Willow Cottage, Alvescot

Flood Risk Assessment

Revision A
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EdenvaleYoung

New Civil Engineer 100 COMPANIES OF THE YEAR 2018

WINNER Design Innovator

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Document Control

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Glossary of Terms

- +CC - Return period inclusive for the predicted effects of Climate Change
- 1D - One-Dimensional
- 2D - Two-Dimensional
- AMAX - A series containing the peak flows recorded at a gauge from each year
- AOD - Above Ordnance Datum (0m sea level, Newlyn, UK)
- Channel Cross Section - profile view of a river channel, normally obtained by surveying a line across the watercourse
- Critical Storm - A storm that produces peak run off in the watershed
- Culvert - A device used to channel water, similar to a pipe though may be larger
- Defended - A scenario in which river defences are used
- FEH - Flood Estimation Handbook
- Fluvial - Referring to the processes associated with rivers and streams
- FRA - Flood Risk Assessment
- GIS - Geographic Information System
- Hydraulic Model - The mathematical process of analysing the interaction of water and the connected environment
- Hydrology - The calculation of catchment based flow rates
- Inflow - Source of water within a modelled domain
- FMP Software - One-Dimensional hydraulic model – Representation of watercourses
- FMP-TUFLOW - Hydraulic program that dynamically links FMP and TUFLOW (1D-2D)
- LiDAR - Light Detection And Ranging, remote sensing technology to measure distance typically used to obtain topographic data over a large area
- Outflow - The method by which water may leave a modelled area
- Overtopping - Where water has passed over a feature that might ordinarily prevent flow
- f100 - 1% annual probability fluvial event
- f1000 - 0.1% annual probability fluvial event
- f100CC - 1% annual probability fluvial event with an allowance for the predicted effects of climate change
- fMED - The median of the set of annual maximum flow data (AMAX)
- TUFLOW Software - Two-Dimensional hydraulic model – Representation of floodplain
- Undefended - A scenario in which river defences are ignored

1 Introduction

Edenvale Young Associates (EVY) has been commissioned by Robert Rhodes to undertake a Flood Risk Assessment (FRA) to evaluate the flood risk associated with the development of a bridge across the Shill Brook near Alvescot, West Oxfordshire. The proposed location for the bridge is shown in Figure 1.1. The bridge will give the land owner access between two parcels of their land, rather than a connection using another landowner's property.

The aim of this FRA is to assess the Baseline and Post-development flood risk at this location and explain the strategy for mitigating flood risk in order to ensure that the development will remain safe during its lifetime and not increase the flood risk to others. The scope of the FRA includes:

- Discussion on the the development proposals.
- A review of historical flood risk to the site.
- A review of published data and mapping on flood risk.
- A review of the Strategic Flood Risk Assessment for the area.
- A discussion on the application of National Planning Policy Framework (NPPF).
- Results from baseline hydraulic modelling to evaluate current flood risk to the site.
- Analysis of third party impacts.

As no known detailed hydraulic modelling exists for this section of watercourse, a hydraulic model was built for this study. The model has been run for Baseline and Post-development scenarios for the 5% AEP (1 in 20 year), 1% AEP (1 in 100 year), and the 1% AEP (1 in 100 year) with an allowance for climate change.

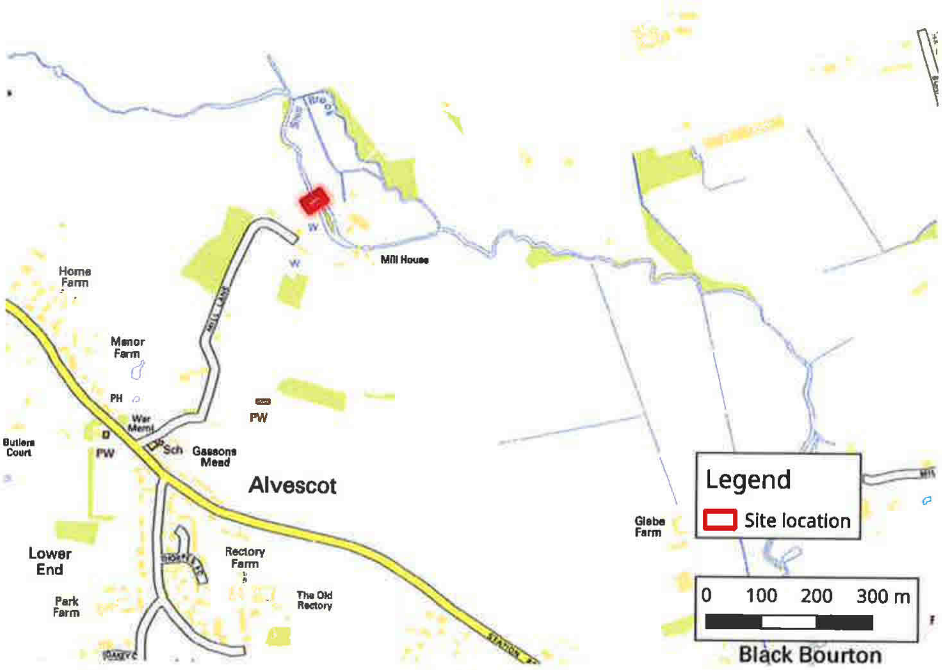


Figure 1.1: Location of the proposed new bridge

2 Development Proposal

2.1 Overview

The development comprises the construction of a new vehicular bridge across the Shill Brook to allow access between Willow Cottage and Time Out Farm, both owned by the same landowner. At present, access to Time Out Farm is via a neighbouring property; installation of the new bridge will allow access between two properties across land within the same ownership. A track will link the bridge to existing properties on either side of the watercourse.

This FRA does not constitute detailed design of the bridge. The hydraulic modelling undertaken as part of this study is intended to demonstrate that the bridge can meet the requirements of the National Planning Policy Framework (NPPF).

2.2 Environment Agency Consultation

Pre-application advice was sought from the Environment Agency (EA) by a previous consultant in respect to a proposal for the new bridge. This included the provision of the technical note which provided suggested design criteria based on the geometry of other local structures. No hydraulic modelling was undertaken.

In their response, the EA stated that:

"We have no objection 'in principle' with a new proposed bridge in this location. However, you will need to demonstrate that the new bridge does not increase flood risk or negatively impact the ecology of the Shill Brook."

The response continues to state that the EA expect to see detailed hydraulic modelling undertaken to inform an FRA, in order that it can demonstrate that the proposed bridge will not cause disbenefit to third parties. The hydraulic modelling undertaken for this project seeks to fulfill this requirement.

Additionally, the EA were asked about their guidance and expectations for setting the soffit height of the bridge. They confirmed that, *"300mm above the Central [Climate Change] Allowance would be sufficient in this instance."*

3 Published Information

3.1 Environment Agency Flood Risk Mapping

3.1.1 Historical Flood Risk

Historical flooding to the area of interest was investigated using recorded flood information held by:

- The Environment Agency.
- The Level 1 Strategic Flood Risk Assessment[1] for West Oxfordshire.

The site of interest does not feature in the EA's Historic Flood Map, nor does it appear as a flooded location in the SFRA.

3.1.2 Flood Zone Classification

Figures 3.1 to 3.3 shows the flood zone classification at the proposed bridge location. The mapping shows that there are no areas benefiting from the defences in the vicinity of the site. The mapping has been extracted from the UK Government's flood map for planning[2] and interestingly shows that the development is within Flood Zone 1. At present, this Flood Zone classification is not fully expected or trusted, and thus this project seeks to undertake detailed modelling of this area to confirm the Flood Zone of the site of interest. It is expected that the site must be in Flood Zone 3 as it traverses a watercourse.

3.1.3 Rivers and Seas

A copy of the "long term flood risk mapping" shown on the UK government website[3] is presented in Figure 3.4. This shows the long term flood risk on the Shill Brook adjacent to the proposed bridge site. The development is just outside of the zone of fluvial flooding.

[1] https://www.westoxon.gov.uk/media/0adg2zs5/env9-west-oxfordshire-district-council-strategic-flood-risk-assessment-update-report-november-2016.pdf
[2] https://flood-map-for-planning.service.gov.uk/
[3] https://flood-warning-information.service.gov.uk/long-term-flood-risk/map

Figure 3.1: Flood Risk for Planning

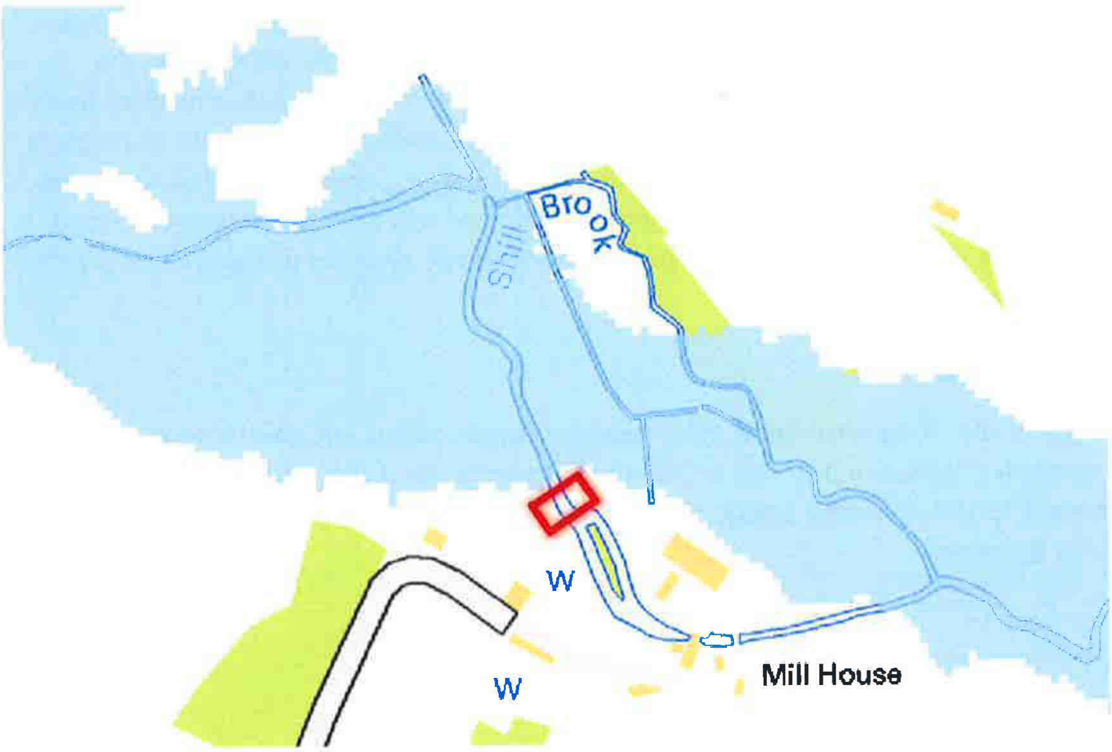


Figure 3.2: Flood Risk for Planning

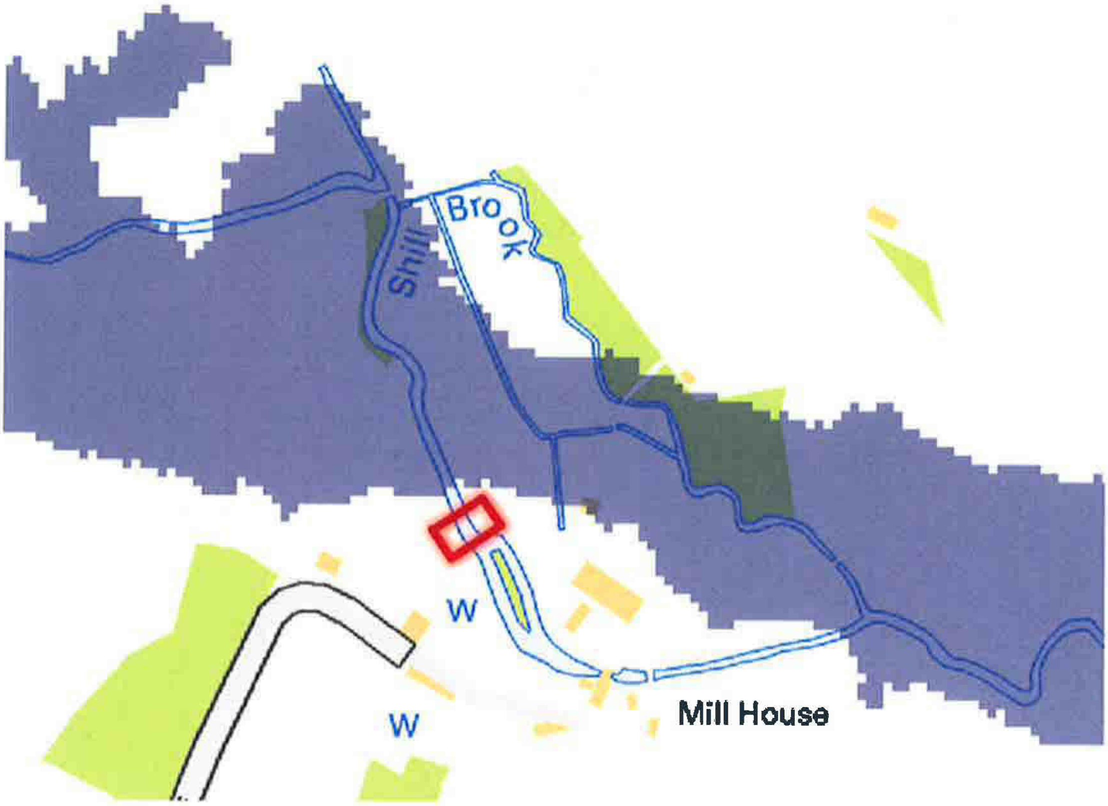


Figure 3.3: Flood Risk for Planning

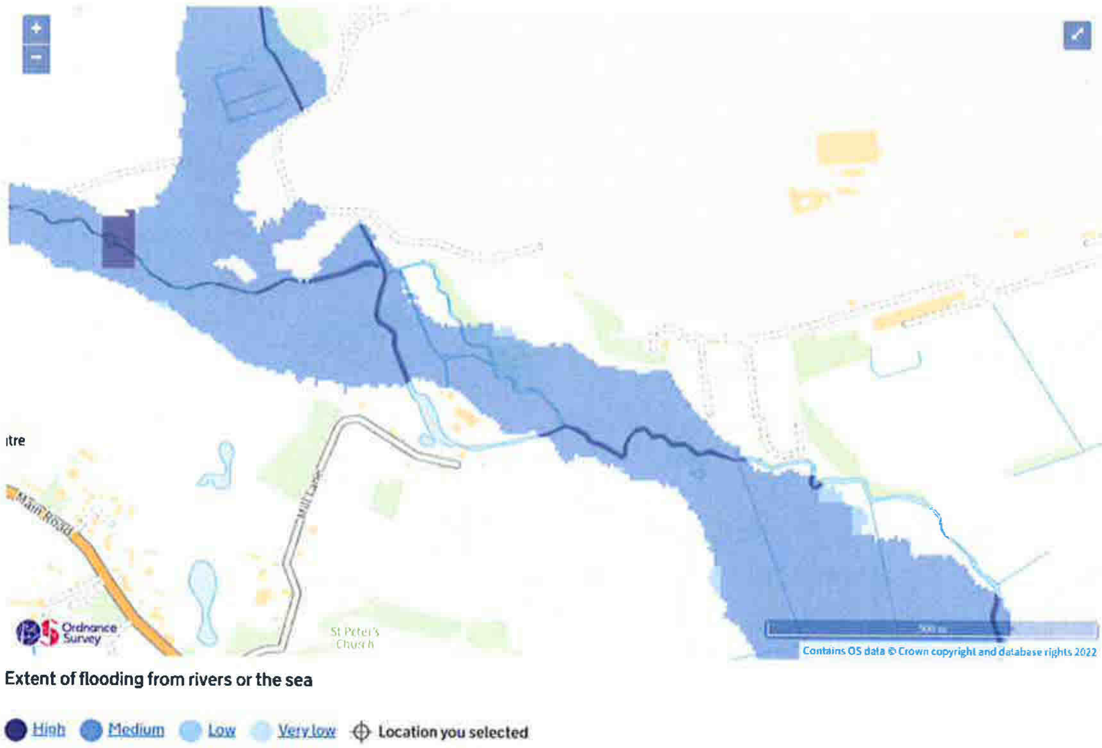


Figure 3.4: Long Term Flood Risk

3.1.4 Surface Water Flood Risk

Figures 3.5 to 3.7 show the surface water flood risk to the site which have been downloaded from the UK Government website [4]. The mapping gives flood depths on the site for high, medium and low risks. Importantly it should be recognised that the depths shown on the figures reflect the existing surface water flood risk and not surface water flood risk to the proposed bridge. The predicted depth of surface water is not considered to present a flood risk to the bridge which will be raised above the maximum surface water level.

Figure 3.5: Surface Water Flood Risk (High <3.3%)

3.1.5 Groundwater

Mapping provided in the SFRA shows that the area of interest is in the category of >=25% < 50% in terms of susceptibility to groundwater flooding. There are no specific records provided for groundwater flooding at the site. Given this information and the nature of the proposed risk of groundwater flooding, it is not considered a significant issue.

3.1.6 Reservoirs

A copy of the Reservoir Inundation mapping is shown in Figure 3.8. The site is not shown to be at risk from this source of flooding.

