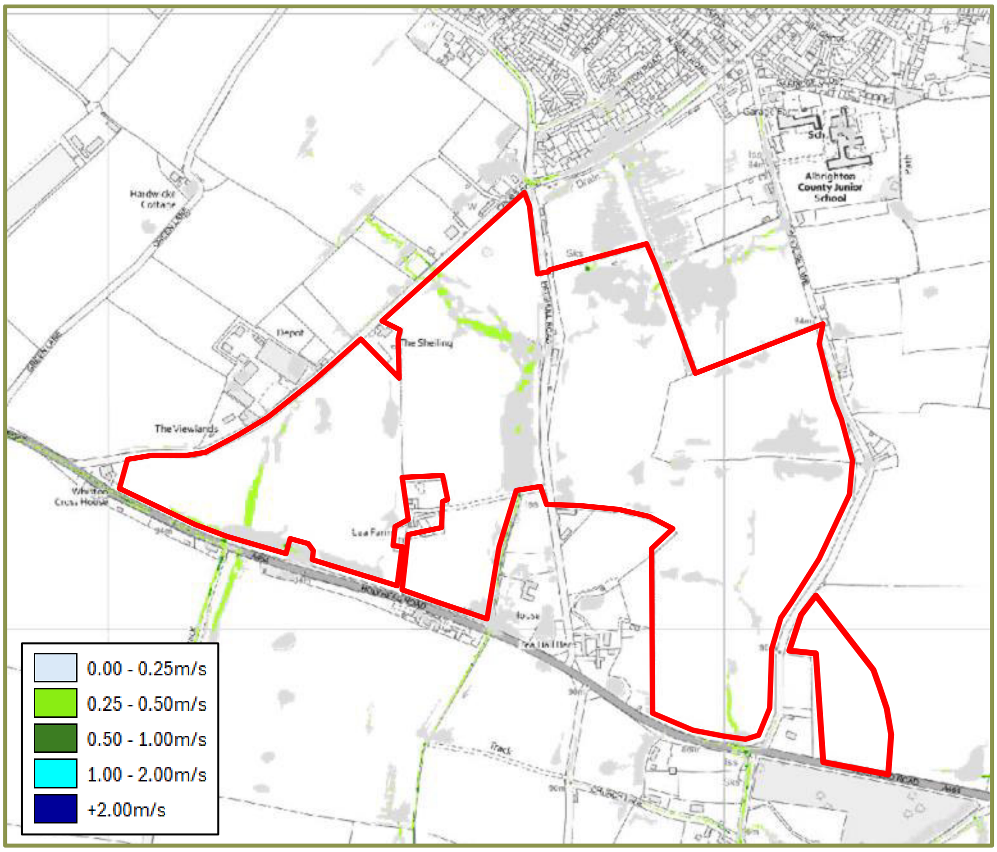
Figure 3.2: Modelled 1000-year Flood Depth



Flood Velocity

3.1.7 Figure 3.3 shows that the flood velocity within the Site for Pathway 1 is between 0.00 and 0.50m/s, while the flood velocity for Pathway 2 is between 0.00 and 0.50m/s.

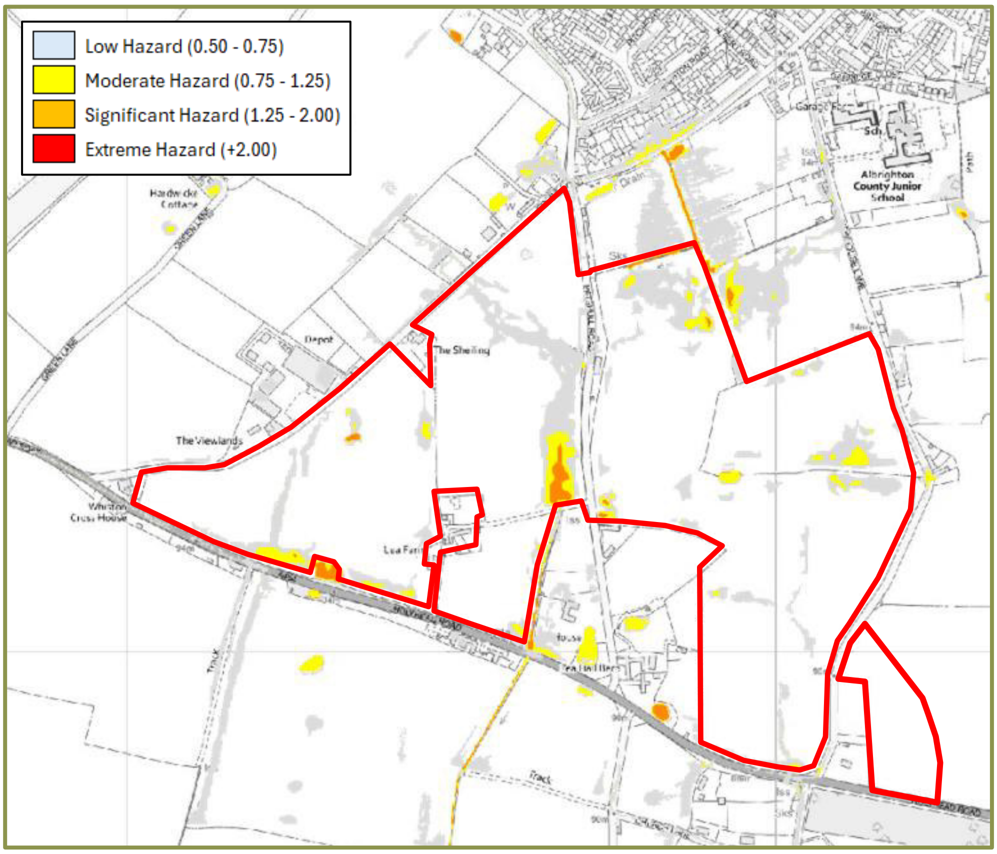
Figure 3.3: Modelled 1000-year Velocity



Flood Hazard

3.1.8 Figure 3.4 shows the flood hazard associated with the flow pathways within the Site boundary. Pathway 1 is classed as having a low to significant hazard (0.50 to 2.00) and Pathway 2 is classed as having a low to significant hazard (0.50 to 2.00). Hazard categories within the model domain vary depending upon the depth and velocity.

Figure 3.4: Modelled 1000-year Hazard



Message Layers

3.1.9 No negative depth warnings are present during the entirety of the model run. The model is considered to be healthy and stable.

3.1.10 An assessment of the warning and check messages is included below:

- Check 2118 - Lowered SX ZC Zpt to 1D node bed level. This refers to a Z flag that has been used to adjust the elevation of an object when the bed level is higher. The location of this has been checked and is as expected

3.2 Mass Balance Error

3.2.1 The TUFLOW User Manual states that a healthy model should display less than a ±1% error or 2 or 3% depending on the objectives of the modelling. Due to all cells being wetted during the model runs, the mass balance error for surface water modelling fluctuates greatly during the initial model run.

