M54 to M6 Link Road

TR010054

Volume 7

7.1 Flood Risk Assessment

Regulation 5(2)(a)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

January 2020

Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

M54 to M6 Link Road

Development Consent Order 202[ ]

7.1 Flood Risk Assessment

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1 Introduction

1.1 Background

1.1.1 Highways England is developing a link road between the M54 and M6 to provide a link between Junction 1 of the M54, M6 North and the A460 to Cannock. The M54 to M6 Link Road ('the Scheme') aims to reduce congestion on local/regional routes, particularly the A449 and A460 and deliver improved transport links to encourage the development of the surrounding area.

1.1.2 As part of the environmental assessment for the Scheme, a Flood Risk Assessment (FRA) is required to identify the sources of flood risk to and from the Scheme.

1.2 Scheme and location

1.2.1 Highways England has assessed highway options to address congestion issues on the A460 Cannock Road, through the villages of Shareshill and Featherstone with the aim to divert through traffic away from the villages onto a more suitable link road between the M54 and M6. The Scheme is located between the M54 and M6 and would provide a link from Junction 1 of the M54 to the M6 north and to the A460 to Cannock. The Scheme would provide a strategic link between the M54 Junction 1 and M6 Junction 11. From south to north the main components of the Scheme are:

- Replacement of the existing M54 Junction 1 with free flow slip roads between the new link road and the M54. This would allow the freeflow of traffic between the M54 and the new link road in both directions and maintain connectivity with the existing local road network, via three new roundabouts.
- Construction of a new dual carriageway between M54 Junction 1 and the M6 Junction 11. The alignment of the carriageway would be located to the east of the existing A460 and the villages of Featherstone, Hilton and Shareshill and west of Hilton Hall.
- Dark Lane would be stopped-up between the final property and the junction with Hilton Lane.
- The realignment of Hilton Lane on a bridge over the mainline of the Scheme. The bridge would be reconstructed on a similar alignment and would provide sufficient clearance for the new road.
- Provision of an accommodation bridge and access track across the mainline of the Scheme to retain access to severed land to the east of the Scheme. The route of the new link road would then continue north to the east of Brookfield Farm to link into the M6 Junction 11.
- Enlargement of the M6 Junction 11 signalised roundabout to accommodate a connection to the new link road and realign existing connections with the A460 and M6. Two replacement bridges would be required over the M6 to provide an increase in capacity from two lanes to four lanes of traffic on the roundabout. This work would raise the height of the junction by approximately 1.5m.

1.2.2 Chapter 3: Assessment of Alternatives of the Environmental Statement (ES) [TR010054/APP/6.1] describes the various options that have been developed and considered; ultimately resulting in the definition of the Scheme.

1.2.3 The design for the Scheme can be seen below in Figure 1.1. The centre of the Scheme boundary is approximately X 394960, Y 305670.