[4] https://flood-warning-information.service.gov.uk/long-term-flood-risk

Figure 3.6: Surface Water Flood Risk (Medium 3.3% to 1%)

Figure 3.7: Surface Water Flood Risk (Low 0.1% to 1%)

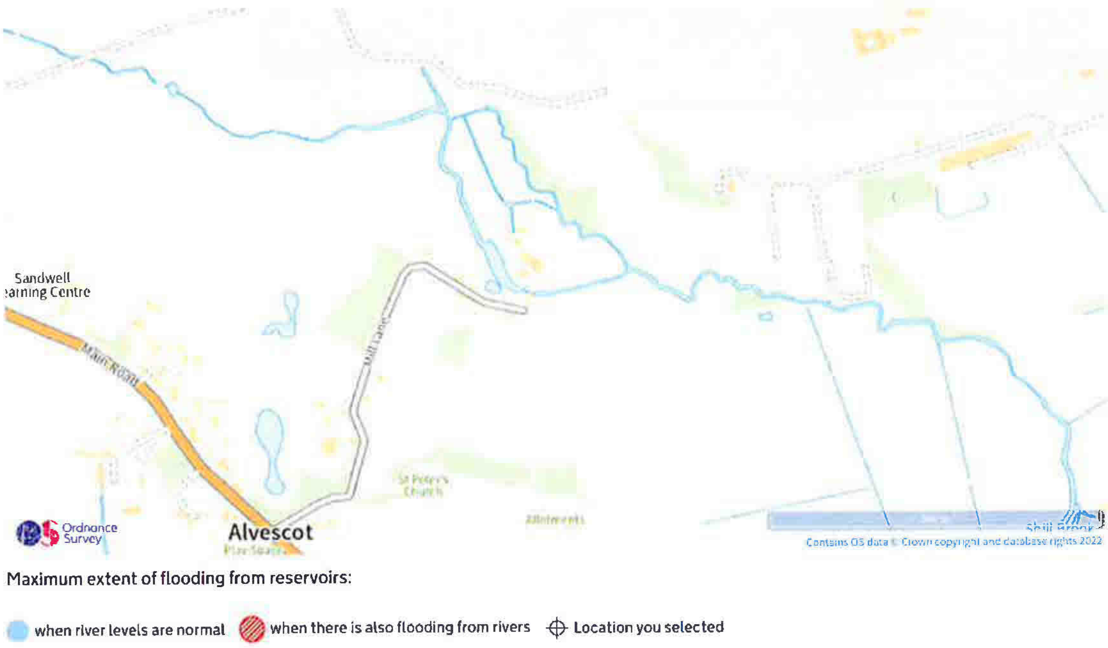


Figure 3.8: Reservoir Inundation

3.2 Strategic Flood Risk Assessment

3.2.1 Flood Risk Mapping

West Oxfordshire District Council has undertaken a Strategic Flood Risk Assessment (SFRA) to inform local planning policy in relation to flood risk. This includes the following documents which have been downloaded from the Local Authority's website:

- AECOM Consulting: West Oxfordshire Level 1 Updated Strategic Flood Risk Assessment: Final Report: November 2016.

The SFRA documents have been reviewed in the context of this study and information has been used where applicable to inform the findings and recommendations of this FRA. It can be confirmed that:

- Flood zone mapping given in the SFRA is commensurate with the mapping shown in Figure 3.4.
- Surface water mapping given in the SFRA is commensurate with the surface water mapping shown in Figures 3.5 to 3.7.
- The site is within a flood warning zone.

3.2.2 Functional Flood Plain

The SFRA defines the functional floodplain as the 1 in 20 year return period (5% AEP) extent which is likely to place the development site inside the functional flood plain (Flood Zone 3b) as it is adjacent to the Shill Brook. However, Water Compatible development is considered to be appropriate in Flood Zone 3b but the applicant must prepare an Exception Test in accordance with Clause 164 of the NPPF.

It is the intention that the soffit for the bridge is set above the 1.0% AEP plus allowance for climate change event but there will be short ramps up to the soffit of the bridge which will be within the functional flood plain. However, the volume associated with these ramps will be negligible by comparison to the functional floodplain.

4 National Planning Policy

4.1 Introduction

The National Planning Policy Framework (NPPF) clauses 159 to 169 details the policy associated with flooding and the sequential, risk-based approach for managing flood risk.

4.2 The Sequential Test

The Sequential Test is used to, where possible, steer development to sites at a lesser risk of flooding. Given that this structure is a bridge and must cross the water to provide access to the opposite bank of the Shill Brook, it would not be feasible to locate the structure elsewhere. The application of the Sequential Test is not applicable in this instance.

4.3 Vulnerability

Flood Risk Vulnerability is determined by the type and use of the development and falls into one of five classifications which ranges from from Essential Infrastructure to Water Compatible. These classifications are used to determine whether a proposed development is compatible with the flood zone in which it is located. Annex 3 of the NPPF and Table 2 of the Flood Risk and Coastal Change Guidance gives the Flood Risk Vulnerability for a range of different types of development. More common examples are given below:

- Essential Infrastructure - Essential transport infrastructure (including mass evacuation routes)
- Highly Vulnerable - Basement dwellings; operational police and ambulance stations
- More Vulnerable - Housing, halls of residence and hospitals
- Less Vulnerable - Shops, restaurants, cafes and offices
- Water Compatible - Water-based recreation, nature conservation and biodiversity

Bridges are not specifically included within the standard classifications contained in Table 2 of the NPPF. On the basis that such a structure must span the river, it seems reasonable that the bridge would be categorised as Water Compatible.

4.4 The Exception Test

Table 3 of the Flood Risk and Coastal Change Guidance (reproduced as Table 4.1) shows whether a particular type of development (i.e vulnerability) is compatible with the flood zone in which it is located. As noted above, the bridge is located in Flood Zone 3b and considered to be 'Water Compatible' development. Water compatible development in Flood Zone 3b does not require the Exception Test and development is considered appropriate.

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Comp Vulnerable
Zone 1	Yes	Yes	Yes	Yes	Yes
Zone 2	Yes	Exception Test	Yes	Yes	Yes
Zone 3a	Exception Test	No	Exception Test	Yes	Yes
Zone 3b	Exception Test*	No	No	No	Yes*

Table 4.1: Flood Zone and Vulnerability Compatibility

**In Flood Zone 3b (functional floodplain) essential infrastructure that has to be there and has passed the Exception Test, and water-compatible uses, should be designed and constructed to:*

- *remain operational and safe for users in times of flood*
- *result in no net loss of floodplain storage*
- *not impede water flows and not increase flood risk elsewhere*

This FRA seeks to address these requirements with information obtained from the hydraulic modelling.

4.4.1 Climate Change

Technical Guidance for climate change gives the flow allowances appropriate to the development. The allowances have been extracted from the peak river flow map which is shown in Figure 4.1. The percentage to be applied is dependent on the development type, life span of the development and flood zone in which the scheme is located. The relevant information is summarised below:

- River Basin District - Cotswolds Management Catchment.
- Development Lifespan - 60 years.
- Flood Zone - Flood Zone 3.

Table 4.2 shows the climate change allowances for fluvial flow are applicable to the scheme.

Climate Change Epoch	Percentage
Central	30%

Table 4.2: Climate Change Allowances for Flow

Cotswolds Management Catchment peak river flow allowances

	Central	Higher	Upper
2020s	11%	17%	31%
2050s	13%	21%	43%
2080s	30%	43%	82%

This map contains information generated by UK Centre for Ecology and Hydrology using UK Climate projections.

Figure 4.1: Fluvial Climate Change Allowances

5 Fluvial Flood Risk

5.0.1 Overview

A 1D/2D hydraulic model was built in order to represent the existing (baseline) scenario. Modelled peak levels for the 1% AEP plus 30% allowance for climate change have been extracted from the model in order to recommend an appropriate soffit level for the proposed bridge.

5.1 Hydrology

A bespoke hydrological analysis has been undertaken to derive design peak flows to the Shill Brook and Unnamed Tributary of the Shill Brook. This analysis has followed standard Flood Estimation Handbook (FEH) approaches. Three estimation points were identified, as set out in Table 5.1.

Estimation Point	Grid Reference	Area (km^2)	Location
SB01	427350, 205200	29.81	Shill Brook, confluence with Unnamed Tributary
TRIB01	427400, 205250	7.03	Unnamed Tributary, confluence with Shill Brook
SB02	427700, 204900	37.2	Shill Brook at downstream of site

Table 5.1: Flow Estimation Points

QMED estimates at all locations were determined using catchment descriptors and donor transfer. For consistency and due to the close proximity of these estimation nodes, growth factors were derived only at node SB02 and applied to all estimation points. Similarly, a single hydrograph shape was derived at SB02 using ReFH2, with the same hydrograph shape and storm duration used for all inflow locations. The hydrographs were scaled to match the statistical peaks.

The intervening catchment area upstream of SB02 was accounted for by scaling the design peak flow at SB02 relative to the intervening catchment size and has been applied as a distributed inflow within the hydraulic model.

Table 5.2 below summarises the design peak flows used within the model. For completeness, the design peak estimate at SB02 has been included, although it should be noted that this design flow is not applied to the model and was instead used as a check node.

The FEH proforma is included in Appendix A.

Estimation Point	2yr	20yr	100yr	100yr+30%cc	1000yr
SB01	1.453	2.955	4.122	5.360	6.305
TRIB01	0.581	1.180	1.645	2.140	2.517
SB02	1.853	3.769	5.257	6.830	8.040
SB02i (Intervening)	0.0183	0.036	0.051	0.070	0.078

Table 5.2: Flow Estimation Points

5.2 Hydraulic Modelling

5.3 Product 4 Information

There was no Product 4 data available for the study location as there is no previous hydraulic modelling at this site.

5.4 Model Scenarios

There are two hydraulic modelling scenarios which are of relevance to this FRA. These are:

- Baseline scenario.
- Post-development scenario.

The **Baseline Model** is typically defined as the hydraulic model of a river, city or catchment held by a regulator and supplied to a consultant for the purposes of undertaking an FRA. Baseline models are normally maintained by the EA. However, in this case where the EA held no previous model at this location, Edenvale Young built a bespoke model for this study. This model incorporates topographic survey data of the site to ensure that the model is representative of local conditions, including ground levels, buildings / walls etc.

The **Post-Development Model** incorporates the proposed bridge. The modelling approach that has been adopted for these elements is described in more detail in the following sections.

These models have been built for the purpose of assessing flood risk to the development in the Baseline and Post-development scenarios. The changes applied for the purpose of this project have been applied to both the 1D and 2D domains. Table 5.3 summarises the models used as part of this modelling exercise.

5.5 Baseline Model

The model of the Shill Brook at Alvescot was built by Edenvale Young for the purpose of this FRA. The model was built using industry standard methods. The model extent is only local to the site of interest, as shown in Figure 5.1.

Model	Baseline	Post-Development
Version Number (Internal Reference)	v16	v16
Results Suffix	-A	-B
Summary	Baseline model which includes detailed topographic survey of the site.	Modifies the Baseline Model to incorporate representation of the proposed bridge.

Table 5.3: Summary of Baseline and Post-Development modelling scenarios

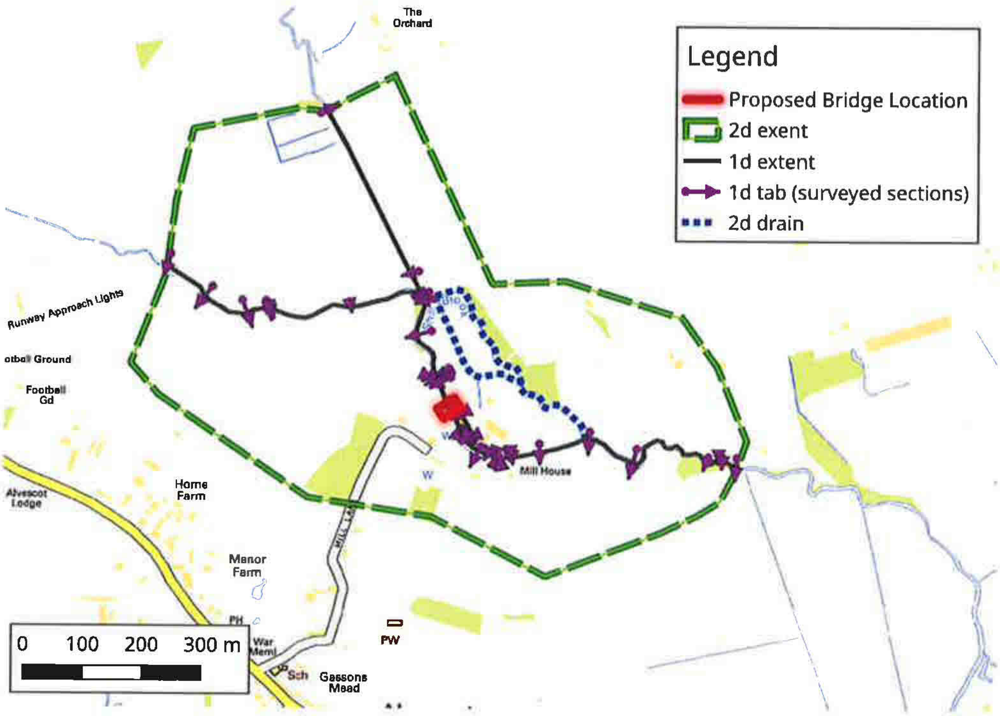


Figure 5.1: Extent of the hydraulic model

5.6 Software Choice

The 1D scheme was modelled using ESTRY, in particular making use of TUFLOW's 1D solver, which is an industry-standard modelling package and is extensively used in the UK. It is particularly adept at simulating complex structures, overbank flows and general channel networks. The latest versions of TUFLOW HPC software have been used in order to model the 2D floodplain. TUFLOW HPC has been in wide use in the UK since 2017 and is a stable and extensively tested two-dimensional (2D) modelling package.

The latest (stable) versions of the software packages were used:

- ESTRY- TUFLOW Version: 2020-10-AD-iDP-w64

5.7 Model Geometry and Terrain

The main survey used to inform the hydraulic modelling was undertaken by Infomap Surveyin March 2022. The sections were exported from the supplied CAD drawings and converted into a cross-sectional chainage suitable for implementing within the 1D Model. The supplied survey cross section locations can be seen in Figure 5.1.

Additional survey was undertaken by Grantham Coates Surveys Ltd in March 2021. This data provided additional information about several river cross sections at the location of the proposed bridge.

Both sets of survey data were used to inform the geometry of the 1D domain. The watercourse in this model has been schematized in 1D using the ESTRY software. This allows for a more accurate representation of the channel bathymetry and conveyance, as well as the ability to accurately represent structures such as arch bridges and culverts.

Composite 1m LiDAR data was download from the EA website. This composite was generated in 2020, albeit makes use of earlier data. This data was used to inform the geometry of the 2D domain. The model 2D cell size was set to 2m, which as reasonable due to the relatively small model domain and size of the watercourse.

Modifications to the geometry were required to better represent the local area. These modifications included:

- Representation of a significant drainage ditch forming off the left bank of the Shill Brook. This has been represented using a 2D gully line, as seen in Figure 5.1.
- Banks were specifically surveyed along the Shill Brook in 2022. These banks have been applied using a thick Z-line, and are applied as to overwrite the underlying LiDAR values, as the survey is more trusted than the LiDAR.

5.8 Model Roughness

Manning's n roughness coefficient values have been selected based on Chow (1959). 1D river roughness values were based on modeller judgement of cross-section photographs received with the survey data. Values varied between individual cross sections as some location noted silty beds or heavily vegetated banks.

Roughness values in the 2D domain have been based on Open-source (OS shapefiles) data, which were downloaded from the OS data hub website.

5.9 Structures

Within the modelled 1D river network are several structures, including various bridges (flat deck or arched) as well as a few weirs which control the flow split both upstream and downstream of the site of interest. These structures were added to the 1D domain using survey data provided.

5.10 Downstream Boundary

A Head-Time (HT) boundary has been applied at the downstream extent of the model. The elevation applied was 79mAOD which is the banktop value at this location.

5.11 Initial conditions

Both the 1D (Shill Brook) and 2D (eastern ditch) have initial conditions set so they they start wet with a small amount of water in them. This has been done to ensure stability and to replicate normal conditions.

5.12 Simulation Parameters

All TUFLOW simulation parameters have been left at their default values. TUFLOW HPC implements an adaptive timestep, meaning it changes over time to meet the conditions of the model control numbers. The model was given a runtime of 60 hours.

5.13 Post-Development Model Build Summary

The proposed bridge will be clear-span and therefore there is no need to model the bridge itself in the 1D domain. It is assumed that the bridge will be 300mm above the modelled water level of the 1 in 100 plus climate change Baseline model results, and with an assumed construction depth of 500mm to account for the deck of the bridge.

As such, the Post-Development model introduces a single Z Shape and Material layers to represent the proposed condition. These layers are summarised in Table 5.4.

TUFLOW layer	Purpose
Z-Shape	Applied in the 2D to represent the ramp up to the bridge. The ramp has a 1 in 20 slope.
Material layer	Applied in the 2D to represent the change of roughness caused by the new track to and from the bridge

Table 5.4: Summary of TUFLOW Layers

Since the completion of the modelling exercise, design considerations have meant that the alignment and gradient of the bridge ramp vary slightly from the configuration that has been modelled. It is considered that the variation in design is sufficiently minor that this would cause negligible difference in results and the conclusions of the modelling exercise would still stand. Figure 5.2 shows the location of the modelled and proposed bridge. Design drawings for the bridge are included in Appendix B and these drawings should be referred to for further detail.