3.2.2 On all runs, 1D mass error is above 0% between time 0 and 5 hours. 2D error peaks at -1.9%, which is attributed to initial wetting of the model. Mass balance error is within the acceptable threshold for all model runs for the type of model that is being undertaken (Table 3.1).

Table 3.1: Mass Balance Error

Model Run	Maximum Cumulative Error (%)	Maximum 1D Error (%)	Maximum 2D Error (%)
30-year	Between -1% and 1% for all model runtime	0.0% from start to finish	Between -1% and 1% for all model runtime
100-year	Between -1% and 1% for all model runtime	0.0% from start to finish	Between -1% and 1% for all model runtime
1000-year	Between -1% and 1% for all model runtime	0.0% from start to finish	Between -1% and 1% for all model runtime
30-year+35% Climate Change	Between -1% and 1% for all model runtime	0.0% from start to finish	Between -1% and 1% for all model runtime
100-year+40% Climate Change	Between -1% and 1% for all model runtime	0.0% from start to finish	Between -1% and 1% for all model runtime

3.2.3 The TSMB1D2D results file, which represents error within linking cells, can be used to spatially locate cumulative mass error in situations where areas of instability are not evident. No error was shown within the files for all model runs.

3.2.4 The model is stable, with no fluctuation in ‘Qi’, ‘Qo’ or ‘Dvol’, which represents the variation between inflow and outflow volumes.

3.2.5 It is considered that the constructed model is healthy and representative.

4.0 Baseline Flood Mapping

4.1 Methodology

4.1.1 Flood depth mapping was undertaken within MapInfo software. As the model is a 2D model with embedded 1D culverts, results are produced for the out-of-bank floodplain based upon the underlying 2m grid derived from 1m DTM LiDAR data. Results were produced in 'xmdf' format and imported into MapInfo, where the results were mapped and contoured.

4.1.2 Dry islands and polygons smaller than 200m^2 were also removed from the outlines.

4.1.3 The purpose of this modelling exercise is to fix surface water flood outlines, representative of surface water flooding for the catchment to determine surface water flood extents in the development Site. Contouring of the results allows for the production of low (1 in 1000-year), medium (1 in 100-year) and high (1 in 30-year) risk areas of surface water flooding.

4.1.4 Flood outlines for the medium and high-risk outlines were also produced to represent flood risk to the Site for the lifetime of the development for the 1 in 30-year +35% and 1 in 100-year +40% climate change events. The contoured and mapped results are presented in Figures 4.1 and 4.2 and Drawings 001 and 002.

Figure 4.1: Modelled Flood Extents (Run 001)

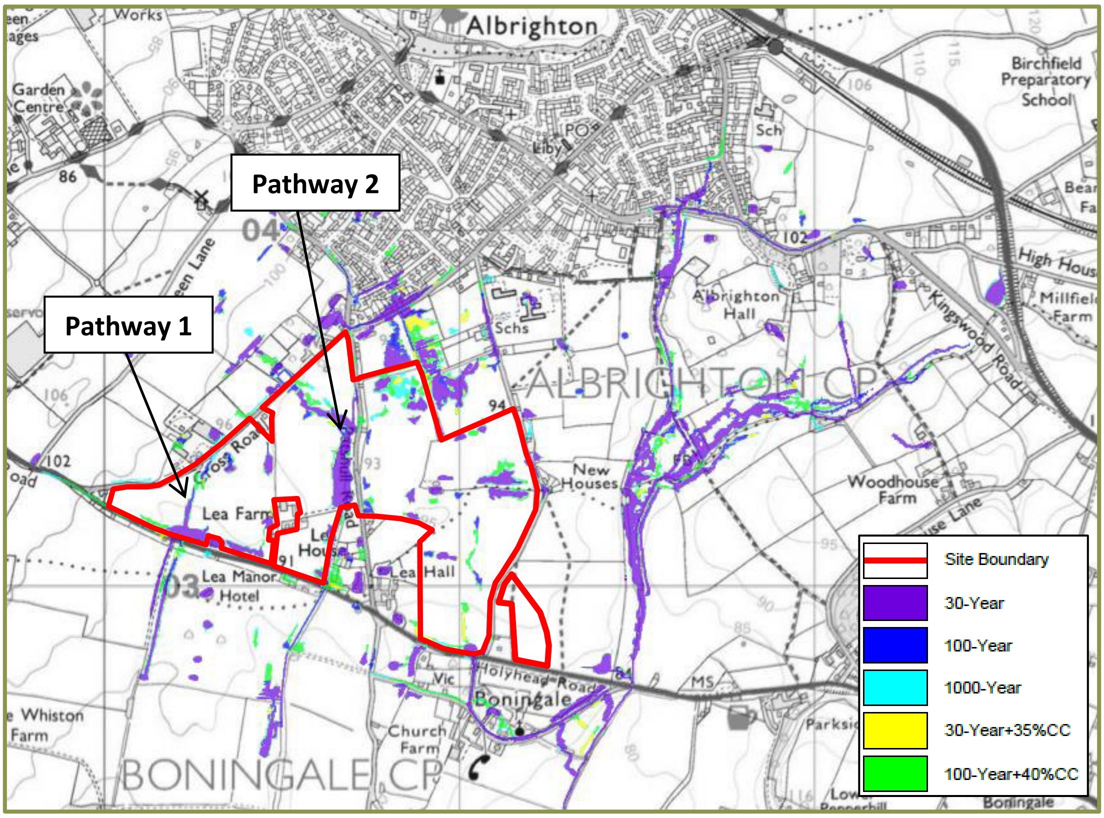
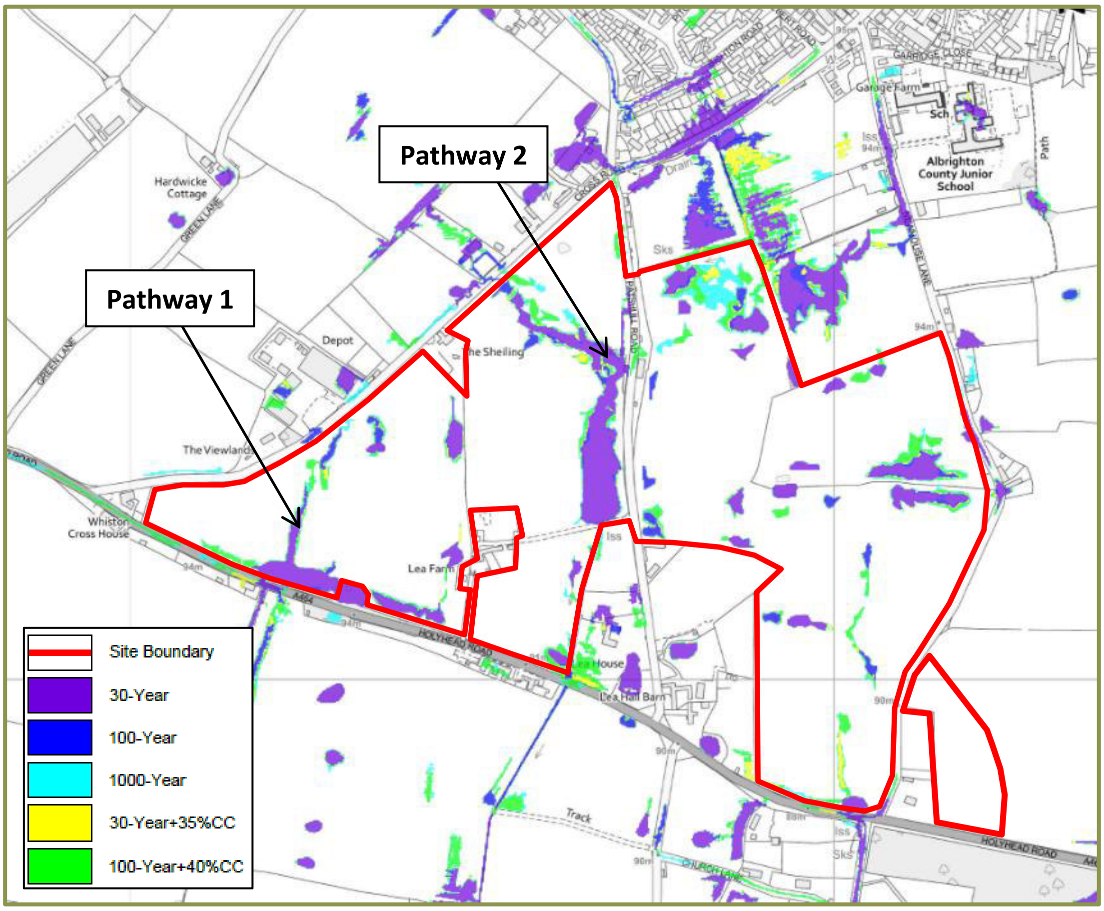