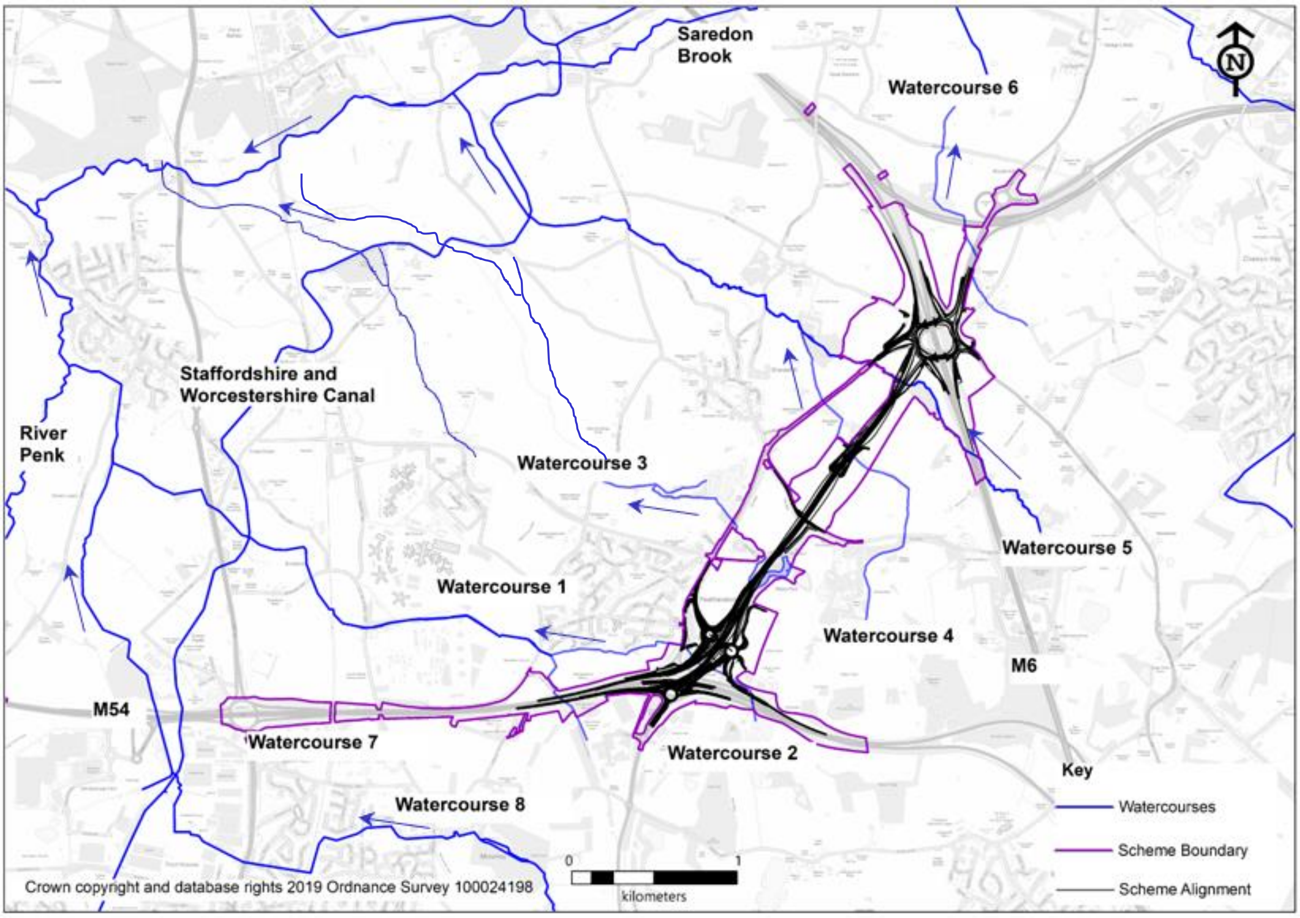


Figure 1.1: A map of the Scheme development area, showing ordinary watercourses.

1.2.4 There are six ordinary watercourses (shown in Figure 1.1, listed in Table 1.1) which intersect the route alignment. In addition, there are two ordinary watercourses (Watercourses 7 and 8) which are within 1 km of the Scheme boundary.

1.2.5 Watercourses 1 to 8 are tributaries of the River Penk or Saredon Brook, which are main rivers.

Table 1.1: Watercourses and Scheme crossings

Watercourse Number	Watercourse Name
1	Unknown
2	Unknown
3	Unknown
4	Unknown
5	Latherford Brook
6	Unknown
7	Unknown
8	Waterhead Brook

1.3 Methodology

1.3.1 An FRA is required to assess the risks from all sources of flooding to and from a proposed development. Section 10 of the National Planning Policy Framework (NPPF) (Ref 1) provides national policy in relation to development and flood risk. This is supported by the Planning Policy Guidance (PPG) (Ref 2) which accompanies the NPPF. The NPPF emphasises the need for a risk-based approach to be adopted through the application of the 'Source-Pathway-Receptor' model. In accordance, the approach to this FRA is based on the Source-Pathway-Receptor model.