5.14 Model Runs

Modelling has been undertaken representing both Baseline and Post-Development scenarios for the following AEP events; 20%, 1%, and 1% + CC. The full suite of runs

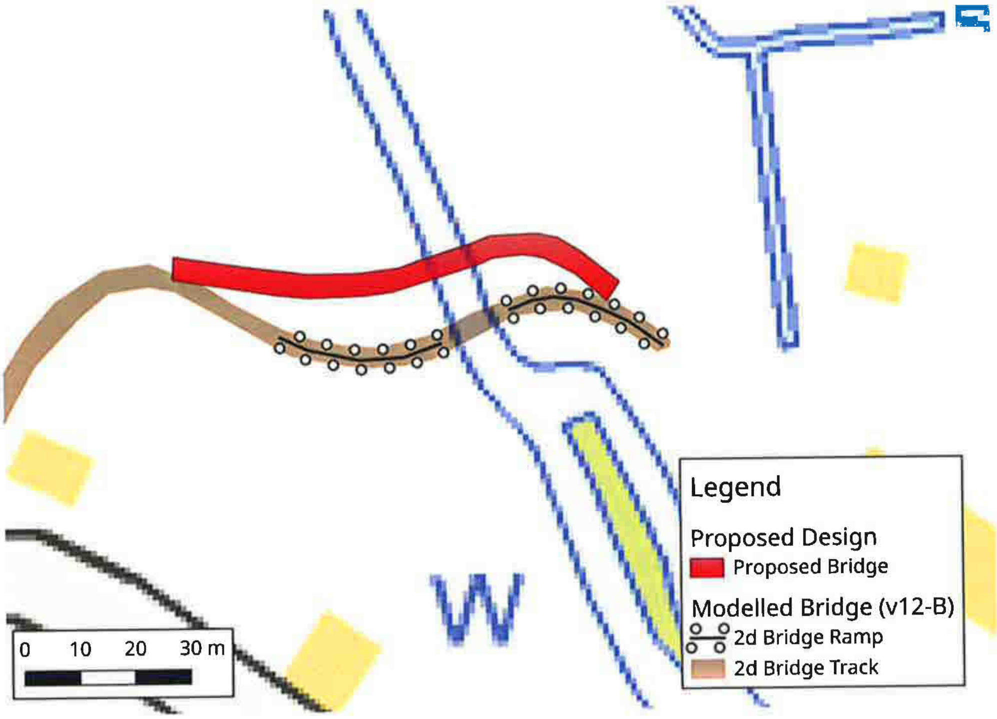


Figure 5.2: Alignment of the modelled bridge compared to the approximate alignment of the proposed bridge.

is shown in Table 5.5.

Scenario	AEP	Climate Change
Baseline	5%	0%
Baseline	1%	0%
Baseline	1%	30%
Post Development	5%	0%
Post Development	1%	0%
Post Development	1%	30%

Table 5.5: Model Runs

5.15 Sensitivity

In addition to the Baseline and Post-development runs a number of sensitivity analyses have been undertaken in order to asses the impact upon the results, in line with best practice. Sensitivity analysis has been carried out out on the baseline scenario model in the 1% AEP event plus climate change scenario on the following variables:

- Manning's Roughness Coefficient (1D and 2D domain).
- Input flow.

Following industry standard, the magnitude of the roughness coefficients were increased (Scenario R+20) and decreased (Scenario R-20) by 20%. Results are shown in Figures 5.3 and 5.4, and they demonstrate that the model is not very sensitive in general to changes in the Manning's roughness coefficient, especially at the proposed bridge location. Rather, the roughness appears to impact how much water is displaced into the eastern ditch and field.

A sensitivity check was also carried out on the impact of applied flows into the model. Flows were increased (Scenario Q+20) and decreased (Scenario Q-20) by 20%. Results are shown in Figures 5.5 and 5.6, and they demonstrate that the model is somewhat sensitive to flow. Levels were seen to increase by 0.013m in the Q+20 scenario around the location of the proposed bridge, and equally decreased by 0.021m in the Q-20 scenario.

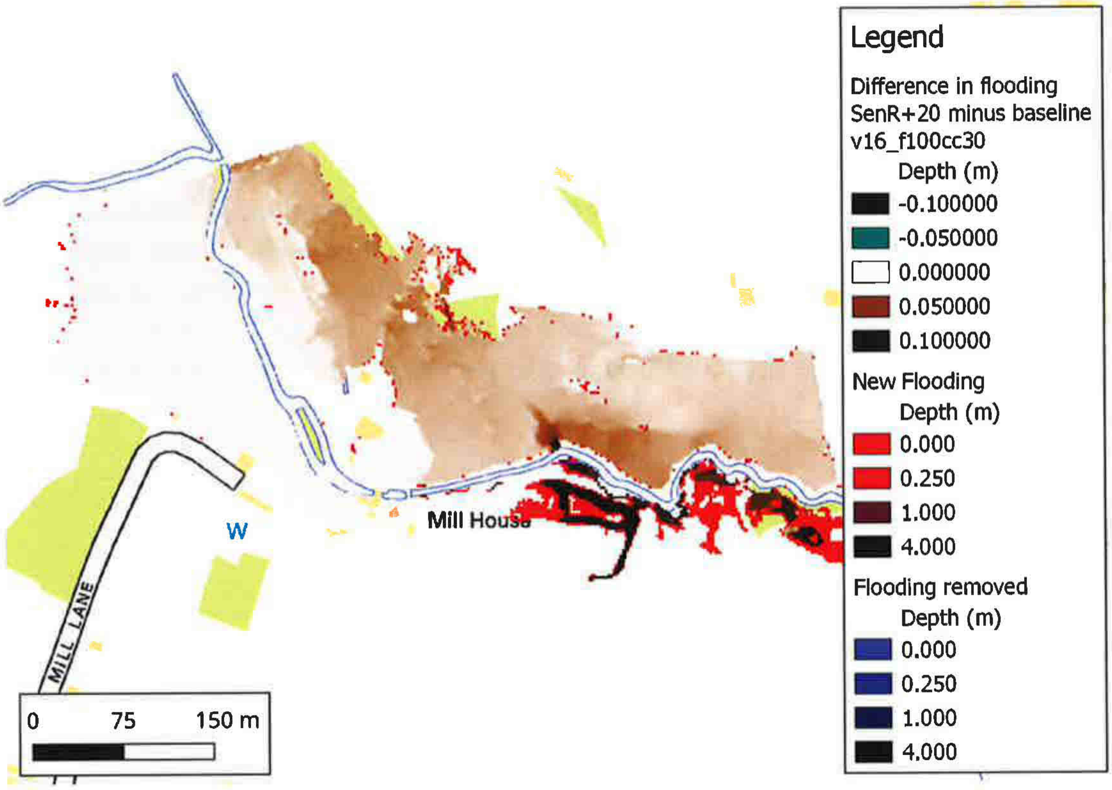


Figure 5.3: Difference map comparing Scenario R+20 to Baseline Results for the 1% AEP event plus climate change scenario

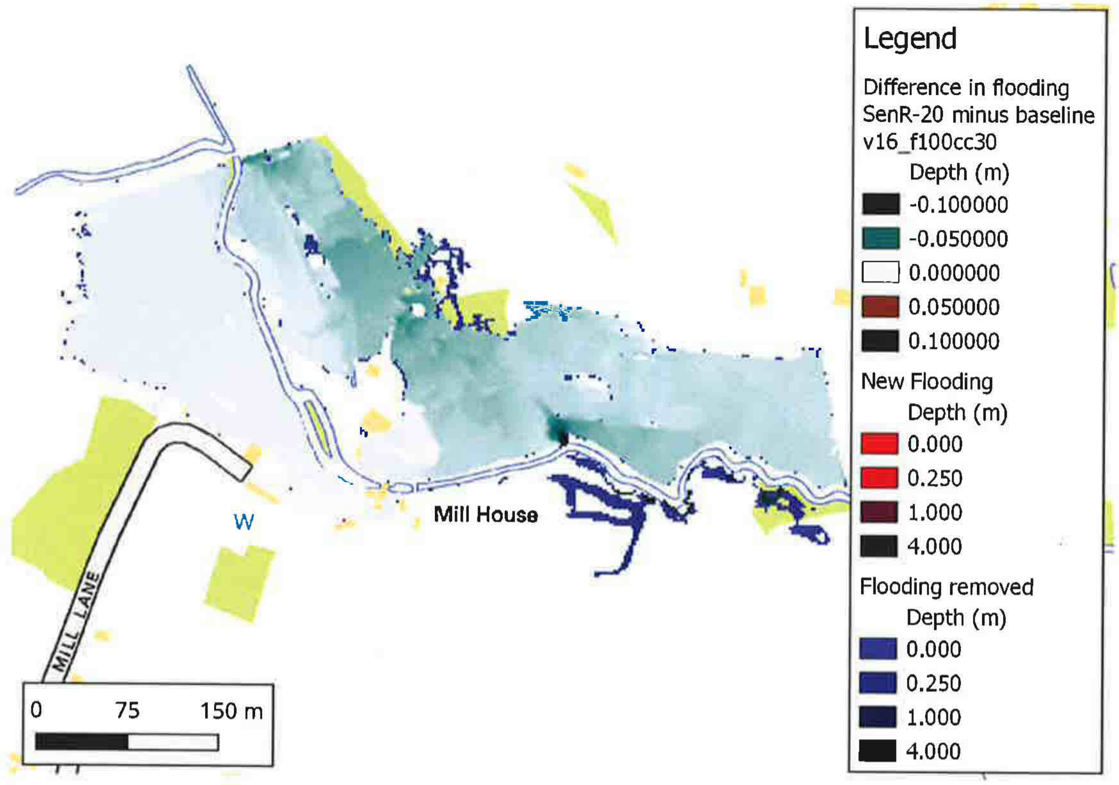


Figure 5.4: Difference map comparing Scenario R-20 to Baseline Results for the 1% AEP event plus climate change scenario

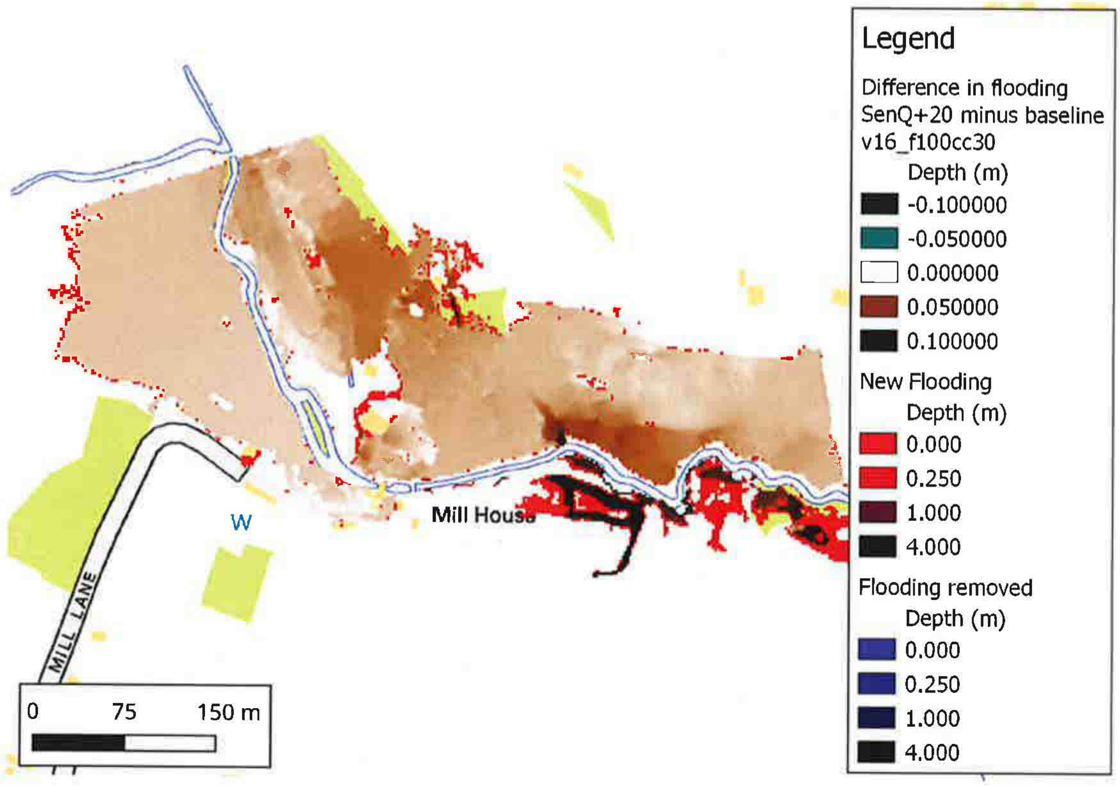


Figure 5.5: Difference map comparing Scenario Q+20 to Baseline Results for the 1% AEP event plus climate change scenario

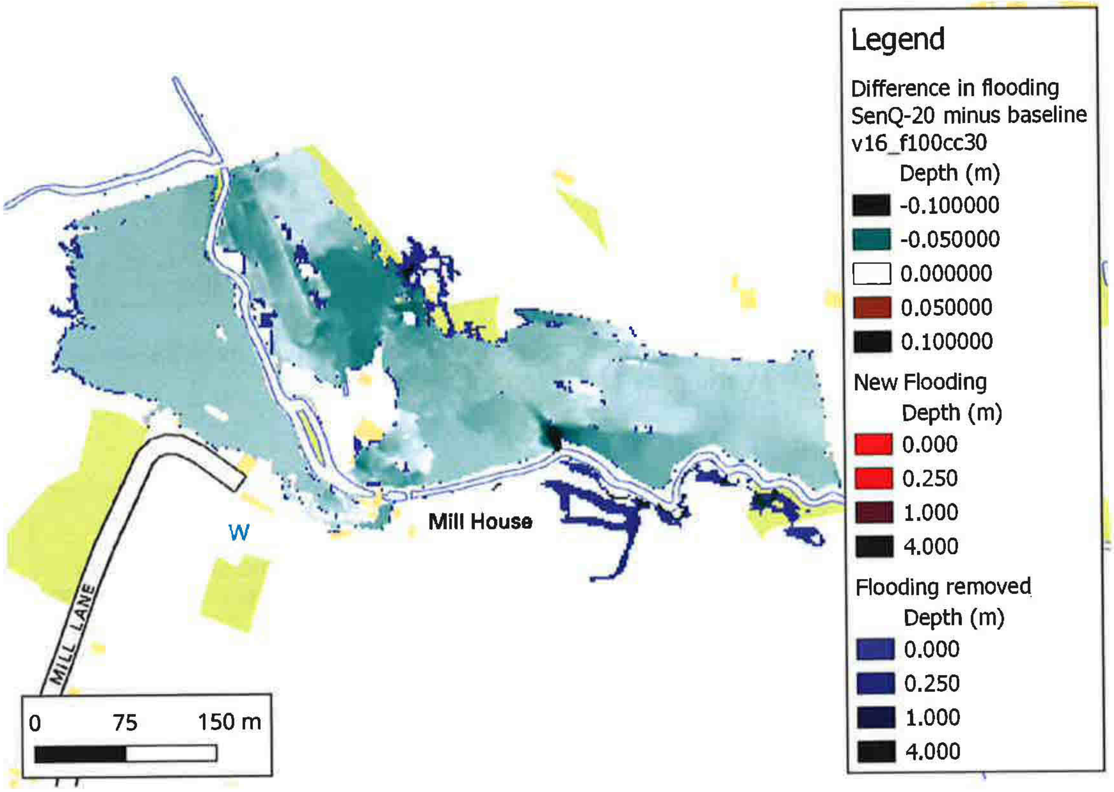


Figure 5.6: Difference map comparing Scenario Q-20 to Baseline Results for the 1% AEP event plus climate change scenario

5.16 Hydraulic Modelling Results

5.16.1 Overview

The following sections present a selection of results, which demonstrates a local 1 in 20 and 1 in 100 year return period flood which is commensurate with Flood Zone 3b and Flood Zone 3 respectively. This representation is considered to be of higher resolution than that of the current EA Flood Zone mapping. Additionally, the results demonstrate the impacts of the proposed bridge development when comparing the Baseline most to the Post-development scenario. The primary method of comparison, in relation to flood risk, is the creation of 'difference mapping', which examines the difference in maximum flood level resulting from the scheme, including areas of new and removed flooding. This allows for the assessment of any potential third party impacts that may be caused by the development.

5.16.2 Flood Depth and Level

Figures 5.7 to 5.14 shows the maximum depth results of the hydraulic modelling for the Baseline and Post-development scenarios for a 5% AEP event, 1% AEP event, and 1% AEP event plus climate change scenario. The results indicates that the site would be inundated in a 5% AEP, 1% AEP, and 1% AEP events with depths varying across the site.

Figures 5.7 and 5.8 can also be viewed to show the expected Flood Zone 3b and Flood Zone 3, respectively.