Figure 4.2: Modelled Flood Extents – Site (Run 001)



Top: Catchment View ***Bottom:*** *Site View* ***Red****: Site Boundary*

4.2 Reality Check

4.2.1 Figures 4.3 and 4.4 present Environment Agency Surface Water mapping and Enzygo modelled flood outlines for the 100-year and 1000-year events. The below analysis uses model output Run 001.

Environment Agency Surface Water Flood Mapping

4.2.2 A comparison of Environment Agency 100-year surface water mapping (medium risk [Figure 4.3]) and the modelled 100-year flood surface water extent shows that outlines are largely similar to the Environment Agency mapping. Though Pathways 1 and 2 are more defined in the Enzygo Ltd modelled outlines. There is also a noticeable reduction to the surface water ponding located in the northern extent of the Site to the east of Patshull Road.

4.2.3 A comparison of Environment Agency 1000-year surface water mapping (low risk) and Enzygo Lt modelled 1000-year surface water flood extent (Figure 4.4) shows that mapped flood extents are similar to the Environment Agency outlines. As per the 100-year return period there is a noticeable reduction to the surface water ponding located in the northern extent of the Site to the east of Patshull Road.

4.2.4 For both return events the surface water flooding shown to be located along the extent of Patshull Road has been reduced/removed, this is due to the Site-specific topographical survey included within the model runs and the reinforcement of watercourses within the model domain. The minimal variations between Enzygo produced flood outlines and the ones produced by the Environment Agency are due to having a coarse ground model.

Figure 4.3: Environment Agency Surface Water Mapping (Medium Risk – 100-year event)

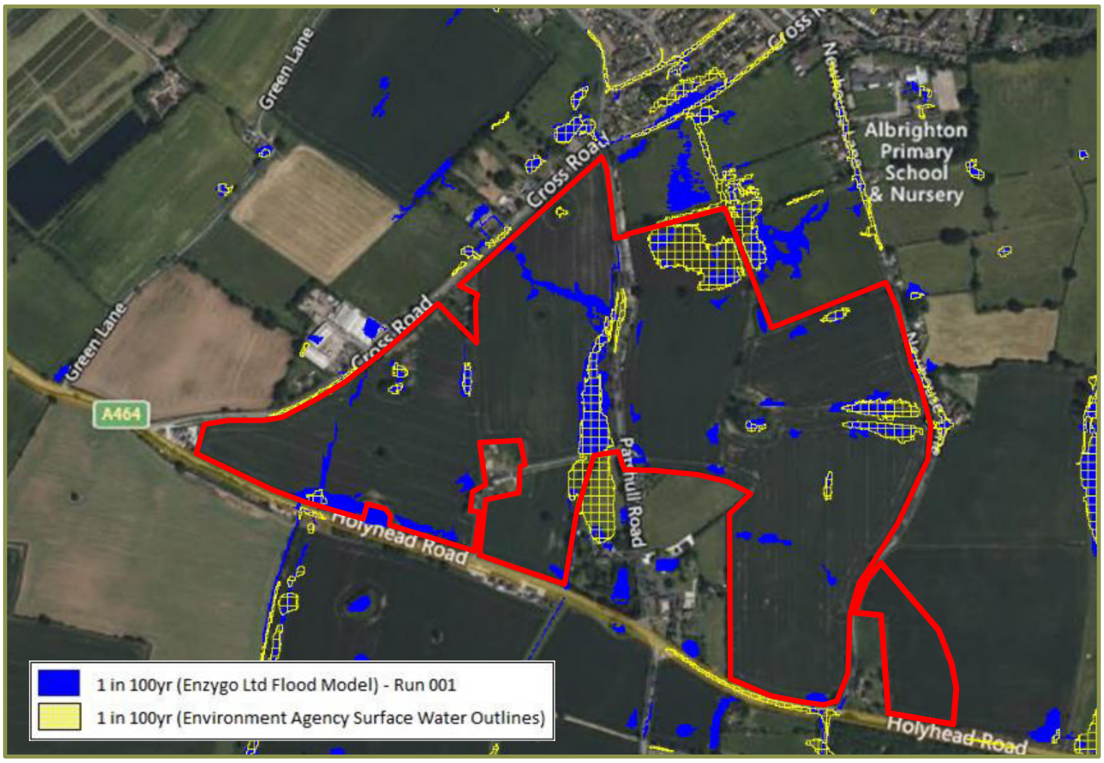
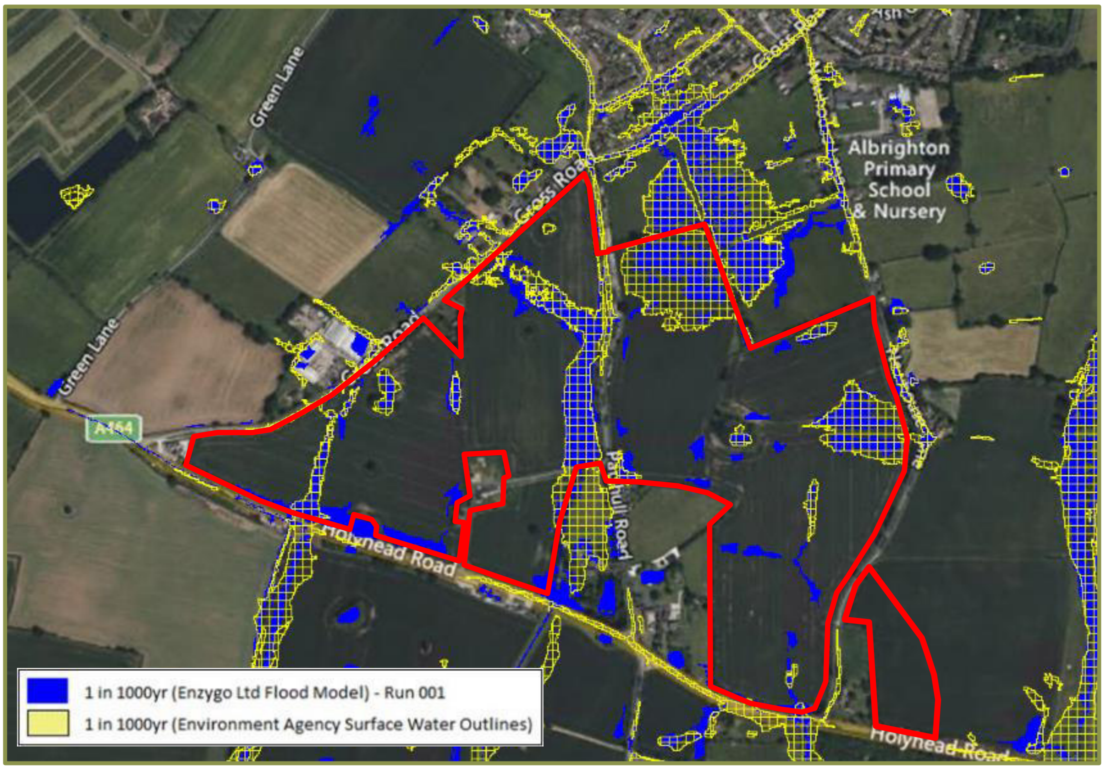