1.3.2 The Source-Pathway-Receptor model firstly identifies the causes or 'sources' of flooding to and from a development based on a review of local conditions and consideration of the effects of climate change. The nature and likely extent of flooding arising from any one source is considered, e.g. whether such flooding is likely to be localised or widespread. The presence of a flood source does not always infer a risk. It is the exposure 'pathway' or the flooding mechanism that determines the risk to the receptor and the effective consequence of exposure. For example, sewer flooding does not necessarily increase the risk of flooding unless the sewer is local to the site and ground levels encourage surcharged water to accumulate. The varying effect of flooding on the 'receptors' depends largely on the sensitivity of the target. Receptors include any people or property within the range of the flood source, which are connected to the source of flooding by a pathway. For there to be a flood risk, all the elements of the model (i.e. a flood source, pathway and receptor) must be present. Furthermore, effective mitigation can be provided by removing one element of the model.

1.3.3 This approach involves a desk-based study of available information in combination with hydraulic modelling to establish the levels of flood risk. Once the flood risks were established, mitigation measures are proposed (where necessary) and residual risks are addressed.

1.4 Aims and objectives

1.4.1 The aim of this report is to provide an FRA to inform Highways England of the flooding risks posed to and by the Scheme in support of a Development Consent Order (DCO) application for the Scheme. The FRA has been prepared in accordance with the National Policy Statement for National Networks (NPSNN) (Ref 3), NPPF, its associated PPG and other relevant local policy *(as listed in Section 2)*.

1.4.2 To achieve the above aim the following objectives were met:

- review of existing site data including Environment Agency flood risk data, ground conditions, scheme proposals and reference to relevant policy including Strategic Flood Risk Assessments (SFRA), Preliminary Flood Risk Assessments (PFRA), Surface Water Management Plans and Local Flood Risk Management Strategies *(as listed in Section 2)*;
- liaison with the Environment Agency to outline and agree requirements for the site-specific FRA;
- liaison with the Lead Local Flood Authority (LLFA), Staffordshire County Council, to outline and agree requirements for the site-specific FRA;
- liaison with the design and environment teams to obtain Scheme drawings, proposed drainage Scheme drawings, topographical data, ecology survey information, etc.;
- assessment and interpretation of available information to identify potential sources of flood risk. These include fluvial, pluvial (surface water), groundwater, combined, foul or surface water sewers, and infrastructure failure (e.g. canals, reservoirs, pumped catchments) including any history of burst water mains, blocked sewers, canal breach events etc.);
- hydraulic modelling to confirm baseline conditions and assess the fluvial flood risk impact near the Scheme. This included modelling of the existing baseline conditions and of the Scheme for a series of magnitude fluvial events;
- identification of potential measures to mitigate the fluvial flood risk impacts of the Scheme;
- a review of the surface water drainage design that has been prepared for the Scheme, and incorporation of the design calculations into the FRA; and
- discussion and provision of recommendations for flood mitigation measures including compensatory storage for the fluvial volume and residual risk mitigation measures in line with the conclusions of the drainage strategy, where applicable.

1.5 Data sources

1.5.1 The baseline conditions for the Scheme have been established through a desk-based study and via consultation with the Environment Agency and the LLFA; and have been utilised to inform the assessment made within this report. Data collected during this assessment is described in Table 1.2.