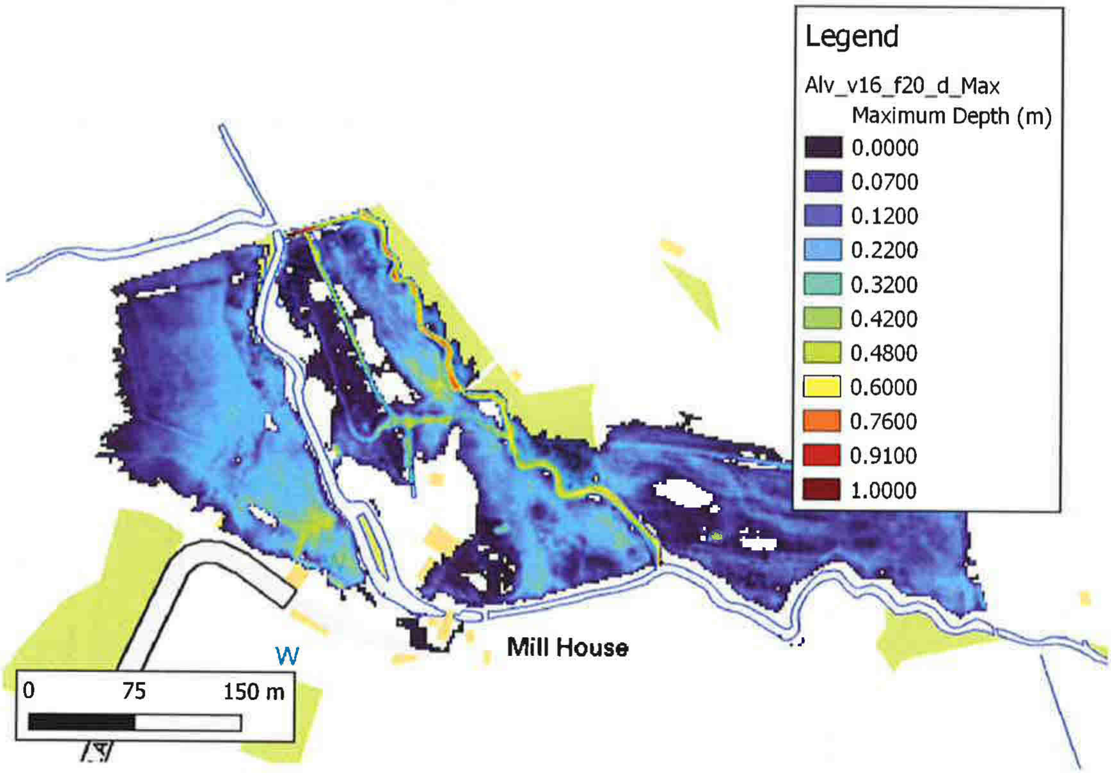


Figure 5.7: Baseline Results Peak Water Depth for a 5% AEP event

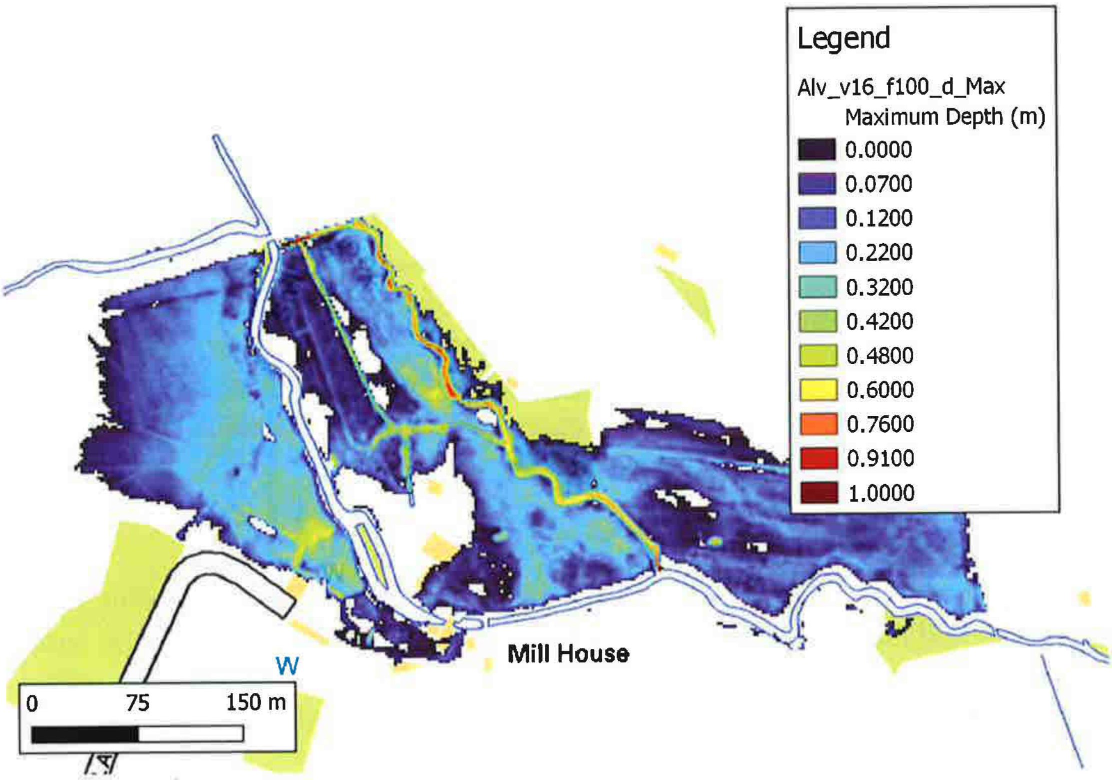


Figure 5.8: Baseline Model Results - Peak Water Depth for a 1% AEP event

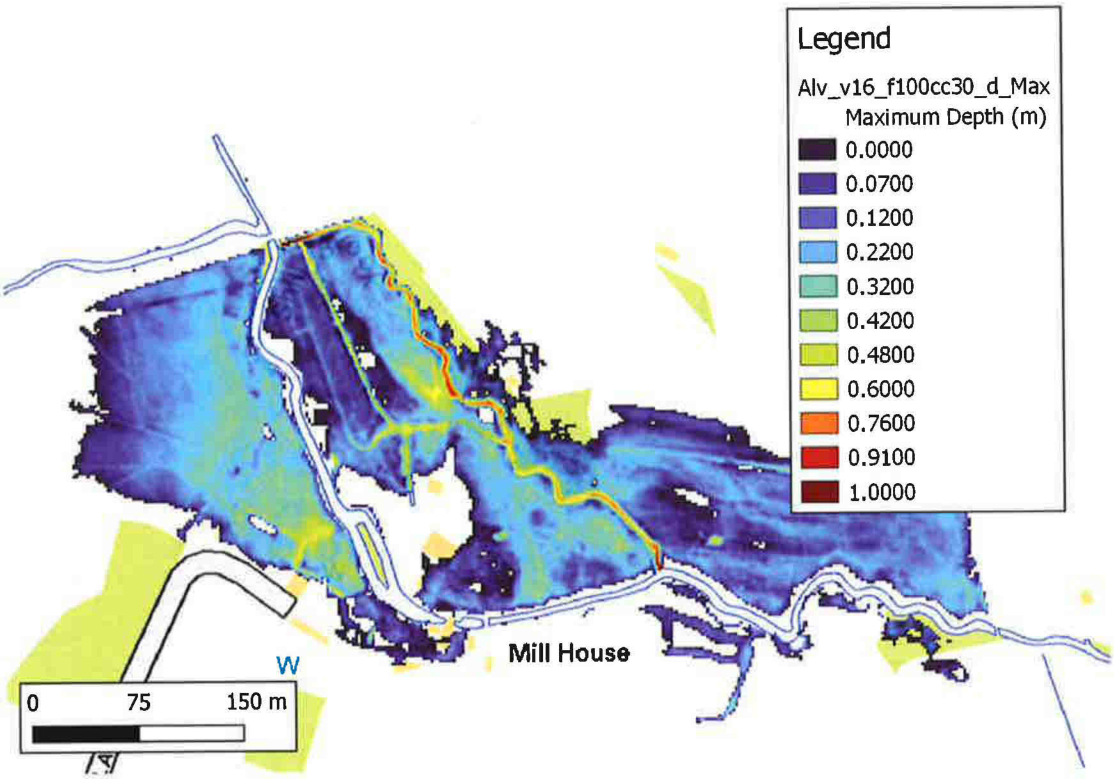


Figure 5.9: Baseline Model Results - Peak Water Depth for a 1% AEP plus climate change event

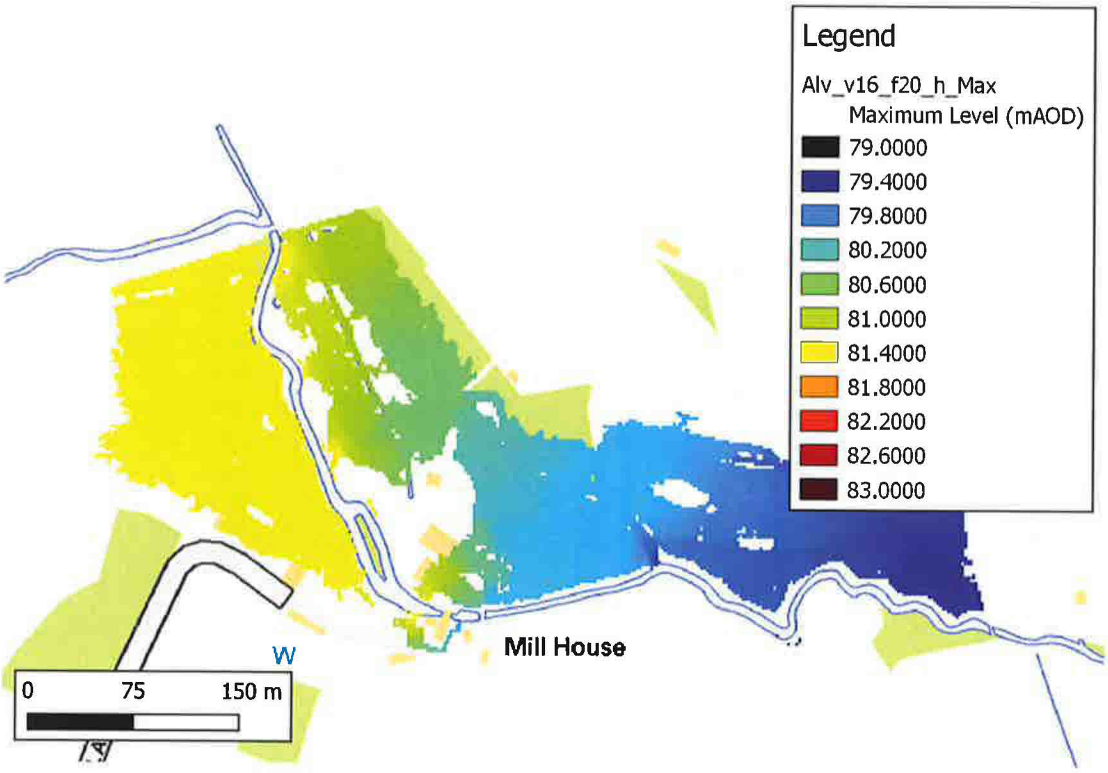


Figure 5.10: Baseline Results Peak Water Level for a 5% AEP event

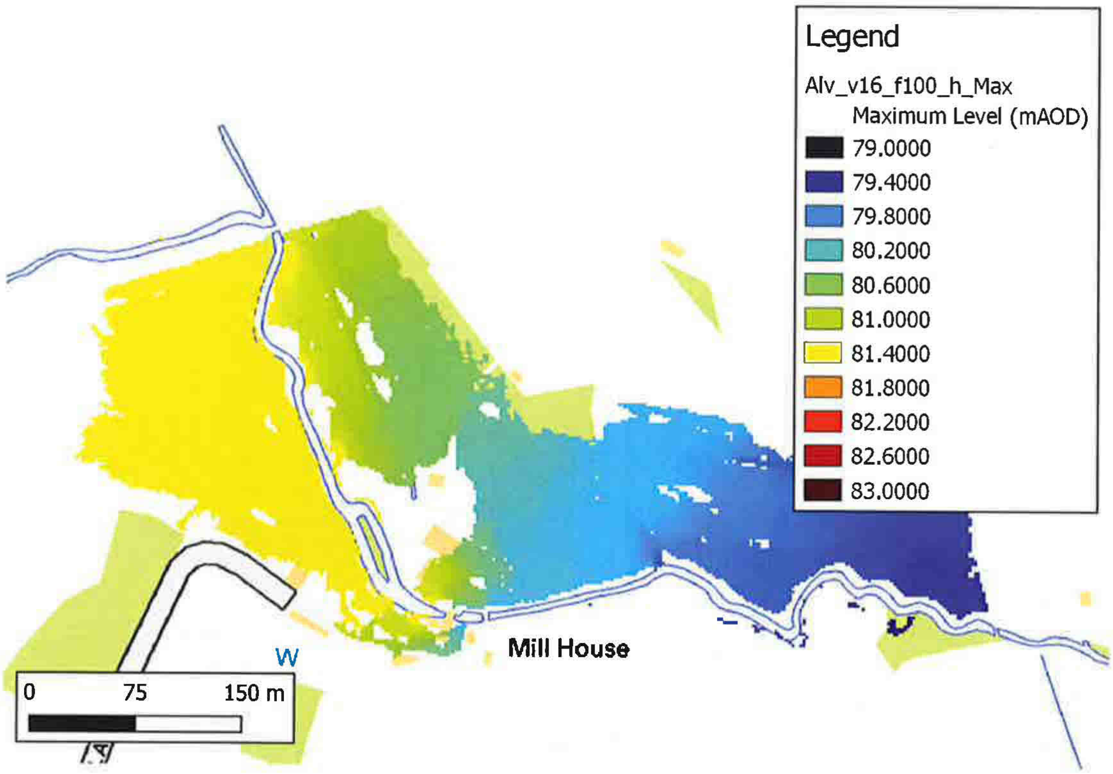


Figure 5.11: Baseline Model Results - Peak Level Depth for a 1% AEP event

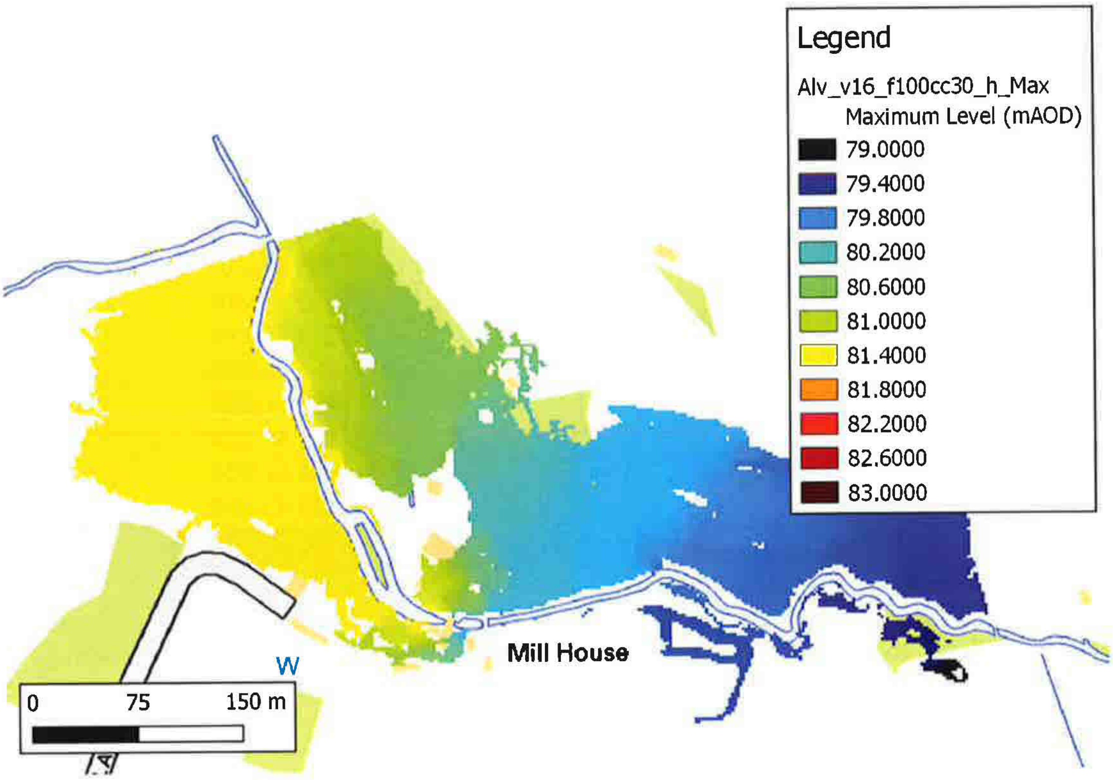


Figure 5.12: Baseline Model Results - Peak Water Level for a 1% AEP plus climate change event