Figure 4.4: Environment Agency Surface Water Mapping (Low Risk – 1000-year event)



4.2.5 The inclusion of the topographical survey for the Site within the direct rainfall model means that when the Enzygo Ltd and Environment Agency surface water mapping is compared there is a variation in depths for Pathway 1, with Environment Agency mapping showing 0.30m and for Pathway 2 showing 0.90m. The velocity of Pathways 1 and 2 have been reduced by the modelling exercise from 1.00m/s to 0.50m/s. The maximum hazard rating based on the Environment Agency mapping for Pathway 1 is 1.25 (moderate hazard) and for Pathway <2.00 (significant hazard) 2.

4.2.6 The variation between the modelled surface water flood extents and the surface water mapping is likely due to the inclusion of detail such as structure conveyance, representation of the watercourse and disaggregated areas of shallow ponding.

5.0 Proposed Model Run

5.1 Introduction

5.1.1 This section details the proposed development (inclusive of surface water control measures), and the outputs of the proposed model runs for the proposed development.

5.2 Proposed Development

5.2.1 The proposal is for a residential development, with associated care home, local centre, secondary school and neighbourhood play area on the 47-hectare (ha) Site.

5.2.2 In order to address the surface water flood from the baseline scenario within the Site, the following is proposed:

- Sequentially develop the Site, limiting the built development (including surface water attenuation) outside the modelled extent of surface water flooding associated with Pathways 1 and 2.
- Intercept Pathways 1 and 2 and redirect flows through a reinforced/realigned ditch network through the centre of the Site to a ditch on the southern boundary, which will flow east towards the existing culvert under Holyhead Road. The interception ditches will be designed to convey the extreme 1 in 1000-peak flow (greater than the 1 in 100-year +40%CC).
- The existing ditch on the eastern boundary of the western parcel will be formalised and increased in size to capture, control and convey flows to the culvert under Holyhead Road. The ditch will be designed to convey the extreme 1 in 1000-peak flow (greater than the 1 in 100-year +40%CC).
- The Ø300mm culvert currently under Holyhead Road will be replaced with a 0.50m (width) x 1.00m (height) rectangular culvert.
- Reinforcement of ground levels within specified areas of the model domain to ensure surface water enters the ditch network on the Site.
- Inclusion of the Ø600mm culvert inlet at the downstream extent of Watercourse 3, which has been assumed to take water south outside of the site catchment.

5.3 Model Run Identifiers

5.3.1 Table 5.1 and the modelling log (Appendix 1) provide summaries of all model runs that are relevant to the analysis undertaken in Section 5.