Table 1.2: Data sources

Purpose	Data source	Comments
Identification of Hydrological Features	1: 25,000 Ordnance Survey (OS) mapping.	Identifies the position of the routes and local hydrological features.
Identification of Existing Flood Risk	Environment Agency Indicative Flood Zone Map (Ref 4).	Identifies fluvial/ tidal inundation extents and historical flooding.
	Environment Agency Long Term Flood Risk Map (Ref 5).	Provides information on the risk of flooding from fluvial, surface water and reservoirs (artificial sources).
	Staffordshire PFRA (Ref 6) South Staffordshire, Cannock Chase, Lichfield & Stafford SFRA 2014 and 2019 (Ref 7 and 8) Staffordshire Local Flood Risk Management Strategy (Ref 9) Shropshire and Staffordshire Local Flood Risk Management Strategy – Part 3: Strategic Environmental Assessment for Staffordshire (Ref 10) River Trent Catchment Flood Management Plan (Ref 11)	Assesses flood risk across the county and borough boundary areas. Includes flood risk from fluvial/tidal, sewers, overland flow and groundwater.
	British Geological Survey records (Ref 12). MAGIC Mapping (Ref 13)	Provides details of geology and hydrogeology in the vicinity of the Site.
Identification of Historical Flooding	Staffordshire PFRA (Ref 6) South Staffordshire SFRA (Ref 7 and 8)	Provides locations of historical flooding.
Details of the Scheme	Proposed alignment drawings The General Arrangement Plans (Application Document TR010054/APP/2.5) General arrangement drawings of proposed watercourse crossing structures	Provides a schematic of the Scheme.
Surface Water Drainage	PFRA, SFRA, Environment Agency Flood Risk from Surface Water Map (online), and Defra Sustainable Drainage Systems (SuDS) – Non-statutory technical standards (Ref 14).	Identifies existing surface water flood risk from the route options. Provides information regarding drainage requirements for the route.
Planning Policy	NPSNN, NPPF, PPG, A Local Plan for South Staffordshire: Core Strategy Development Plan Document (Ref 15).	Provides information regarding national and local policy requirements.
Climate Change Guidelines	Environment Agency Guidance for Flood Risk Assessments: climate change allowances (Ref 16)	Provides guidance on when and how to use climate change allowances in flood risk assessments.

2 Planning Policy and Guidance

2.1.1 The sections below summarise the planning policy and regulatory framework that has a direct influence on the structure and content of this FRA.

2.2 National planning policy context

National Policy Statement for National Networks

2.2.1 The primary basis for deciding whether or not to grant a DCO is the NPSNN which, at Sections 4 and 5, sets out policies to guide how DCO applications will be decided and how the impacts of national networks infrastructure should be considered.

2.2.2 Flood risk paragraphs 5.90 – 5.115 state that the Secretary of State should be satisfied that flood risk will not be increased elsewhere and should only consider development appropriate in areas at risk of flooding where it can be demonstrated that: the most vulnerable development is located in areas of lowest flood risk unless there are overriding reasons to prefer a different location; development is appropriately flood resilient and resistant, including safe access and escape routes where required; that any residual risk can be safely managed, including by emergency planning; and that priority is given to the use of SuDs. Applications for projects should be accompanied by an FRA to assess all risks of flooding and take climate change into account.

2.2.3 In preparing an FRA an applicant should:

- Consider the risk of all forms of flooding arising from the project (including in adjacent parts of the United Kingdom), in addition to the risk of flooding to the project, and demonstrate how these risks will be managed and, where relevant, mitigated, so that the development remains safe throughout its lifetime.
- Take the impacts of climate change into account, clearly stating the development lifetime over which the assessment has been made.
- Consider the vulnerability of those using the infrastructure including arrangements for safe access and exit.
- Include the assessment of the remaining (known as ‘residual’) risk after risk reduction measures have been taken into account and demonstrate that this is acceptable for the particular project.
- Consider if there is a need to remain operational during a worst case flood event over the development’s lifetime.
- Provide the evidence for the Secretary of State to apply the Sequential Test and Exception Test as appropriate.

National Planning Policy Framework

2.2.4 The NPPF published in 2012 and last updated in June 2019, is supported by the PPG, an online resource first published in March 2014 and updated regularly.

2.2.5 The NPPF and PPG must be considered in the preparation of local and neighbourhood plans and are a material consideration in planning decisions. It constitutes guidance for local planning authorities and decision-makers, both in drawing up plans and as a material consideration in determining applications.