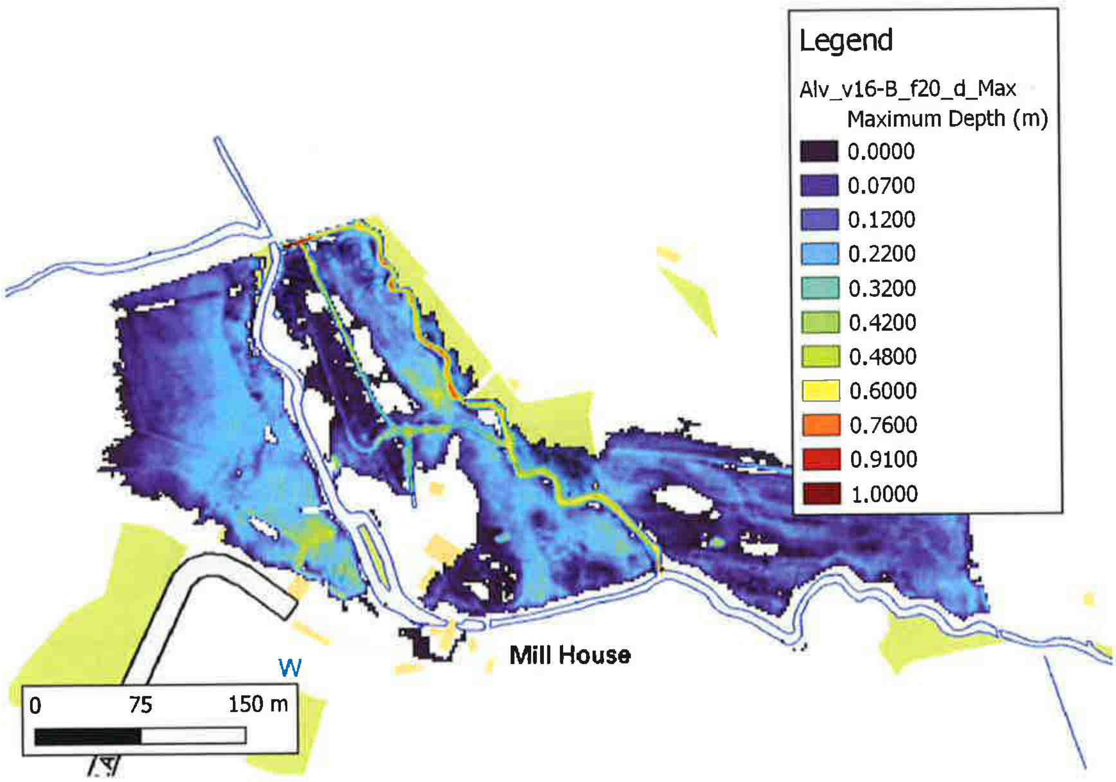


Figure 5.13: Post-development Results Peak Water Depth for a 5% AEP event

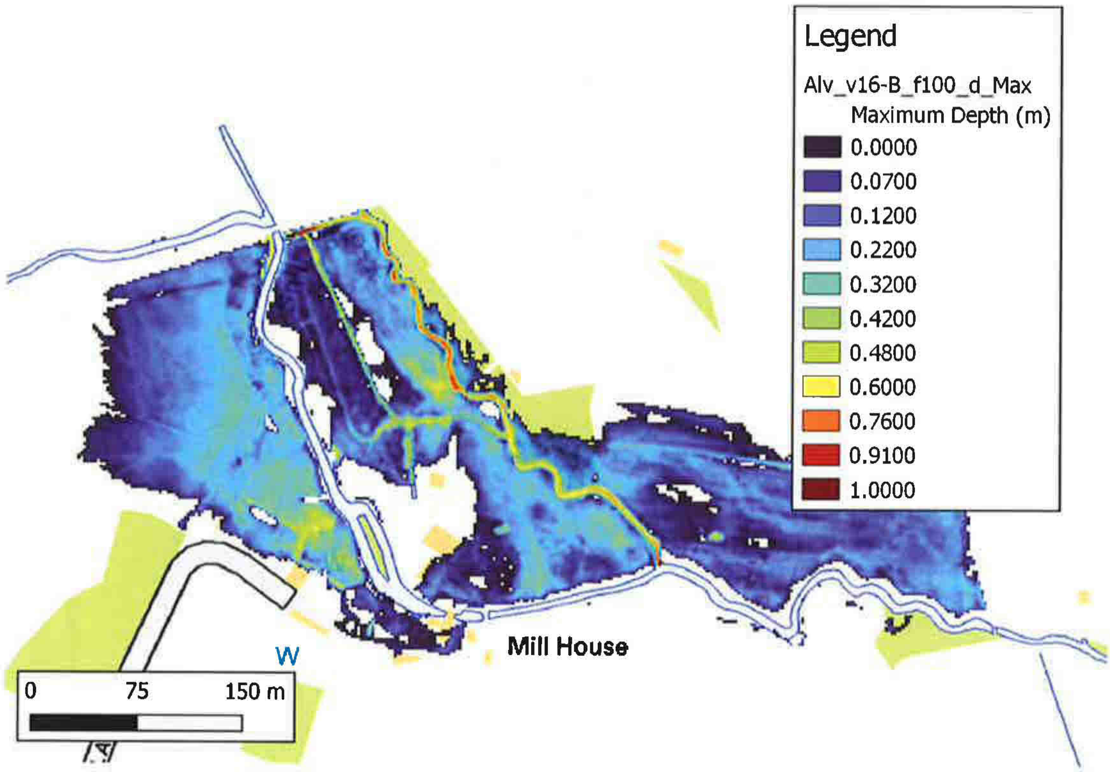


Figure 5.14: Post-development Model Results - Peak Water Depth for a 1% AEP event

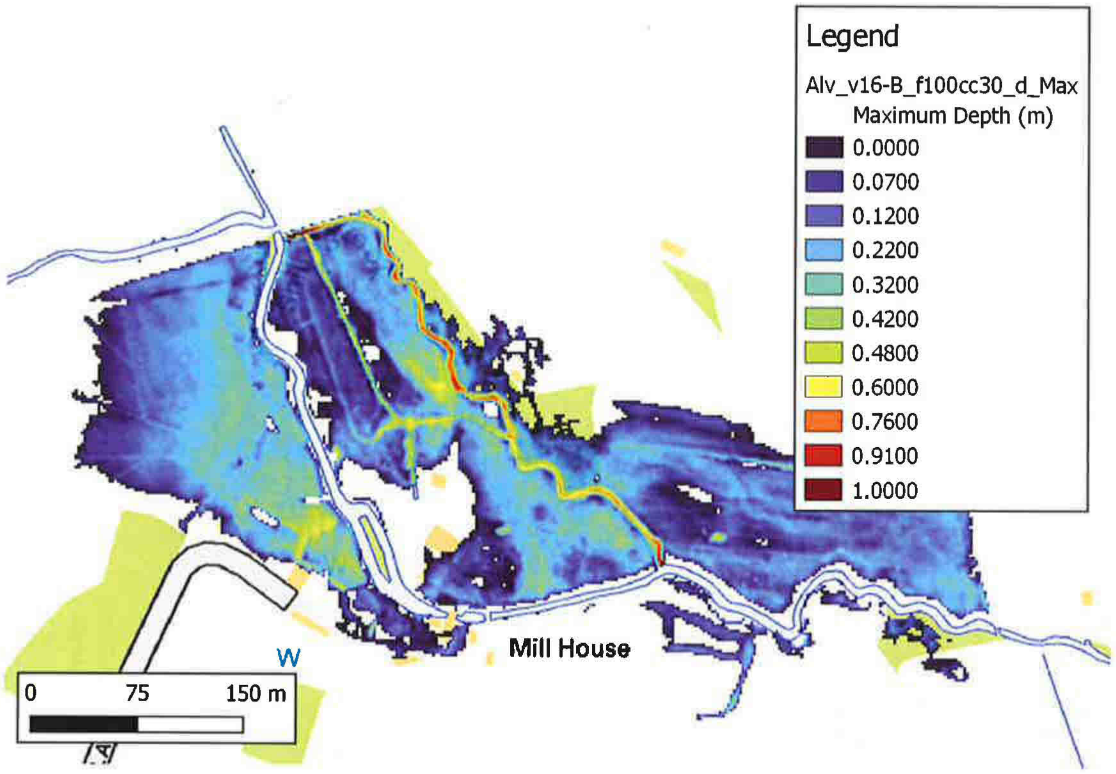


Figure 5.15: Post-development Model Results - Peak Water Depth for a 1% AEP plus climate change event

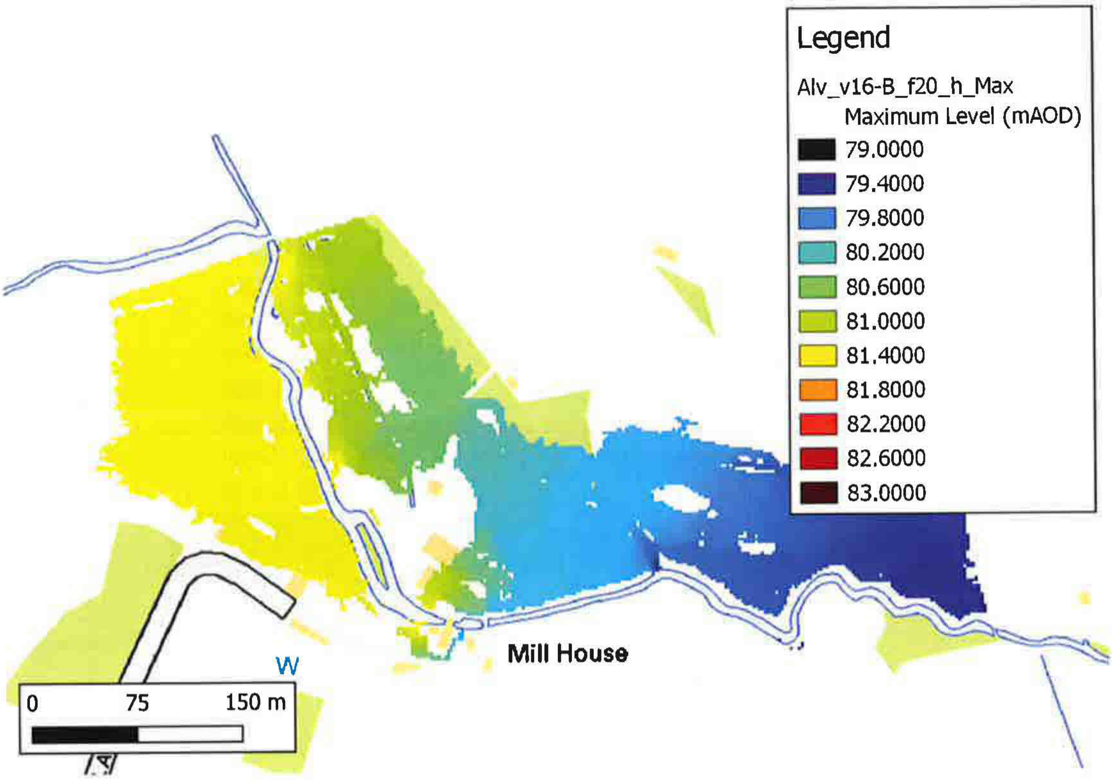


Figure 5.16: Post-development Results Peak Water Level for a 5% AEP event

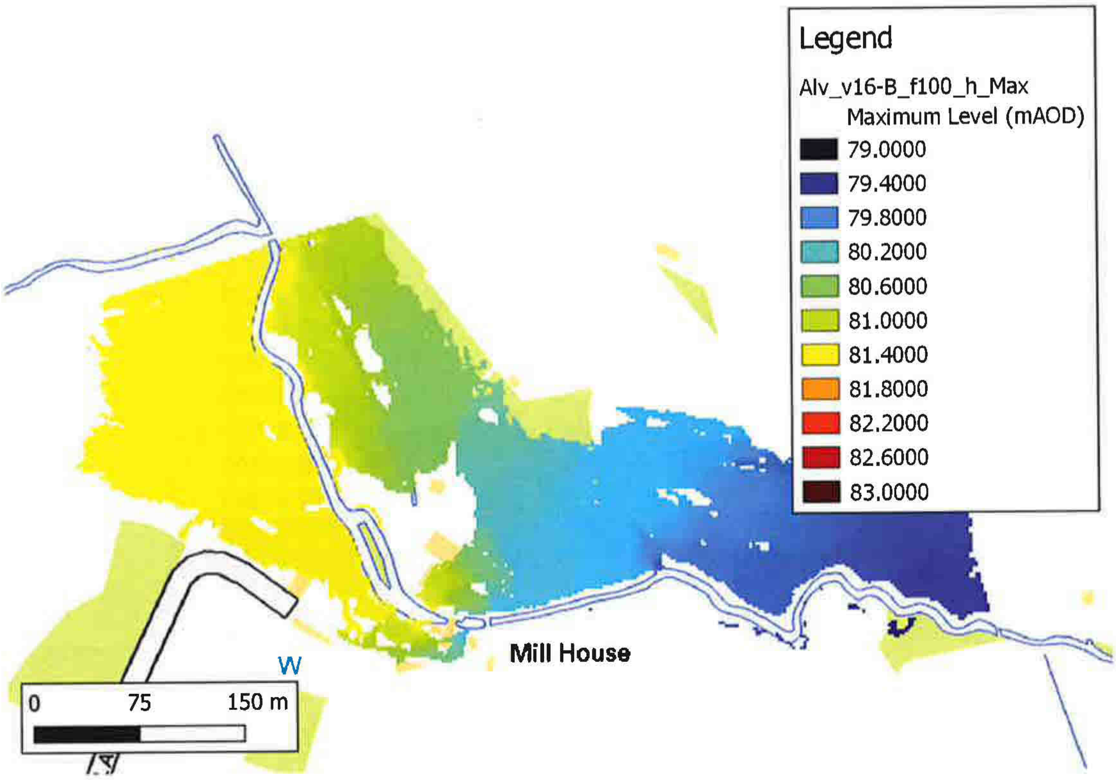


Figure 5.17: Post-development Model Results - Peak Level Depth for a 1% AEP event

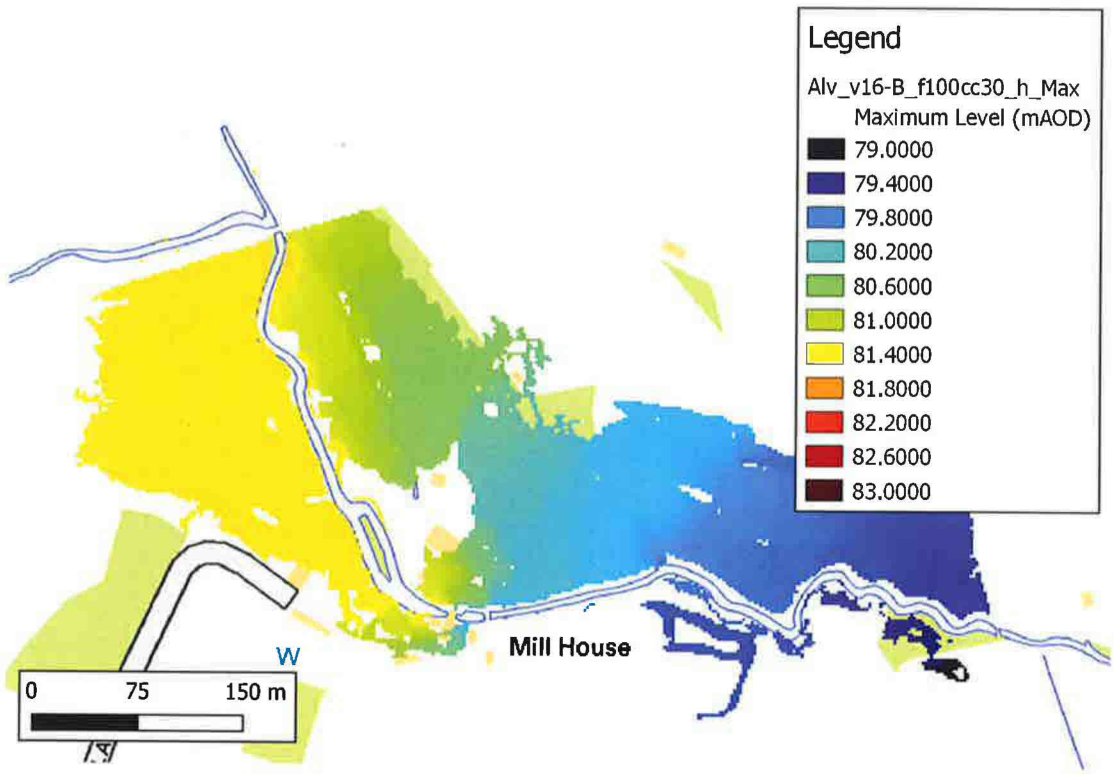


Figure 5.18: Post-development Model Results - Peak Water Level for a 1% AEP plus climate change event

5.16.3 Design Bridge Soffit Level

The design level for the soffit of the bridge (81.734 m AOD) has been determined from the Baseline hydraulic modelling results is defined as the the peak water level for 1% AEP plus climate change event (81.434 m AOD), plus 300mm.

Based on the requirements set out by the EA consultation, *"300mm above the central allowance will be sufficient in this instance"* for the level of the bridge soffit, which through this modelling exercise has been found to be equal to 81.734 m AOD.

5.16.4 Third Party Dis-benefit

Third party dis-benefits have been assessed using difference maps. Figure 5.19 shows the change in flood levels between the Post-development and Baseline model results. The figures shows the numeric difference in level of the post-development and baseline schemes. Areas shaded grey indicate changes in flood level considered negligible (±0.005m) as a result of the development. Areas shaded orange / green show changes in flood level greater than +0.005m and less than -0.005m respectively. Additionally, areas of blue show where flooding has been removed, and areas of red show the location of new flooding.

The modelling demonstrates that there is negligible impact on flood levels for the 1% AEP plus climate change event.

It is therefore considered that the development satisfies the Exception Test requirement not to increase flood risk elsewhere.

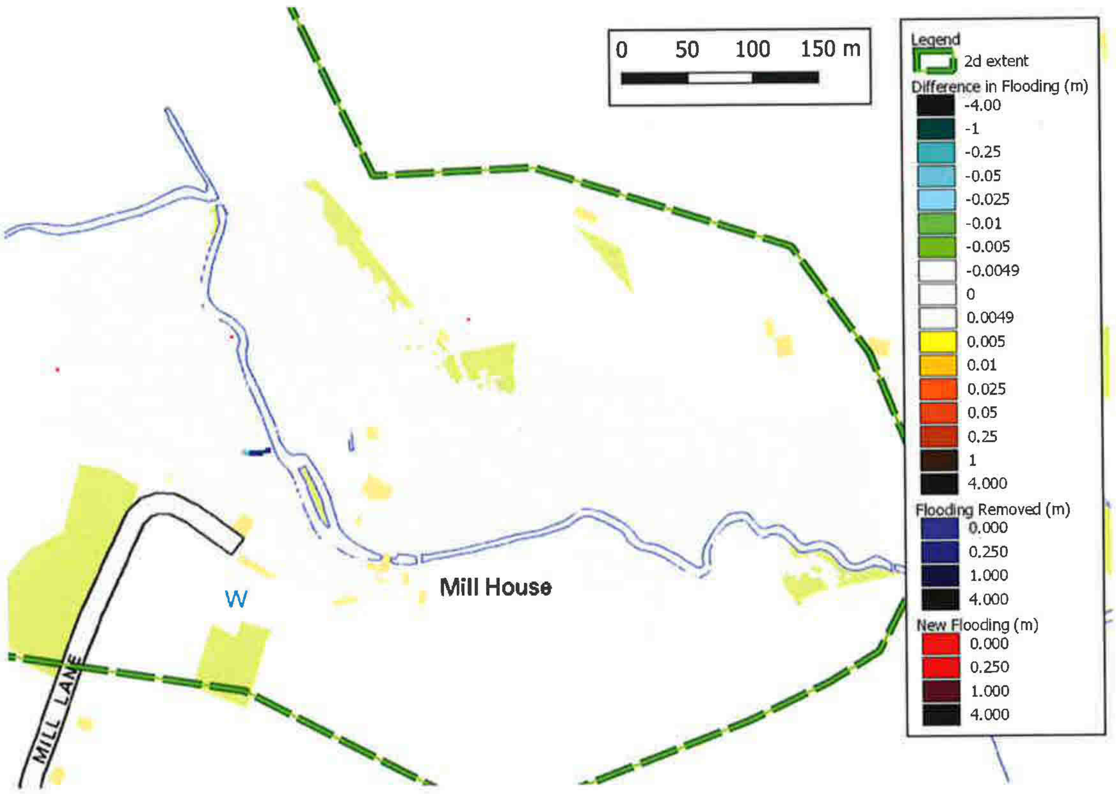


Figure 5.19: Flood Difference Mapping: Post-development Flood Levels minus Baseline Flood Levels for a 1%AEP event plus climate change

6 Conclusions and Recommendations

6.1 Overview

Edenvale Young Associates were commissioned by Robert Rhodes to complete a Flood Risk Assessment for the construction of a bridge for the across the Shill Brook at a private property near Alvescot, West Oxfordshire. The scope of works has included an evaluation of published information, construction of a new hydraulic model of the Shill Brook local the the site of interest to assess flood risk to the site. The results of the modelling have been assessed to establish design requirements and to assess whether there are flood risk issues associated with the construction of the bridge.