Table 5.1: Run Identifiers and Description

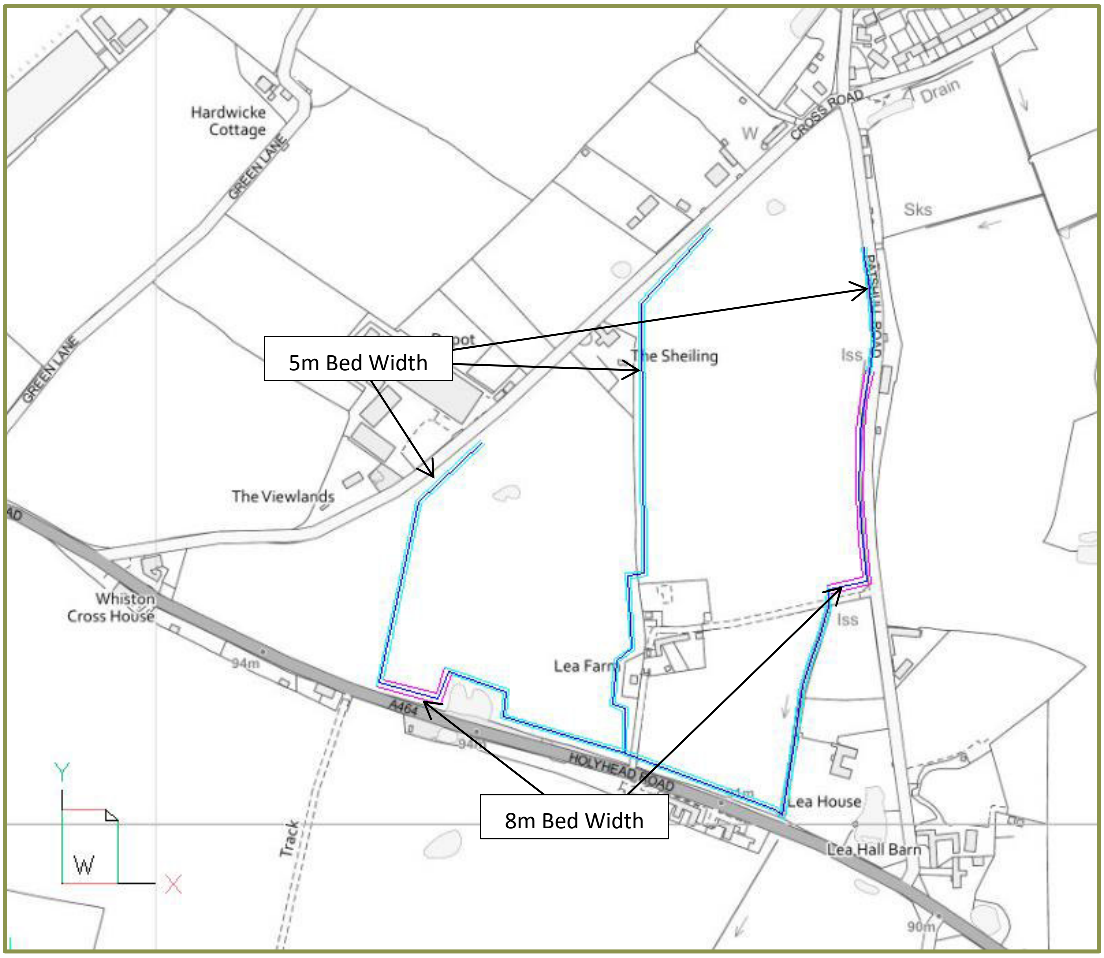
Model Run ID	Scenario Description
~e~_001	Existing free-flowing structures (Baseline)
~e~_017	Diversion channels around the site (most at 5m bed width), 8m where identified. Storage area downstream of the Site. Three areas of land reinforcement to control the flow pathways to the new channels. Crossing under Holyhead Road a 0.50m (W) x 1.00m (H) rectangular culvert.

5.4 Proposed Ditch Reinforcement and Realignment

5.4.1 Existing ditches on the Site have been reinforced and realigned in order to ensure conveyance of surface water flows through the Site. Figure 5.1 shows that the majority of ditches would have a base width of 5m (identified by the cyan buffer), with four reaches having a base width of 8m (identified by the magenta buffer) to intercept surface water flows.

5.4.2 The ditches have been graded to ensure a downslope gradient towards Lea House, where surface water flows are then conveyed under Holyhead Road via the existing ditch network, south, away from the Site.

Figure 5.1: Ditch Reinforcement and Realignment Locations



5.5 Proposed Holyhead Road Crossing

5.5.1 The existing assumed Ø300mm circular culvert under Holyhead Road, would be replaced with a singular 1.00m (W) x 0.50m (H) box culvert. This is to increase conveyance capacity of the surface water flows away from the Site.

5.5.2 Figure 5.2 shows the maximum flows for the maximum depth of 500mm (using OpenChan v1.0 Uniform Flow) of a singular 1.00m (W) x 0.50m (H) box culvert is $0.606m^3/s$. Which is an increase of $0.568m^3/s$ when compared to the assumed existing conveyance asset (Figure 5.3).

Figure 5.2: 1.0m x 0.5m Box Culvert Max Capacity - OpenChan Calculation

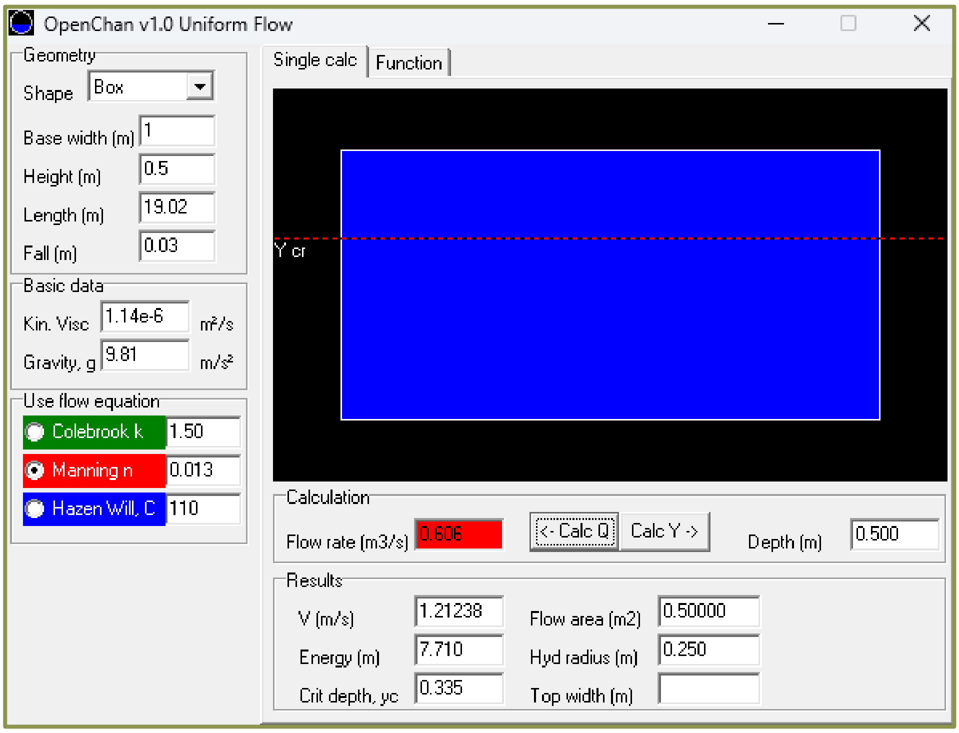
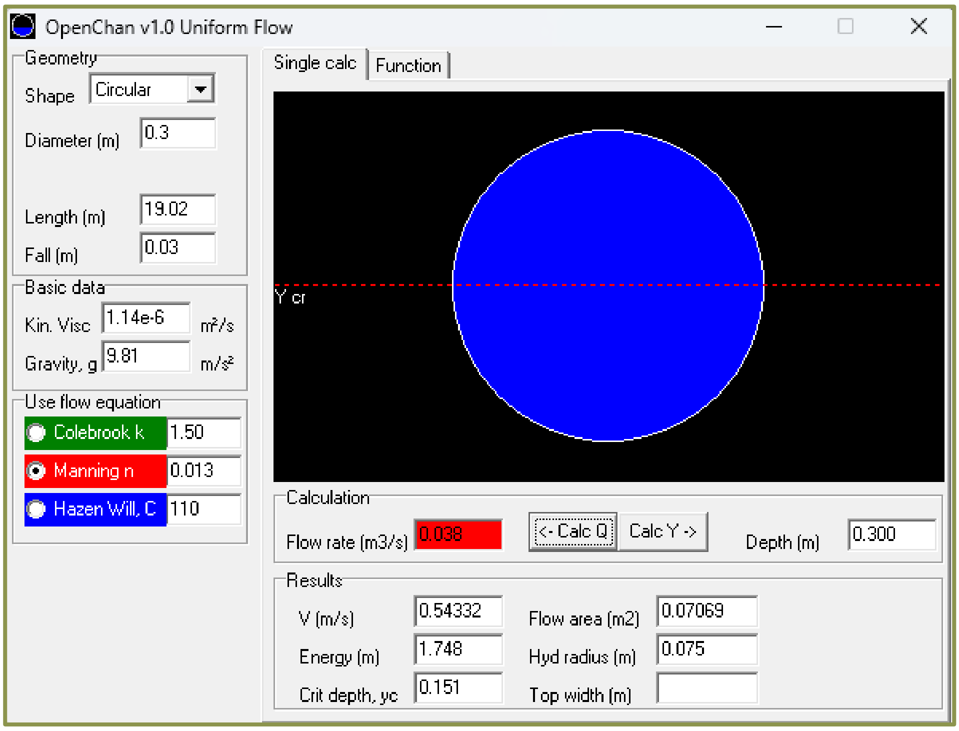