2.2.6 The NPPF and PPG recommend that Local Plans should be supported by a SFRA and develop policies to manage flood risk from all sources, taking account of advice from the EA and other relevant flood risk management bodies, such LLFAs and internal drainage boards. Local Plans should apply a sequential, risk-based approach to the location of development to avoid, where possible, flood risk to people and property and manage any residual risk, taking account of the impacts of climate change, by:

- applying the Sequential Test;
- applying the Exception Test, if necessary;
- safeguarding land from development that is required for current and future flood management;
- using opportunities offered by new development to reduce the causes and impacts of flooding; and
- seeking opportunities to facilitate the relocation of existing development, including housing, to more sustainable locations where climate change is expected to increase flood risk.

2.3 Regional planning policy

Strategic Flood Risk Assessment

2.3.1 The SFRA for South Staffordshire, Cannock Chase, Lichfield, Stafford and Tamworth[15] details flood risk in the county from the various sources as well as identifies cases of historical flooding. This was undertaken in 2014 but has been updated and published in 2019.

2.3.2 The SFRA identifies little in terms of flood risk within or in close proximity to the Scheme area, but it does identify the local area to have a groundwater Source Protection Zone (SPZ). A groundwater SPZ is an area defined based on the time it takes for pollutants to reach an abstraction point. The groundwater SPZ in this area is categorized as an Inner Zone groundwater SPZ, meaning it is most vulnerable and can vary in diameter from 0.1 to 0.5 km. The SFRA informs developers on how the drainage should be considered for future developments in these areas, suggesting attenuated storage of runoff and the application of specific SuDS.

2.3.3 Figure 5-1 identifies specific locations near to the Scheme which have flooded previously, from the various sources: fluvial, pluvial, surface water and sewers. The report suggests the flooding in these locations from pluvial sources occur frequently, potentially every year. More specific detail in the SFRA identifies seven properties in the Shareshill / Featherstone area to be susceptible to surface water / sewer flooding.

2.3.4 Mapping (Ref 16) also included within the Appendices highlights Latherford Brook which intersects the Scheme, as being at a high risk of fluvial flooding (flood zone 3). The risk of flooding is also shown to affect a watercourse to the south-west of the Scheme. When considering the online Flood Map for Planning on the EA website, it appears this watercourse is Watercourse 1, and the modelling for this watercourse is incomplete.

2.3.5 The 2014 SFRA identifies the proposed land within the Scheme boundary area is at partial risk from Groundwater flooding, classifications A, B and C. The susceptibility classifications are as shown in Table 2.1. The 2019 SFRA identifies Areas Susceptible to Groundwater Flooding as strategic scale map showing groundwater flood areas on a 1 km square grid. The data shows that most of the Scheme area has < 25% of each 1 km square as susceptible to groundwater flood emergence.

Table 2.1: Ground water susceptibility classifications

Classification	Description
A	**Limited potential for groundwater flooding to occur**: based on rock type and estimated groundwater level during periods of extended intense rainfall.
B	**Potential for groundwater flooding of property situated below ground level:** periods of extended intense rainfall. Where this may have an impact, you are advised to check that this have not been a problem in the past at this location and/or that measures are in place to sufficiently reduce the impact of the flooding.
C	**Potential for groundwater flooding to occur at surface**: based on rock type and estimated groundwater level during periods of extended intense rainfall. You are advised to check that this has not been a problem in the past at this location and/or that measures are in place to sufficiently reduce the impact of the flooding.
Elsewhere (onshore)	Not considered to be prone to groundwater flooding: based on rock type.

Preliminary Flood Risk Assessment

2.3.6 The PFRA for Staffordshire was written in March 2011. PFRAs aim to provide a high-level overview of flood risk from all sources of flooding within a local area, including the consideration of surface water, groundwater, ordinary watercourse and canals, for both historical and future instances.