6.2 Flood Risk Summary

6.2.1 Fluvial Flooding

Current Environment Agency mapping shows the site as being located just outside of Flood Zones 2 and 3. This mapping was considered to be incorrect. Results of the hydraulic modelling have produced new recommendations for flood extents in the 1 in 100 year and 1 in 20 year flood events local to the site of interest. Based on the modelling, the proposed bridge would be situated within the 1 in 20 year flood extent.

6.2.2 Surface Water Flooding

Surface water flooding occurs following intense rainfall events when water is unable to infiltrate the ground or cannot discharge to a watercourse. Environment Agency mapping shows that the proposed bridge is that at high risk of surface water flooding.

6.2.3 Tidal Flooding

The Shill Brook at this location is not tidally influenced and therefore tidal flooding is not considered to be a risk to the scheme.

6.2.4 Sewer Flooding

Given the rural nature of the proposed scheme it is not considered that sewer flooding is a significant risk

6.2.5 Groundwater Flooding

The site is in the category of >=25% < 50% in terms of susceptibility to groundwater flooding. There are no specific records provided for groundwater flooding at the site. Given this information and the nature of the proposed risk of groundwater flooding, it is not considered a significant issue.

6.2.6 Reservoir Flooding

The site is not affected by reservoir inundation.

6.2.7 Historic Flooding

The site does not appear in the EA's Historic Flood Map, nor does it appear as a flooded location in the SFRA.

6.3 Conclusions

The results of the hydraulic modelling have been used to determine soffit levels for the bridge and evaluate the risk for a 1% AEP event with a 30% allowance for climate change, as well as 5% and 1% AEP events. Based on this work, the following conclusions have been made:

- The proposed bridge will span the Shill Brook and is therefore located within the 1 in 20 year flood extent, equivalent to the Flood Zone 3b.
- Bridges are Water Compatible development and are acceptable within Flood Zone 3b.
- On the assumption that there will be a ramp on the floodplain leading to the bridge, and that the river cross section at the bridge location is not reduced, then there will be no noticeable impact on flood risk at the site or elsewhere.
- The flood risk from surface water, sewer, tide, groundwater, and reservoirs are not considered significant or relevant to this site of interest.
- Upstream sources of debris should be borne in mind although the elevation and clear span construction-type of the proposed bridge means that risk of blockage or debris strike is low.

By setting the bridge soffit at the recommended elevation (see below), the bridge deck will not interact with flood flows. Additionally, the modelling has shown that the ramp to the bridge will have no influence on water levels, and does not impede flows or increase flood risk elsewhere. As discussed earlier, final bridge design has been undertaken after conclusion of the modelling exercise, which means that alignment and gradient of the bridge ramp vary slightly from the configuration that has been modelled. It is considered that the variation in design is sufficiently minor that this would cause negligible difference in results and the conclusions of the modelling exercise would still stand.

An Exception Test is not required for the site but the NPPF indicates that for water compatible uses in Flood Zone 3b should be designed and constructed to:

- *remain operational and safe for users in times of flood*
- *result in no net loss of floodplain storage*
- *not impede water flows and not increase flood risk elsewhere.*

There is no requirement for the bridge to remain operational during floods as it is not intended as an access/egress route. An assessment of third party impacts have been undertaken by comparing flood levels in the Post-development condition with the Baseline state. The hydraulic modelling concluded that there was negligible change in water levels in the model for all events tested for the FRA. There were no third party impacts for all events tested for the FRA. Additionally, there was no loss of floodplain storage based on the results of the modelling.

Given that the bridge has a proposed lifespan of 60 years, the use of the central climate change allowance (30%) as a design criteria will ensure that the bridge remains inconsequential in terms of flood risk for the lifetime of the scheme. It should also be noted that the soffit of the bridge is above the peak modelled level for a 1% AEP plus 30% allowance for climate change event for the sensitivity case where Manning's n roughness coefficient within the model was increased by 20%.

6.4 Recommendations

Based on hydraulic modelling and review of other flood risk related information, the following recommendations are made:

- The bridge soffit should be set at an elevation at least 300mm above 81.43m AOD which is the peak water level for a 1% AEP plus 30% allowance for climate change. This equates to a design soffit level of 81.73m AOD.
- There is no change to the existing channel geometry.

On the basis of the above recommendations, it is considered that the proposed structure meets the requirements of the NPPF.

A FEH Proforma

Flood estimation report: Willow Cottage, Alvescot

Introduction

This report template is a supporting document to the Environment Agency's Flood Estimation Guidelines. It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results. This document can be used for one site or multiple sites. If only one site is being assessed, analysts should remove superfluous rows from tables.

Guidance notes (in red text) are included throughout this document in column titles or above tables. These should be deleted before finalising the document. Where relevant, references to specific sections of the Flood Estimation Guidelines document are included to indicate where further useful information can be found.

Note: Column size / page layout can be adapted, where necessary, to best present relevant information, for example, maps do not need to be within the tables if they would be better as a separate page.

Contents

Approval

Note: This table can be amended / removed to suit the need of the organisation undertaking the assessment. A document revision history can be added after the approval table if required.

If a separate method statement stage is not undertaken add N/A to all cells for method statement and also for initial calculations preparation 'Amendments' column. If a separate method statement is generated, text in initial calculations preparation 'Amendments' could be, for example, 'Completion of calculations following method statement approval'. Revision rows are intended for studies where amendments may be required following application of flows to a hydraulic model which leads to estimates / approaches needing to be revisited, for example.

Revision stage	Analyst / Reviewer name & qualifications	Amendments	Date

Method statement preparation		N/A	N/A
Method statement sign-off		N/A	
Initial calculations preparation	Sally Hatton		N/A
Initial calculations sign-off	Sara Liguori	N/A	
Calculations - Revision 1 preparation			N/A
Calculations - Revision 1 sign-off		N/A	
Calculations - Revision 2 preparation			N/A
Calculations - Revision 2 sign-off		N/A	

Abbreviations

AEP.................................annual exceedance probability
AM...................................Annual Maximum
AREA...............................Catchment area (km^2)
BFI..................................Base Flow Index
BFIHOST..........................Base Flow Index derived using the HOST soil classification
CPRE...............................Council for the Protection of Rural England
FARL...............................FEH index of flood attenuation due to reservoirs and lakes
FEH.................................Flood Estimation Handbook
FSR.................................Flood Studies Report
HOST...............................Hydrology of Soil Types
NRFA...............................National River Flow Archive
OS...................................Ordnance Survey
POT.................................Peaks Over a Threshold
QMED..............................Median Annual Flood (with return period 2 years)
ReFH...............................Revitalised Flood Hydrograph method
ReFH2 ....Revitalised Flood Hydrograph 2 method
SAAR...............................Standard Average Annual Rainfall (mm)
SPR.................................Standard percentage runoff
SPRHOST.........................Standard percentage runoff derived using the HOST soil classification
Tp(0)...............................Time to peak of the instantaneous unit hydrograph
URBAN.............................Flood Studies Report index of fractional urban extent
URBEXT1990...................FEH index of fractional urban extent
URBEXT2000...................Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH...................Windows Frequency Analysis Package – used for FEH statistical method

1 SUMMARY OF ASSESSMENT

1.1 Summary

This table provides a summary of the key information contained within the detailed assessment in the following sections. The aim of the table is to enable quick and easy identification of the type of assessment undertaken. This should assist in identifying an appropriate reviewer and the ability to compare different studies more easily.

Catchment location	River Shill at Alvescot, Oxfordshire.
Purpose of study and scope	This is a simple study which seeks to derive design flows and hydrographs. These flows will be applied to a 1D-2D hydraulic model for the purpose of advising on the soffit height of a proposed bridge and assessing impact to third parties. There is no existing hydrological analyses.
Key catchment features	The catchment of the Unnamed Tributary is small and both the Unnamed Tributary and Shill Brook catchments are considered permeable.
Flooding mechanisms	Fluvial flooding via channel exceedance and overland flow to the site.
Gauged / ungauged	The catchment is ungauged.
Final choice of method	FEH Statistical Method for peak flow design estimates. Design hydrograph shapes derived by fitting hydrographs from ReFH2.3 to match the statistical estimates.
Key limitations / uncertainties in results	Lack of local data.

1.2 Note on flood frequencies

The frequency of a flood can be quoted in terms of a return period, which is defined as the average time between years with at least one larger flood, or as an annual exceedance probability (AEP), which is the inverse of the return period.

Return periods are are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. However, AEP can be helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval. Results tables in this document contain both return period and AEP titles; both rows can be retained or the relevant row can be retained and the other removed, depending on the requirement of the study.

The table below is provided to enable quick conversion between return periods and annual exceedance probabilities.

Annual exceedance probability (AEP) and related return period reference table

AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AEP	0.5	0.2	0.1	0.05	0.033	0.02	0.0133	0.01	0.005	0.001
Return period (yrs)	2	5	10	20	30	50	75	100	200	1,000

2 METHOD STATEMENT

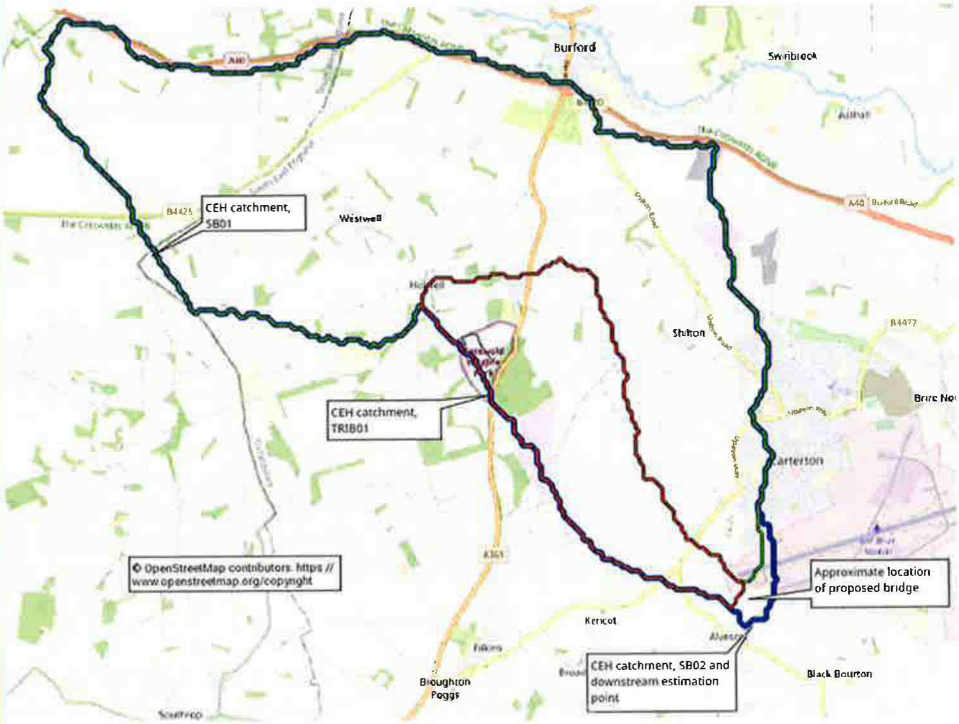
2.1 Requirements for flood estimates

Overview	This document details the hydrological analysis undertaken to derive design peak flows and hydrographs for use in a 1D-2D hydraulic model of the Shill Brook and one of its tributaries at Alvescot, Oxfordshire. The results of the hydraulic modelling will be used for the purpose of advising on the soffit height of a proposed bridge and an eventual Flood Risk Assessment associated with this bridge. Design peak flow estimates and hydrographs will be derived for the following AEP (%) events: 5, 1, 0.1, along with a range of other return period events for completeness. For the 1 % AEP event, design flows will also be derived for the appropriate climate change scenarios[1]. The site is located within the Cotswolds Management Catchment. The Central climate change allowance (2080's epoch), which is applicable to Water Compatible Development in Flood Zone 3b, is 30%. Design estimates are likely to be derived for the Shill Brook and Tributary along with an intervening catchment downstream of the confluence of these watercourses. Flows will be applied as QT boundaries.
Project scope	This is a simple hydrological study. Previous correspondence with the Environment Agency indicated that detailed hydraulic modelling at the site of interest is not available. It is therefore assumed that no previous hydrological analysis has been undertaken that would be relevant to the site of interest. A flood history review, joint probability assessment, rating reviews and ReFH parameterisation are beyond the scope of this study.

2.2 The catchment

Description	The Shill Brook rises at the hamlet of Signet and flows in a south/south easterly direction along the western edge of Carterton, Oxfordshire. Although the upper reach is an Ordinary Watercourse, the Shill Brook is designated as Main River from the village of Shilton until its confluence with the Highmoor Brook at Bampton. Notably, the watercourse runs in culvert beneath Brize Norton Airfield to the south of Carteron and immediately upstream of the site of interest. At the site of interest, the Shill Brook drains a total catchment area of approximately 37.2km2. The catchment can be further divided into two sub-catchments, encompassing the Shill Brook and an unnamed right bank tributary of the Shill Brook. The confluence of the two watercourses is immediately upstream of the site of

[1]https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#peak-river-flow-allowances, updated 22nd May 2022.

	interest. These catchments relative to the site of interest are shown in the Figure below. Both catchments are predominantly rural and permeable. 

2.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 10, released August 2021. This contains data up to water year 2019-2020.

2.4 Gauging stations (flow or level)

The catchment is ungauged. Gauges used later in this report for the derivation of QMED have been included in this table for completeness.

Watercourse	Station name	Gauging authority number	NRFA number	Catchment area (km²)	Type (rated / ultrasonic / level…)	Start of record and end if station closed
River Leach	Leach at Priory Mill Lechlade		39042	76.9	Crump weir	1972 - present
River Thames	Thames at Days Weir		39002	3444.7	Thin-plate weir and radial gates	1938 - 2018
River Thames	Thames at Eynsham		39008	1616.2	Barrage of gates and weirs	1951 - 2016

2.5 Data available at each flow gauging station in Table 2.4

Station name	Start and end of NRFA flood peak record	Update for this study?	OK for QMED?	OK for pooling?	Data quality check needed?	Other comments on station and flow data quality
Leach at Priory Mill Lechlade	1972 - present	No	Yes	Yes	Outside scope	Crump weir.
Thames at Days Weir	1938 - 2018	No	Yes	Yes	Outside scope	Adjustable thin-plate weir and radial gates. Calculated flows within 5% of measured flows, increasing to 10% at flows over 100m3/s.
Thames at Eynsham	1951 - 2016	No	Yes	No	Outside scope	Gates and weirs with site-specific flow calculation. Rating no validated beyond QMED.

2.6 Rating equations

Station name	Type of rating	Rating review needed?	Comments and link to any rating reviews
n/a			

2.7 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available?	Source of data	Details
Check flow gaugings	n/a	n/a	n/a	The catchment is ungauged.
Historical flood data	Yes	Yes	EA Historic Flood Map and Recorded Flood Outlines Dataset. Alvescot Parish Flood Report (2008)	The site is not shown within the freely available EA flood datasets, although these are not necessarily comprehensive. The Alvescot Parish flood report make reference to a trash screen at the inlet to the culvert beneath Brize Norton airfield. There is limited detail in the accompanying text, but this suggests that blockage to the culvert has been problematic in the past. This may influence flows reaching the site of interest, although any blockage would be represented hydraulically.
Flow or river level data for events	n/a			
Rainfall data for events	Outside study scope			
Potential evaporation data	Outside study scope			

Results from previous studies	No			
Other data or information	No			

2.8 Hydrological understanding of catchment

Plots of flow data and interpretation	n/a
Plots of flood peak data and interpretation	n/a

Conceptual model	The site of interest is a crossing of the Shill Brook at Alvescot. Flooding is likely to be caused by the capacity of the Shill Brook and nearby channels being exceeded, resulting in overland flow. Peak flows are of primary importance as the design flows from this study will ultimately be used to recommend a bridge soffit height. This study will only consider fluvial flooding. Other sources of flood risk are unknown and will be considered in a separate FRA.
Unusual catchment features	The catchment area of the Unnamed Tributary (7.03km2) is small. Both catchments are permeable.