Figure 5.3: Assumed Ø300mm Circular Culvert Max Capacity - OpenChan Calculation



5.6 Existing Ø600mm Circular Culvert Inlet

5.6.1 At the downstream extent of Watercourse 3 there is a Ø600mm culvert (Figure 5.4), which at the time that the walkover was undertaken was shown to have a reasonable level of flow. Current Severn Trent asset plans do not show a culverted watercourse on their asset plans. As such, based on the ground levels on the Site and the existing sewer network shown on asset plans, that this identified culverted watercourse flows south (Figure 5.5). This is likely along Patshull Road, with a discharge point to the south of Holyhead Road.

5.6.2 At the time of writing this modelling report a CCTV survey has been scheduled to ascertain the exact location of the Watercourse 3 culvert network, but no reports/results have been received. As such, an assumed route of the culvert has been added to the proposed model and takes any baseflows and surface water inflows to the south of the model domain outside of the Site boundary, this is to simulate that flows will be taken away from the Site.

Figure 5.4: Ø600mm Culvert Inlet for Watercourse 3

Figure 5.5: Ø600mm Culvert Model Routing

5.7 Outline Surface Water Drainage Strategy

5.7.1 Surface water runoff from the Site will be inflated to ground, which offers a betterment to existing conditions with uncontrolled runoff across all return periods.

5.7.2 Surface water runoff from the proposed development would be attenuated on-site up to and including the 1 in 100-year event, plus 40% climate change.

5.7.3 A SuDS drainage scheme is proposed to manage excess runoff from the development, comprising of multiple attenuation basins.

5.8 Proposed Model Layers

5.8.1 The following additional layers were created for the proposed model run:

- 1d_nwke_ALB_017; defines the culverts located within the Site boundary, updated Holyhead Road culvert size and Ø600m culvert route.
- 2d_bc_hx_ALB_017; defines 1D2D linking cells.
- 2d_zsh_ALB_Slope_017; defines reinforcement of ground levels within the model domain.
- 2d_zsh_ALB_Storage_015; define area of land lowering to store surface water.

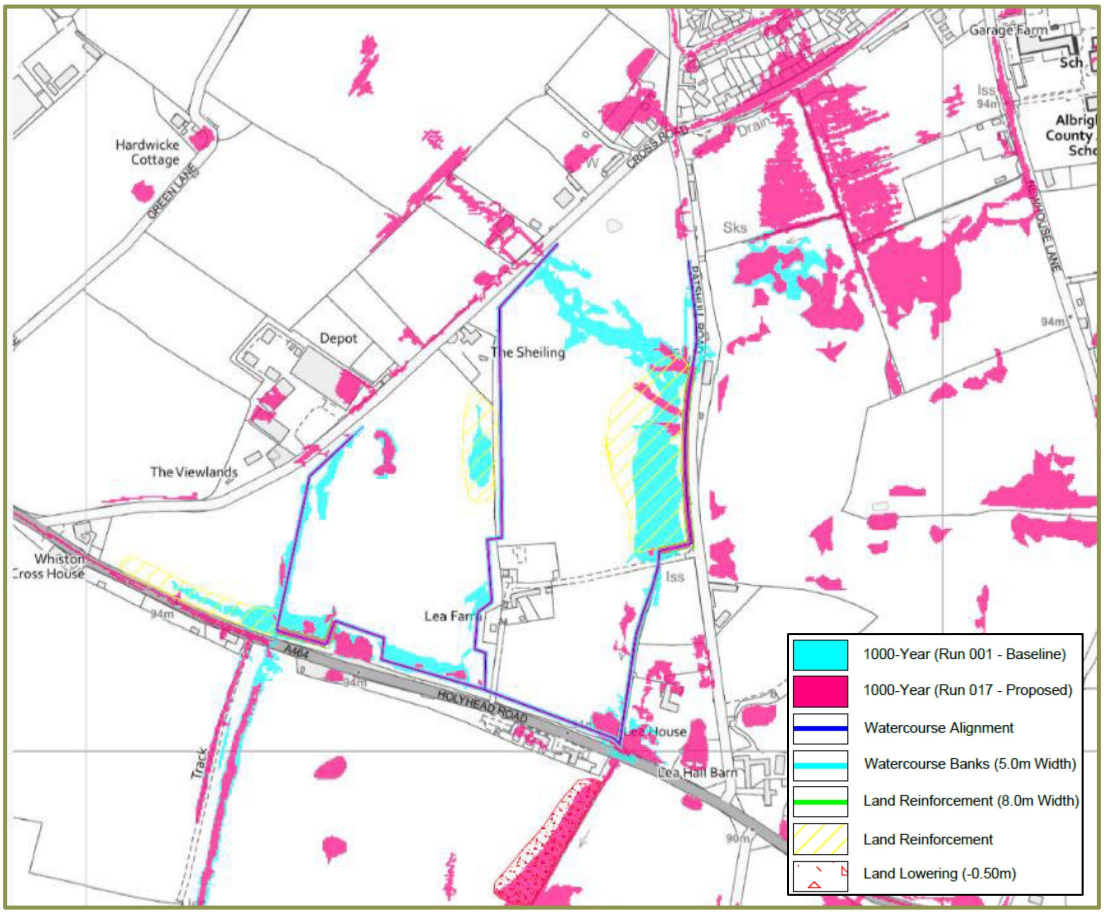
- 2d_zsh_ALB_Channels_016; defines the reinforcement/realignment of channel routing within the model domain.