2.3.7 The Staffordshire PFRA does not identify any risk of flooding within or near the Scheme area (Ref 6).

Catchment Flood Management Plan

2.3.8 Catchment Flood Management Plans (CFMPs) are the Environment Agency's high-level strategic plans for the sustainable management of flood risk at a large catchment-scale. The plan assesses the size, nature and distribution of current and potential future flood risk. As a result of the assessment the CFMP then provides a set of long-term flood risk management policies and an indication as to who is responsible and the types of responses in order to meet those policies.

2.3.9 The nearest main river, the Featherstone Brook tributary of the River Penk, to the Scheme is located approximately 7 km downstream to the north-west. This river, as well as the Scheme area is located within the River Trent catchment area.

2.3.10 The River Trent CFMP identifies the area to have a long history of river, tidal and surface water flooding. The River Trent catchment area is approximately 10,000 km^2 and due to the Scheme's proximity to the coast and its nearest main river, these risks of flooding are minimal.

2.3.11 The CFMP does not identify any risk of flooding specific to the Scheme area.

2.4 Local policy

Staffordshire Local Flood Risk Management Strategy

2.4.1 The Staffordshire Local Flood Risk Management Strategy was written in December 2015 to meet the requirements of the 2010 Flood and Water Management Act. The purpose of the study is to guide the management of local flood risk across the Staffordshire county. The strategy includes the following:

- Information on local flood risk in Staffordshire, highlighting where problems have already occurred, or where areas fall in risk categories.
- Clarification of which authority is responsible for what in relation to the prevention and management of flooding.
- Detail on the measures that will be undertaken to manage flood risk.
- Clarification on how work is prioritised.
- Measures that communities can undertake to improve flood resilience, as it is not possible to stop all flooding.
- Consideration on funding flood risk and investment planning.

2.4.2 The Staffordshire Local Flood Risk Management Strategy does not identify any risk of flooding specific to the Scheme area.

Shropshire and Staffordshire Local Flood Risk Management Strategy – Part 3: Strategic Environmental Assessment for Staffordshire

2.4.3 The Shropshire and Staffordshire Local Flood Risk Management Strategy – Part 3: Strategic Environmental Assessment for Staffordshire was written in March 2014 to review the environmental baseline of Shropshire and to identify potential significant environmental effects that plans, programmes and strategies may have on the existing environment, and therefore increase the consideration of environmental issues in the plan making process. The measures assessed include:

- biodiversity;
- cultural heritage;
- human health;
- material assets;
- soil;
- landscapes; and
- water.

2.4.4 The strategy provides guidance for considering flood risk during the development planning process. The strategy advises:

- measures which should be taken to prevent additional flow from new development entering existing drainage systems and watercourses;

- that all future developments should aim to protect, improve and sustainably manage the use of the water environment to have a positive impact on the human or natural environment;
- on the inclusion of blue corridors and improved linkage to green infrastructure which supports and enhances national policy such as the NPPF, which aims to increase access to high quality open spaces and opportunities for recreation to improve the health and well-being of communities; and
- flood management (particularly with regards to resilience against climate change) should be agreed upon, by engaging relevant stakeholders in consultations during the planning process.

2.4.5 The Shropshire and Staffordshire Local Flood Risk Management Strategy – Part 3: Strategic Environmental Assessment for Staffordshire does not identify any risk of flooding specific to the Scheme area.

South Staffordshire Council Core strategy

2.4.6 South Staffordshire Council's core strategy was adopted in 2012. This document outlines the 'Local Plan' which is a collection of policies making a planning framework for the sustainable development of the district up to 2028. The development policies are structured around the following themes:

- Spatial Strategy
- Environmental quality
- Housing
- Economic vibrancy
- Community safety
- Health and wellbeing
- Children and young people

2.4.7 Specifically relating to flood risk, the Environmental quality policy states that development proposals should be consistent with the NPPF, the Supplementary Planning Documents on the Historic Environment and Biodiversity and other local planning policies. Development proposals should have regard to and support the actions and objectives of the Severn and Humber River Basin Management Plans (RBMPs) and consider the River Severn and River Trent CFMPs.