2.9 Initial choice of approach

Is FEH appropriate?	Yes, both standard FEH methods can be applied to estimate peak flows on the subject catchments.
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	The FEH statistical method is favoured as the catchments are permeable. Given the catchment size of the Unnamed Tributary, the guidance associated with small catchments should be borne in mind.[2] Hydrographs shapes will be derived using ReFH2 from a lumped catchment model at the site. Design peak flow hydrographs will be determined for the two sub catchments and applied at the upstream extent of each watercourse. The intervening catchment area between Shill Brook/Unnamed Tributary confluence and the site will be accounted for via a distributed inflow.
Software to be used (with version numbers)	FEH Web Service[3] / WINFAP 5[4] /ReFH2.3

[2]Flood Estimation Guidelines (6/7/20) Note that the Flood Estimation guidelines were updated during the course of this analysis (7/7/22), but this does not change the approach to small catchments.

[3] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, UK.

[4] WINFAP 5 © Wallingford HydroSolutions Limited 2022

3 LOCATIONS WHERE FLOOD ESTIMATES REQUIRED

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

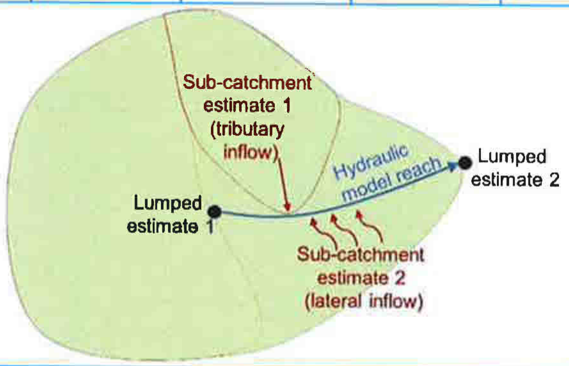
3.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
SB02	L	Shill Brook	Downstream of Site	427700	204900	37.2	n/a
SB01	L	Shill Brook	Shill Brook at confluence with the Unnamed Tributary	427350	205200	29.81	n/a
TRIB01	L	Unnamed Tributary	Unnamed Tributary at the confluence with the Shill Brook	427400	205250	7.03	n/a
Intervening	S	Shill Brook	Intervening Catchment	427700	204900	0.36 (calculated)	n/a

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required.

Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.

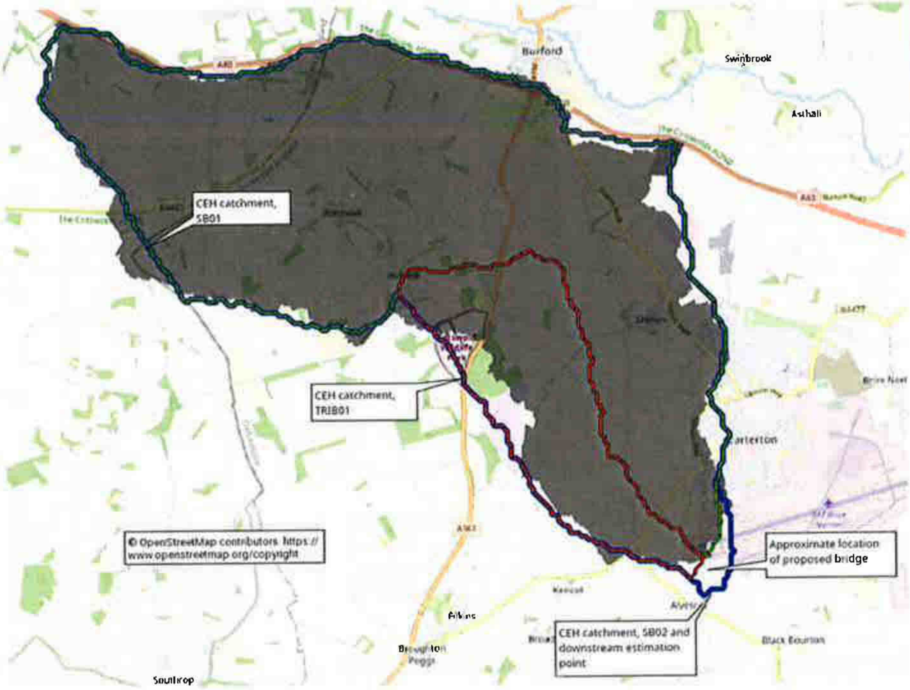
The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



3.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
SB02	1	0.32	0.799	9.14	26.7	694	0.0102	0.072
SB01	1	0.32	0.816	9.77	28.8	699	0.0114	0.0632
TRIB01	1	0.32	0.718	4.17	18.5	677	0.0030	0.0982

3.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes	Catchment delineation has been undertaken using GRASS and LiDAR DTM. It was not possible to delineate a catchment for the Unnamed Tributary using this method; the figure below shows a comparison of the catchment at the confluence of both watercourses, as assessed using GRASS, with the catchment boundary obtained via the CEH web service. There is some variation at the margins of the catchment, with the most notable difference along the western edge. Review of current and historic mapping indicates that it is coincident with a solar farm that now occupies the site of a disused airfield, which may have some influence on local drainage paths.  The discrepancy in this location is approximately 0.7km2, comprising around 1/10 of the TRIB01 catchment. Given that the CEH web service delineates a larger catchment, and there is limited data with which to make any adjustment, the CEH catchment area has been taken forward. Additional review of the LiDAR indicates that the catchments are distinct and that the delineation by the CEH web service seems sensible.
Record how other catchment descriptors were checked and describe any changes.	The catchment is made up of lime rich soils which are freely draining; bedrock geology comprises limestones and sandstones. BFIHOST19 values of 0.799 (SB02), 0.816 (SB01) and 0.718 (TRIB01) are considered reasonable based on this information and indicate the catchments are permeable. No reservoirs are shown on mapping and a FARL value of 1 for both catchments is considered sensible.
Source of URBEXT	URBEXT2000 Value will be updated to the study year (2022).
Method for updating of URBEXT	CPRE formula from 2006 CEH report on URBEXT2000

4 STATISTICAL METHOD

4.1 Application of Statistical method

What is the purpose of applying this method?	Derivation of peak design flows for a range of return periods at the estimation points listed above.

4.2 Overview of estimation of QMED at each subject site

If more than one donor is used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.

The final estimate of QMED should include any relevant donor and urban adjustment. If QMED is derived directly from AMAX or POT data, an urban adjustment factor should not be applied as this is implicitly included in the estimate and would be double-counted.

Site code	QMED (rural) from CDs (m^3/s)		Data transfer					Urban adjust-ment factor UAF	Final estimate of QMED (m^3/s)
			NRFA numbers for donor sites used (see 4.3)	Distance between centroids d_{ij} (km)	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor			
						Weight	Weighted ave. adjustment		
SB02	1.698	DT	39042 39002 39008	7.83 7.94 10.01				1.048	1.769 (rural) **1.853 (urban)**
SB01	1.317	DT	39042 39002 39008	7.47 8.08 9.94				1.059	1.372 (rural) **1.453 (urban)**
TRIB01	0.561	DT	39042	7.93				1.009	0.575 (rural) **0.580 (urban)**

Are the values of QMED spatially consistent?	Yes, see section 5.10.
Method used for urban adjustment for subject and donor sites (delete method in the column to the right as needed)	Kjeldsen (2010)[5] / WINFAP v5[6] . Donor site estimates are not adjusted for urbanisation.

Parameters used for WINFAP v4 urban adjustment if applicable (these are 'standard' values and should be revised if alternative values have been applied)

Impervious fraction for built-up areas, IF	Percentage runoff for impervious surfaces, PR_{imp}	Method for calculating fractional urban cover, URBAN
0.3	70%	From updated URBEXT2000

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).

The QMED adjustment factor A/B for each donor site is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is $(A/B)^a$ times the initial (rural) estimate from catchment descriptors.

Important note on urban adjustment

The method used to adjust QMED for urbanisation published in Kjeldsen (2010)[4] in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable. This is discussed in Wallingford HydroSolutions (2016)[5].

[5] Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

[6] Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.

4.3 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Provide details regarding how potential donors were selected and the reasons why they were chosen / rejected. Include a map if necessary, which shows the location of the study catchment and donor stations under consideration. Section 4 of the Flood Estimation Guidelines provides guidance on selecting a donor(s) for data transfer.	A search was undertaken for all potential QMED donor sites within 25km of each subject site. Both subject sites include multiple potential donors within a 25km radius. SB02 There are 10 potential donors within a 25km2 radius. The closest donor site is the Leach@Priory Mill.(39042). All potential donor sites have a significantly larger area than the subject site but the guidance indicates that it is not necessary to select a donor site on the basis of hydrological similarity and that proximity should be used in preference. Given the number of sites within a 25km radius, the search area has been narrowed to those potential donors within approximately 10km of the subject site. The following sites have been used for the purpose of donor transfer: Leach@Priory Mill Lechlade (39042). Thames @ Days Weir (39002) Thames @ Eynsham (39008) **SB01** There are 10 potential donor sites within a 25km2 radius of the subject site. The closest donor site is the Leach@Priory Mill Lechlade (39042). All potential donor sites have a significantly larger area than the subject site but the guidance indicates that it is not necessary to select a donor site on the basis of hydrological similarity and that proximity should be used in preference. Given the number of sites within a 25km radius, the search area has been narrowed to those potential donors within approximately 10km of the subject site. The following sites have been used for the purpose of donor transfer: Leach@Priory Mill Lechlade (39042). Thames @ Days Weir (39002) Thames @ Eynsham (39008) The Windrush@Newbridge (39006) is 10.89km from SB01, but has been rejected as the NRFA notes that the rating for a side channel should be reviewed but this was not available on the NRFA website. **TRIB01** FEH guidelines recommend that for small catchments (<25km2) a single QMED donor should be used and this donor should be selected on the basis of proximity to the subject site. This recommendation is made as per the findings of the as yet unpublished Phase 2 Small Catchments report. Subcatchment TRIB01 has an area of 7.03km2. The closest potential donor is the Thames @ Days Weir (39002). Although the catchment is significantly larger than the subject site, it is recommended that the donor is selected on the basis of proximity. It is also noted that the QMED estimated is marginally higher than if the next closest gauge – Leach @ Priory Mill Lechlade – were used and is therefore considered conservative given the purpose of this project.

4.4 Donor sites chosen and QMED adjustment factors

When QMED is estimated from POT data, it should also be adjusted for climatic variation; this is not the same as climate change. Climatic variability can result in flood-rich or flood-poor periods. A short record might only include flood-rich years or flood-poor years, this will distort the QMED estimate. FEH Volume 3, Chapter 20, provides the methodology to adjust QMED for climatic variation. It is recommended that this carried out if the station record is shorter than 14 years.

QMED from catchment descriptors is the 'as rural' value (for rural donors), i.e. with no urban adjustment factor applied.

The adjustment ratio is the adjustment in full, with no distance factor applied.

NRFA no.	Method (AM or POT)	Adjustment for climatic variation?	QMED from flow data (A) (deurbanised)	QMED from catchment descriptors (B) (rural)	Adjustment ratio (A/B)
39042	AM	No	3.056	2.992	1.021
39002	AM	No	141.243	133.189	1.06
39008	AM	No	71.803	64.355	1.116

4.5 Derivation of pooling groups

A single pooling group has been derived for the SB02 estimation point. The same pooling group will be used to determine growth curves at SB01 and TRIB01.

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons	Weighted average L-moments L-CV and L-skew, (before urban adjustment)
SB02_PG01 (default)	SB02	No	The default pooling group was found to be heterogeneous and a review of the pooling group was desirbable. A review of the pooling group was undertaken based on the distribution of L-moments. 7011 Black Burn @ Pluscarden Abbey. Reviewed and **removed** due to a short record of 7 years. 39033 Winterbourne Stream @ Bagnor. Site was reviewed and **retained.** NRFA indicates flows are estimated well by tha rating. 28058 Henmore Brook @Ashbourne. Reviewed based on the distribution of L-moments and **retained**. Although the highest spot flow does not fit the rating well, the site is still gauged beyond QMED and non-modular flow is confirmed by gaugings. 26013 Driffield Trout Stream @ Driffield. Reviewed and **retained**. Relatively short record but gauged to within 22% of AMAX1 and no bypassing.	L-CV = 0.287 L-skewness = 0.155

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons	Weighted average L-moments L-CV and L-skew, (before urban adjustment)
SB02_PG02	SB02	No	No further sites were added to the pooling group as the combined length of record was in excess of 500 years, Removal of a single site did not make a significant difference to the distribution of L-moments and it was not considered that further review of the group would be of benefit.	L-CV = 0.274 L-skewness = 0.143

Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).

4.6 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period / 1% AEP
SB02	P	SB02_PG02	GL (Z = 1.7145) GL Z-value is just outside of the acceptable bounds but has been taken forward as it produces a steeper growth curve at higher return periods and is generally used for UK sites.	Urban	Location: 1 Scale: 0.282 Shape: -0.145	2.837

Notes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

Urban adjustments are all carried out using the method of Kjeldsen (2010).

Growth curves were derived using the procedures from Science Report SC050050 (2008).

4.7 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	5	10	20	50	100	200	500	1000	
	Flood peak (m^3/s) for the following AEP (%) events									
SB02	1.853	2.653	3.202	3.769	4.579	5.257	6.002	7.106	8.040	
SB01	1.453	2.081	2.511	2.955	3.590	4.122	4.706	5.572	6.305	
TRIB01	0.580	0.831	1.002	1.180	1.433	1.645	1.879	2.224	2.517	
Intervening	0.018	0.026	0.031	0.036	0.044	0.051	0.058	0.069	0.078	

5 REVITALISED FLOOD HYDROGRAPH 2 (REFH2) METHOD

5.1 Application of ReFH2 method

What is the purpose of applying this method?	Derivation of design peak flows and hydrographs for the purpose of a Flood Risk Assessment

5.2 Catchment sub-divisions for ReFH2 model

n/a catchment is rural

5.3 Parameters for ReFH2 model

SB01 and TRIB01 are included in the table below for the only purpose of comparing ReFH2 peak flows with the statistical peak flows .

Site code	Method	Tp_{rural} (hours)	Tp_{urban} (hours)	C_{max} (mm)	PR_{imp} % runoff for impermeable surfaces	BL (hours)	BR
SB01	CD	8.899		940.145		75.861	3.201
SB02	CD	8.775		899.532		73.818	3.124
TRIB01	CD	6.293		728.851		58.302	2.761
Brief description of any flood event analysis carried out			n/a				
Methods: OPT: Optimisation, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)							

5.4 Design events for ReFH2 method: Lumped catchments

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
SB01	Rural	Winter	15
SB02	Rural	Winter	15
TRIB01	Rural	Winter	11

5.5 Design events for ReFH2 method: Sub-catchments and intervening areas

Site code	Season of design event	Storm duration (hours)	Storm area for ARF (if not catchment area)	Reason for selecting storm
All	Winter	15	n/a	A single catchment wide storm applied at all estimation points
Results of storm duration testing.	n/a			

5.6 Flood estimates from the ReFH2 method

The figures below use the critical storm duration for the SB01 and TRIB01 catchments, rather than the catchment wide storm listed in 6.5.

Site code	Flood peak (m^3/s) for the following return periods (in years)									
	2	5	10	20	50	100	200	500	1000	
	Flood peak (m^3/s) for the following AEP (%) events									
SB01	1.01	1.42	1.75	2.13	2.74	3.32	3.98	4.95	5.74	
SB02	1.41	1.91	2.35	2.85	3.67	4.44	5.31	6.6	7.65	
TRIB01	0.45	0.63	0.77	0.94	1.2	1.44	1.73	2.13	2.46	

7 DISCUSSION AND SUMMARY OF RESULTS

5.7 Comparison of results from different methods

T

Site code	Ratio of peak flow to FEH Statistical peak					
	Return period 2 years / 50% AEP			Return period 100 years / 1% AEP		
	ReFH	ReFH2	Other method	ReFH	ReFH2	Other method
SB01		0.695			0.805	
SB02		0.734			0.845	
TRIB01		0.776			0.875	

5.8 Final choice of method

Choice of method and reasons Include reference to type of study, nature of catchment and type of data available.	The FEH Statistical Method will be used to derive peak inflows (QMED from catchment descriptors and donor transfer, growth curves from a single pooling group and GL distribution). For consistency a single pooling group has been applied as the estimation points are within close proximity of each other. Design estimates will be fitted to a hydrograph from ReFH2. This is a simple study of an ungauged catchment. The catchments are permeable and the FEH Statistical Method would generally be favoured. The statistical method also provides conservative estimates compared to ReFH.
How will the flows be applied to a hydraulic model?	Applied as QT boundaries to the upstream extent of both watercourses. The intervening catchment will be applied as a lateral inflow. Hydrographs have been derived using ReFH2 for catchment SB02. The same hydrograph and storm duration will be used for all inflows. Whilst it is acknowledged that, in reality, the catchments would respond differently and therefore hydrographs shapes would differ, it is considered that they are similar enough and close enough for the same hydrograph shape to be used.

5.9 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	Gauges considered suitable for inclusion in the pooling group are based on the quality, data and comments available in the NRFA. This information is assumed to be reliable. The selected QMED donors are assumed to be sufficiently representative of the subject site.
Discuss any particular limitations,	The FEH Statistical method and ReFH are not intended for extrapolation up to the 1 in 1000 year return period. The selected QMED donors are assumed to be sufficiently representative of the subject site. ReFH2 design hydrographs are derived from the model parameters estimated from catchment descriptors. Whilst recommend for permeable catchments, a review of historical floods has not been undertaken due to the simple nature of this study.

Provide information on the uncertainty in the design peak flow estimates and the methodology used	Uncertainty bounds for the 95% and 68% confidence intervals for QMED at estimation point SB01, SB02 andTRIB01 are provided in the table below. It should be noted that the FEH guidelines provide confidence interval values for zero, one or six donor sites. In this instance, three donors sites have been used to derive QMED at SB01 and SB02. The figures in the table below are therefore based on the confidence intervals for six donor sites at SB01 and SB02.