5.9 Proposed Model Run Outputs

5.9.1 Figure 5.6, Drawings 003 and 0004 shows the inclusion of the proposed measures as detailed in Section 5.2. The inclusion of the proposed measures means that surface water within the Site can be controlled to ensure flooding of the Site does not impact the proposed development. The small instance of the surface water flooding aligned to the west of Watercourse 1 is shallow and is sporadic in nature on mapping, due to the triangulation of the ground model.

Figure 5.6: Proposed Model Run Flood Outlines - Run 001 (Baseline) vs Run 017 (Proposed)

1000-Year Return Period

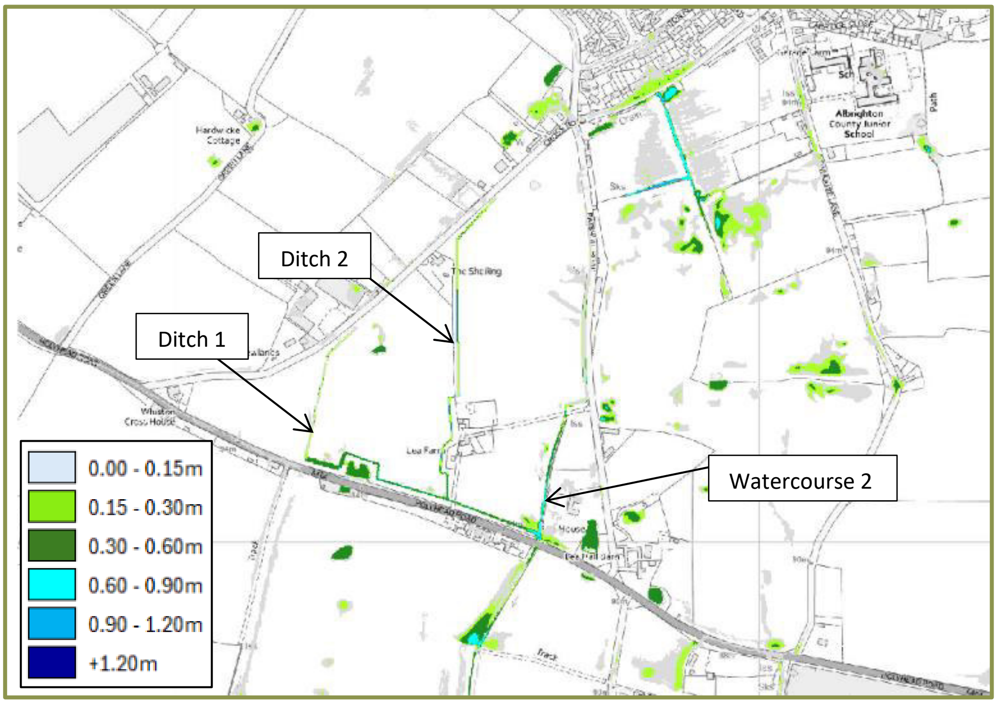


5.9.2 It should be noted that for all return periods surface water flooding located within the Site boundary will be dealt with by the proposed drainage strategy for the Site, with attenuation sized for the 100-year+40%CC event, with a +300mm freeboard (which is a betterment to existing conditions).

Flood Depths

5.9.3 Figure 5.7 shows that based on the produced output mapping the flood depth across the model domain. The maximum flood depth for Watercourse 2 is 0.90m, Ditch 1 is 0.90m and Ditch 2 is 0.60m for the 1000-year flood event.

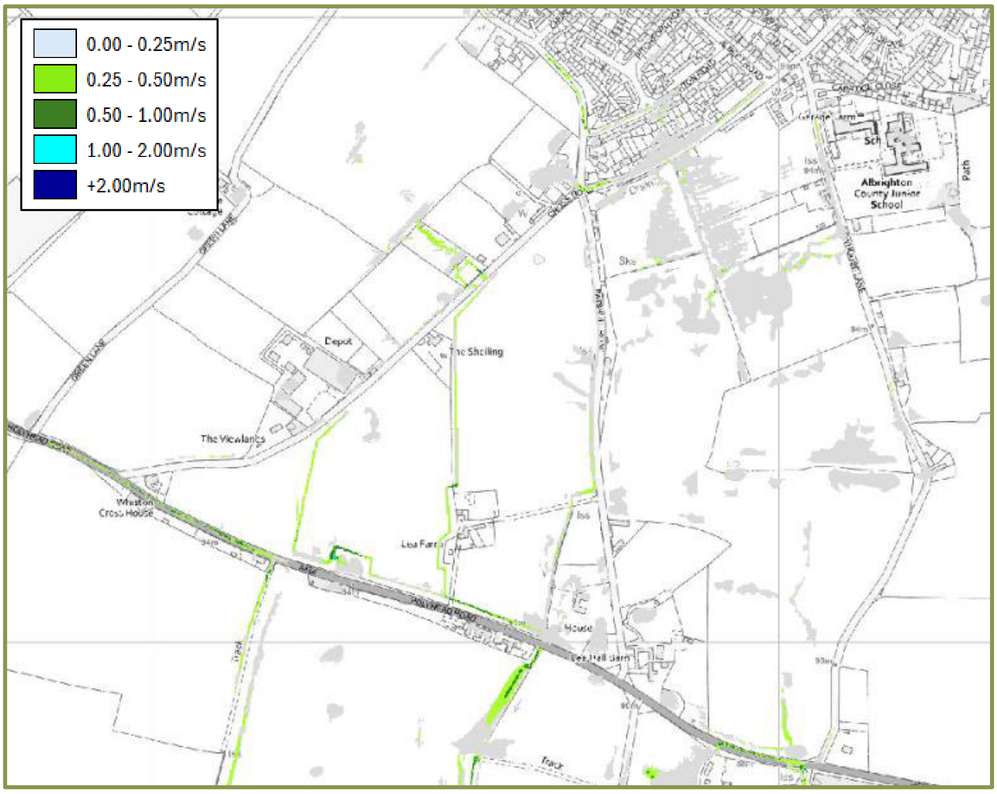
Figure 5.7: Flood Depth Mapping – 1000-year (Run 017)



Flood Velocity

5.9.4 Figure 5.8 shows that based on the produced output mapping the flood velocity across the model domain. The maximum flood velocity for Watercourse 2 is 0.50m/s, Ditch 1 is 1.00m/s and Ditch 2 is 1.00m/s for the 1000-year flood event.