	QMED (ms/s)	68% CL		95% CL	
		Lower	Upper	Lower	Upper
SB01	1.45	1.03	2.03	0.74	2.86
SB02	1.85	1.32	2.59	0.95	3.65
TRIB01	0.58	0.41	0.82	0.29	1.17

Comment on the suitability of the results for future studies	Peak flow estimates have been derived for the purpose of advising on an appropriate bridge soffit height along the Shill Brook in addition to assessing any third party impact of the proposed bridge. The analysis is not intended for other purposes.
Give any other comments on the study	

5.10 Checks

Are the results consistent, for example at confluences?	Peak flow estimates are consistent based on catchment size. The combined flow from SB01 and SB02 is larger than the estimate for SB02. This is reasonable as TRIB01 and SB01 would not be expected to peak at the same time.
What do the results imply regarding the return periods / frequency of floods during the period of record?	The site is ungauged.
What is the range of 100-year / 1% AEP growth factors? Is this realistic?	SB02 100 year growth factor = 2.837 This is within the typical range as set out in the FEH Guidelines (2.1-4). The same growth factor has been applied to SB01 and TRIB01.
If 1000-year / 0.1% AEP flows have been derived, what is the range of ratios for 1000-year / 0.1% AEP flow over 100-year / 1% AEP flow?	Ratio of 1000 year / 100 year flow SB02: 1.529
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	There are no known previous hydrological assessments.
Are the results compatible with the longer-term flood history?	Information about the long term flood history is not available
Describe any other checks on the results,	Hydraulic model results will be sense checked.

5.11 Final results

Site code	Flood peak (m³/s) for the following return periods (in years)									
	2	5	10	20	50	100	200	500	1000	
	Flood peak (m³/s) for the following AEP (%) events									
SB01	1.453	2.081	2.511	2.955	3.590	4.122	4.706	5.572	6.305	
TRIB01	0.58	0.831	1.002	1.18	1.433	1.645	1.879	2.224	2.517	
SB02	1.853	2.653	3.202	3.769	4.579	5.257	6.002	7.106	8.04	
Intervening Catchment	0.018	0.026	0.031	0.036	0.044	0.051	0.058	0.069	0.078	

5.12 Uncertainty bounds

This table reports the flows derived from the uncertainty analysis detailed in Section 5.9. The 'true' value is more likely to be near the estimate reported in Section 5.11 than the bounds. However, it is possible that the 'true' value could still lie outside these bounds.

The values in the table below relate to the 95% confidence interval.

Site code	Flood peak (m³/s) for the following return periods (in years)							
	2		20		100		1,000	
	Flood peak (m³/s) for the following AEP (%) events							
	50		5		1		0.1	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
SB01	0.74	2.86	1.48	5.94	2.02	8.45	2.9	13.62
SB02	0.95	3.65	1.88	7.58	2.58	10.78	3.7	17.37
TRIB01	0.29	1.17	0.57	2.44	0.77	3.49	1.13	5.61

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, hydraulic model, or reference to table below)	Hydrographs are derived from ReFH and are located in the QT folder.

6 ANNEX

Default and reviewed pooling groups used as part of the Statistical Method.

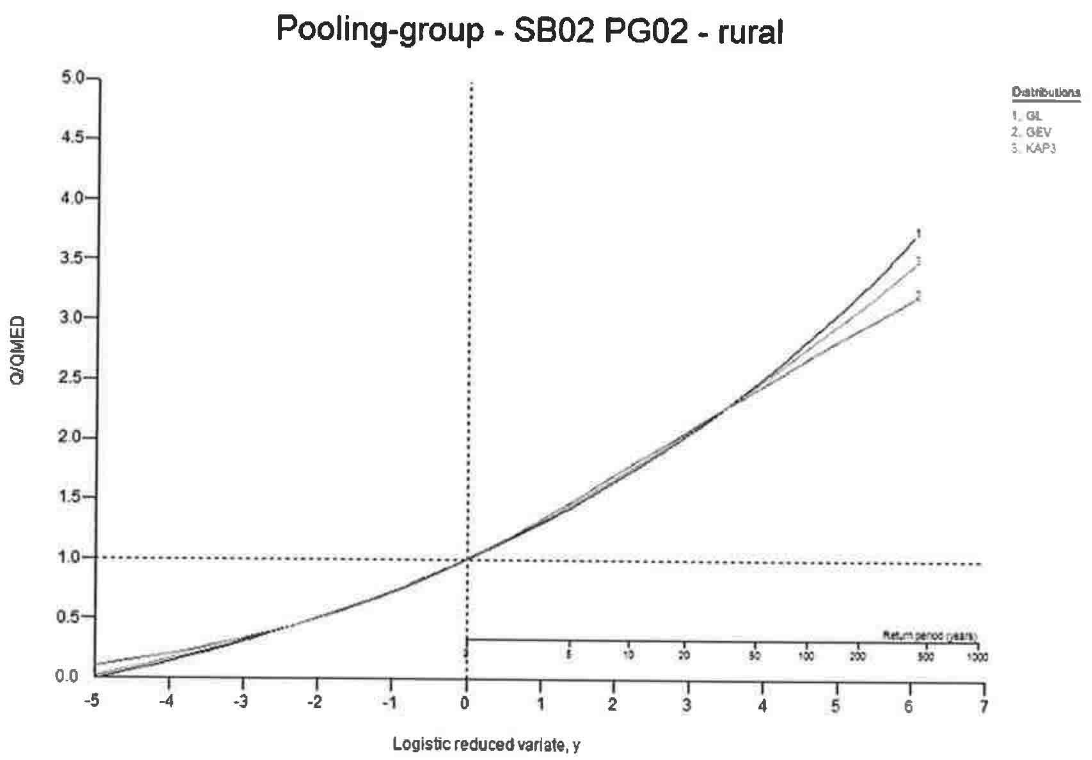
SB02_PG02

	Station	Distance (SDM)	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Discordancy
1	41020 (Bevern Stream @ Clappers Bridge)	0.475	51	13.66	0.204	0.205	0.174	0.171	1.458
2	53017 (Boyd @ Bitton)	0.51	47	13.87	0.243	0.245	0.083	0.08	0.117
3	39033 (Winterbourne Stream @ Bagnor)	0.524	58	0.401	0.342	0.342	0.383	0.382	1.901
4	36004 (Chad Brook @ Long Melford)	0.532	53	4.938	0.304	0.305	0.167	0.166	0.47
5	26013 (Driffield Trout Stream @ Driffield)	0.558	10	2.685	0.292	0.293	0.281	0.28	2.2
6	36010 (Bumpstead Brook @ Broad Green)	0.607	53	7.5	0.377	0.379	0.173	0.172	0.939
7	9006 (Deskford Burn @ Cullen)	0.654	9	21.783	0.3	0.3	0.129	0.129	0.376
8	26014 (Water Forlornes @ Driffield)	0.661	22	0.431	0.298	0.299	0.12	0.119	0.4
9	28058 (Henmore Brook @ Ashbourne)	0.69	13	8.838	0.188	0.19	-0.109	-0.111	1.198
10	30004 (Lymn @ Partney Mill)	0.695	58	7.184	0.224	0.225	0.03	0.029	0.287
11	41022 (Lod @ Halfway Bridge)	0.709	50	16.25	0.296	0.297	0.174	0.172	0.189
12	33054 (Babingley @ Castle Rising)	0.73	44	1.132	0.204	0.205	0.069	0.068	0.554
13	24007 (Browney @ Lanchester)	0.738	15	10.981	0.222	0.222	0.212	0.211	1.294
14	36003 (Box @ Polstead)	0.748	60	3.875	0.314	0.317	0.088	0.086	0.663

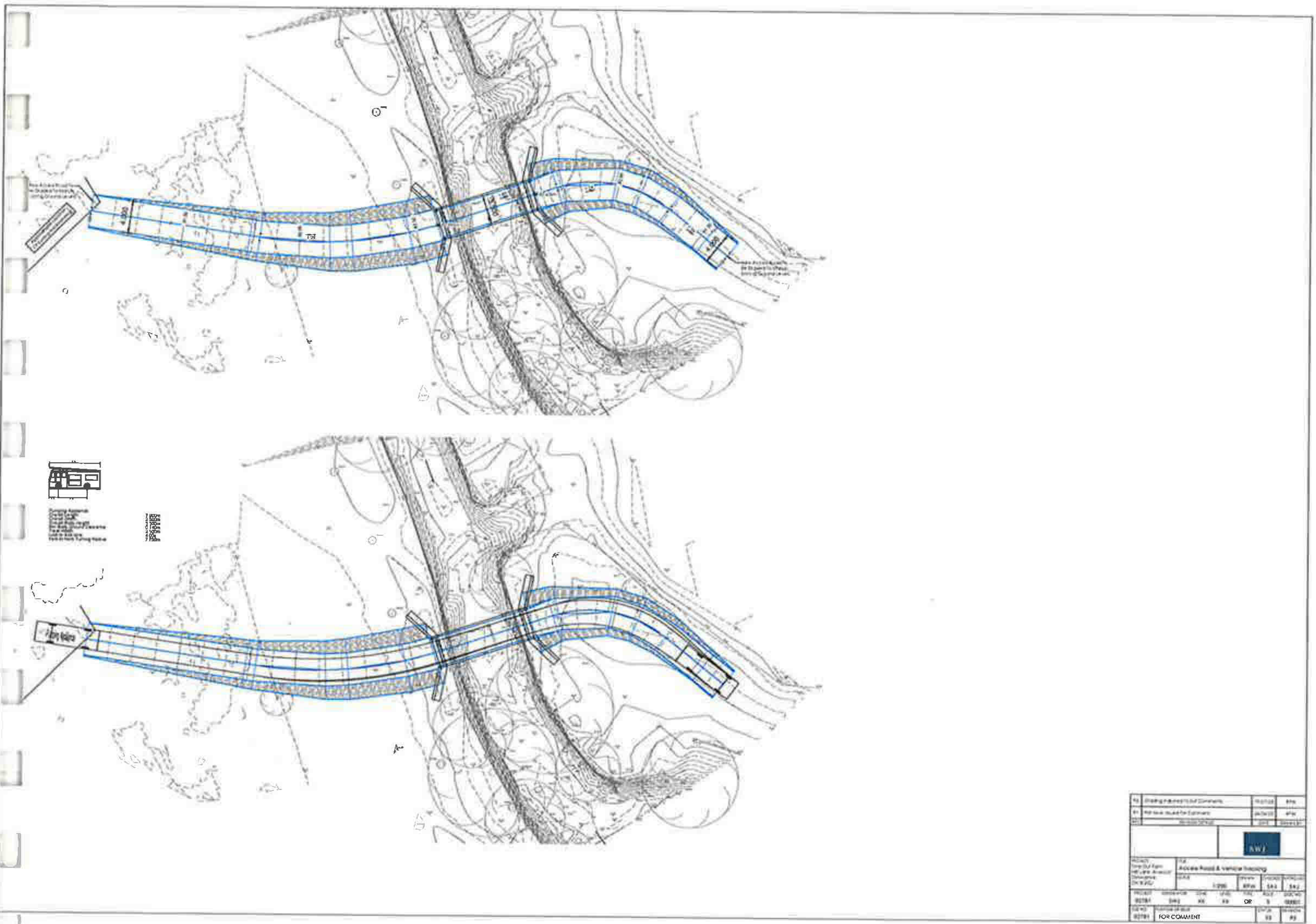
SB02_Default

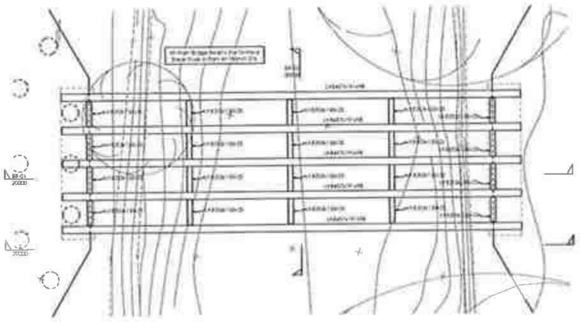
	Station	Distance (SDM)	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Discordancy
1	7011 (Black Burn @ Pluscarden Abbey)	0.468	7	5.205	0.544	0.544	0.571	0.571	2.954
2	41020 (Bevern Stream @ Clappers Bridge)	0.475	51	13.66	0.204	0.205	0.174	0.171	1.458
3	53017 (Boyd @ Bitton)	0.51	47	13.87	0.243	0.245	0.083	0.08	0.117
4	39033 (Winterbourne Stream @ Bagnor)	0.524	58	0.401	0.342	0.342	0.383	0.382	1.901
5	36004 (Chad Brook @ Long Melford)	0.532	53	4.938	0.304	0.305	0.167	0.166	0.47
6	26013 (Driffield Trout Stream @ Driffield)	0.558	10	2.685	0.292	0.293	0.281	0.28	2.2
7	36010 (Bumpstead Brook @ Broad Green)	0.607	53	7.5	0.377	0.379	0.173	0.172	0.939
8	9006 (Deskford Burn @ Cullen)	0.654	9	21.783	0.3	0.3	0.129	0.129	0.376
9	26014 (Water Forlornes @ Driffield)	0.661	22	0.431	0.298	0.299	0.12	0.119	0.4
10	28058 (Henmore Brook @ Ashbourne)	0.69	13	8.838	0.188	0.19	-0.109	-0.111	1.198
11	30004 (Lymn @ Partney Mill)	0.695	58	7.184	0.224	0.225	0.03	0.029	0.287
12	41022 (Lod @ Halfway Bridge)	0.709	50	16.25	0.296	0.297	0.174	0.172	0.189
13	33054 (Babingley @ Castle Rising)	0.73	44	1.132	0.204	0.205	0.069	0.068	0.554
14	24007 (Browney @ Lanchester)	0.738	15	10.981	0.222	0.222	0.212	0.211	1.294
15	36003 (Box @ Polstead)	0.748	60	3.875	0.314	0.317	0.088	0.086	0.663

SB02_PG02 (selected Pooling Group) – growth curves

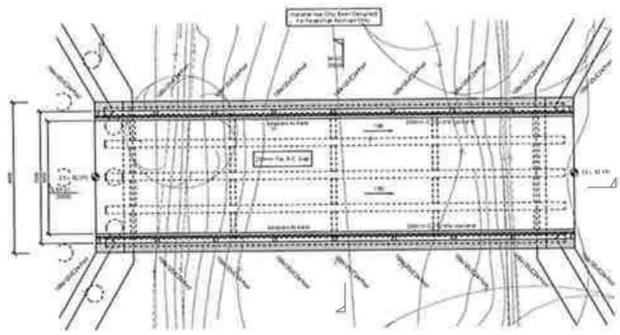


B Outline Design


Access Road & Vehicle Tracking
FOR COMMENT

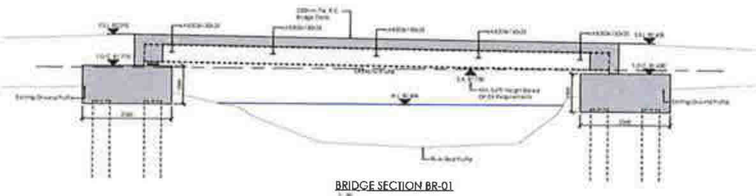


STEELWORK PLAN ON BRIDGE DECK

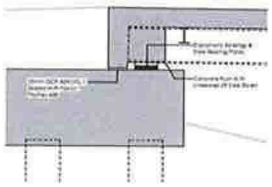


CONCRETE PLAN ON BRIDGE DECK

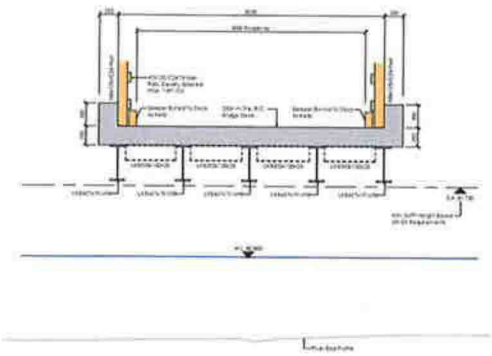
Bridge Deck Layout						
1:50	RPW	SRJ	SRJ			
8298	SWJ	XX	XX	DR	S	10001
FOR COMMENT					S3	P2



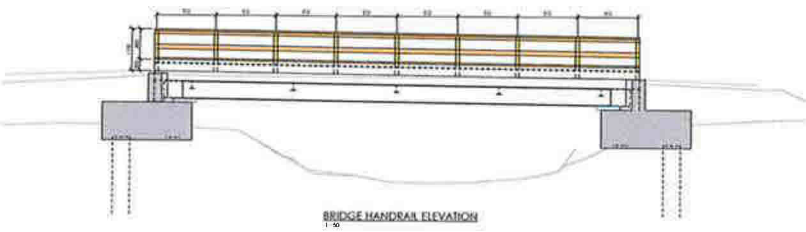
BRIDGE SECTION BR-01



TYPICAL ABUTMENT DETAIL



BRIDGE SECTION BR-02



BRIDGE HANDRAIL ELEVATION

CONSTRUCTION HAZARDS AND RISKS
• None relevant to this drawing

MAINTENANCE/ CLEANING HAZARDS AND RISKS
• None relevant to this drawing

DEMOLITION HAZARDS AND RISKS
• None relevant to this drawing

GENERAL NOTES

TITLE	Bridge Sections & Details
SCALE	As indicated
DRAWN	RPW
CHECKED	SAJ
APPROVED	SAJ
PROJECT	02785
ORIGINATOR	SWJ
ZONE	XX
LEVEL	XX
TYPE	DR
ROLE	S
DWG NO.	20000
JOB NO.	02785
PURPOSE OF ISSUE	FOR COMMENT
STATUS	S3
REVISION	P2