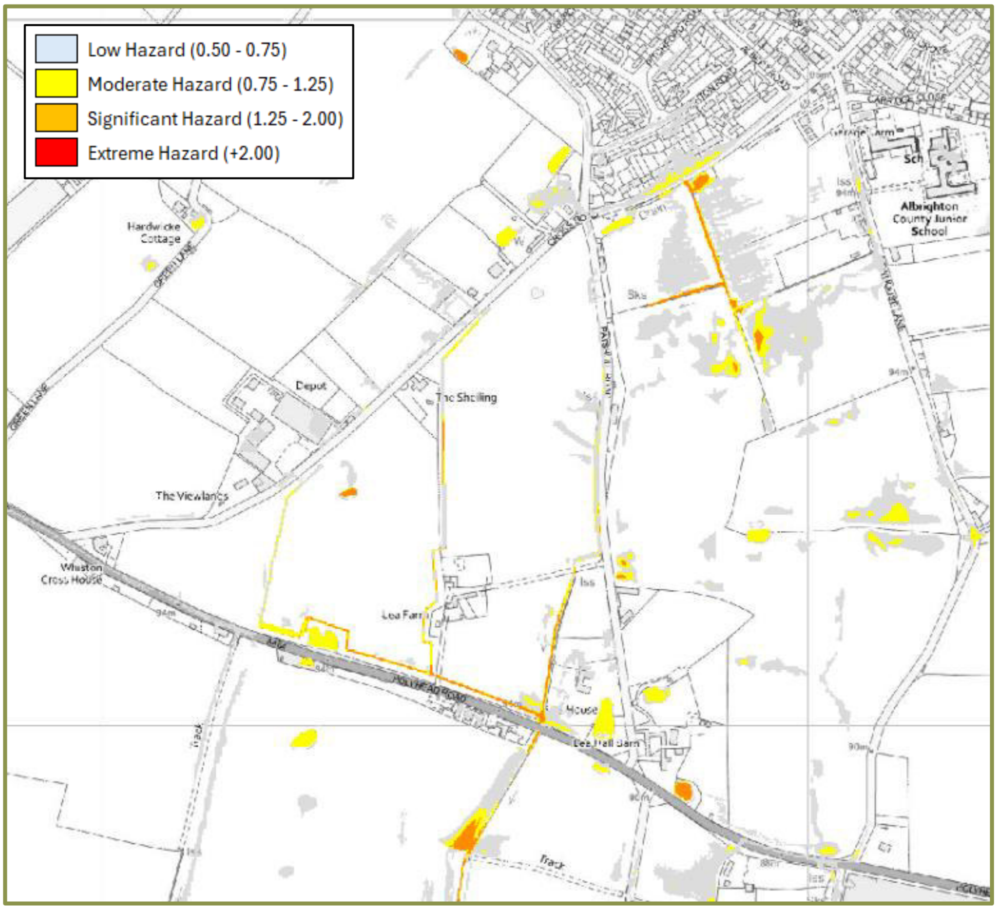
Figure 5.8: Flood Velocity Mapping – 1000-year (Run 017)



Flood Hazard

5.9.5 Figure 5.9 shows that based on the produced output mapping the flood hazard across the model domain. The maximum flood hazard for Watercourse 2 is a significant hazard (1.25 - 2.00), Ditch 1 is a significant hazard (1.25 - 2.00), and Ditch 2 is a significant hazard (1.25 - 2.00), for the 1000-year flood event.

Figure 5.9: Flood Hazard Mapping – 1000-year (Run 017)



5.10 Proposed Model Run Summary

5.10.1 The inclusion of the proposed measures means that surface water within the Site can be controlled to ensure flooding of the Site does not impact the proposed development.

6.0 Summary and Conclusions

6.1 Introduction

6.1.1 This report presents a direct rainfall modelling exercise for a Direct Rainfall 2D TUFLOW for the catchment based on 1m DTM LiDAR Data and topographical survey in order to define baseline flood extents for the development Site.

6.1.2 The Site is shown to lie in Flood Zone 1 (low risk) but is shown to be at risk from surface water flooding.

6.1.3 The model was run for a range of return periods to establish the baseline surface water flood extents and parameters. Current climate change allowances of +35% and +40% representing the Severn Middle Worcestershire Management Catchment Upper End Estimates (2061 – 2125) has also been applied to the 1 in 30-year and 100-year, respectively.

6.1.4 A hydrological assessment, inclusive of a desk-based assessment of catchment descriptors, was undertaken, which utilised ReFH2 software, due to the small catchment size, to provide hydrological inputs, in the form of net rainfall input for the model.

6.2 Existing Flood Risk

6.2.1 The baseline model was run for a range of return periods to establish the baseline fluvial flood extents and parameters. Up-to-date climate change allowances +35% and +40% (representing the Severn Middle Worcestershire Management Catchment [Upper End: 2061 – 2125]) have also been applied to the 1 in 30-year and 100-year event, respectively following Environment Agency guidance.

6.2.2 The results from the modelling exercise shows that flood extents within the Site are slightly reduced and/or have a slight variation in certain locations when compared to Environment Agency surface water mapping but overall extents are comparable. This provides confidence in the modelled outputs.

6.2.3 The variation in flood extent is due to the inclusion of structure information as well as using detailed LiDAR and topographical survey information to include a representation of the topography of the Site.

6.2.4 The model results show that there are two main flow pathways across the Site. The western pathway (Pathway 1) and the central pathway (Pathway 2) have been identified across all return periods for the Site (30-year, 100-year, 1000-year, 30-year +35%CC and 100-year +40%CC). Both pathways are orientated north to south and follow the natural topography of the Site to exit on its southern boundary. Instances of surface water ponding within the Site boundary will be dealt with by the proposed drainage strategy for the Site.

6.2.5 A comparison of Environment Agency 100-year and 1000-year surface water mapping that the flood extents are slightly increased in certain areas and reduced in other areas when compared to Environment Agency surface water mapping. The variation between the modelled surface water flood extents and the surface water mapping is likely due to the inclusion of detail such as structure conveyance, representation of the watercourses and disaggregated areas of shallow ponding.

6.3 Proposed Development

6.3.1 The inclusion of the proposed measures means that surface water within the Site can be controlled to ensure flooding of the Site does not impact the proposed development.

6.4 Conclusion

6.4.1 The 2D TUFLOW and direct rainfall hydraulic modelling has utilised topographical survey data and up to date hydrological inputs. The exercise has demonstrated the existing/baseline fluvial flood outlines within the Site. The modelling has demonstrated a small decrease in flood extent, when compared to Environment Agency surface water mapping, however, overall flood extents are comparable.

DRAWINGS