2.4.8 With regards to the impacts of Climate change, Staffordshire County Council will require development to be designed to cater for the effects of climate change, and also guiding development away from known areas of flood risk as identified in the SFRA, Surface Water Management Plan and consistent with NPPF.

2.5 Other relevant policy and guidance

Design Manual for Roads and Bridges

2.5.1 Guidance outlined in the Design Manual for Roads and Bridges (DMRB) (Ref 17) was referenced during the analysis of flood risk regarding river crossings such as culverts and bridges. The DMRB was introduced in 1992 in England and Wales, and later in Scotland and Northern Ireland. It includes all current standards, advice notes and other documents relating to the design, assessment and operation of trunk roads, including motorways.

2.6 Consultation

2.6.1 The proposed scope of the FRA assessment was detailed in the Environmental Impact Assessment Scoping Report submitted to the Planning Inspectorate ('the Inspectorate') on 11th January 2019. An overview of the Inspectorate's Scoping Opinion in relation to the water environment is presented in Table 13.5 of the ES, TR010054/APP/6.1]. These comments have been used to direct this FRA and the development of mitigation measures for Flood Risk related to the Scheme.

2.6.2 The Sow and Penk Internal Drainage Board provided no comments, as their response stated that the Scheme was outside of their area of concern.

2.6.3 In addition to comments provided by the Environment Agency and Staffordshire County Council as part of the DCO process, a series of consultation meetings were held. The meetings sought to agree the approaches required as part of the ES, FRA and design of the Scheme as follows:

- 9th of May 2019, Highways England representatives met with the Environment Agency to discuss consultation requirements for the Scheme.
- 10th of June 2019, Highways England representatives met with the LLFA, Staffordshire County Council to discuss the Scheme and impact on Watercourses.
- 18th of July 2019, Highways England representatives met with the Environment Agency to consult on developments to the Scheme design.
- 6th of August 2019, Highways England representatives met with the Environment Agency and the LLFA to consult on developments to the Scheme design.

2.7 Climate change

2.7.1 The Environment Agency published climate change guidance in February 2016 (Ref 16), which has been updated in 2019. The guidance indicates that climate change is likely to increase river flows, sea levels, rainfall intensity, and wave height and wind speed. The 2019 information and advice has therefore been used to complete this FRA, however there is a risk that changes to the EA's stance on climate change may impact the design of the Scheme and so further consultation with the EA should be undertaken as this Scheme progresses through the DCO process.

2.7.2 The EA as part of the engagement undertaken for this FRA, indicated that a climate change allowance of 50% should be used to assess flood risk and design appropriate mitigation for the Scheme. This is the Upper End allowance for the Humber River Basin District anticipated for the 2080's.

Peak River Flow Allowances by River Basin District

2.7.3 The peak river flow allowances show the anticipated changes to peak flow by river basin district. The range of climate change allowances is based on percentiles (Table 2.2). A percentile is a measure used in statistics to describe the proportion of possible scenarios that fall below an allowance level. The 50th percentile is the point at which half of the possible scenarios for peak flows fall below it and half fall above it:

- central allowance is based on the 50th percentile;
- higher central is based on the 70th percentile; and
- upper end is based on the 90th percentile.

2.7.4 If the central allowance is a 30% increase in peak flow, scientific evidence suggests that it is just as likely that the increase in peak river flow will be more than 30% as less than 30%.

2.7.5 At the higher central allowance, 70% of the possible scenarios fall below this value. So, if the higher allowance is a 40% increase in peak flow, then current scientific evidence suggests that there is a 70% chance that peak flows will increase by less than this value, but there remains a 30% chance that peak flows will increase by more.

2.7.6 At the Upper End, 90% of the possible scenarios fall below this value. So, if the higher allowance is a 50% increase in peak flow, then current scientific evidence suggests that there is a 90% chance that peak flows will increase by less than this value, but there remains a 10% chance that peak flows will increase by more.

Table 2.2: Climate change allowance for the Humber River Basin District

Allowance Category	Total potential change anticipated for 2020s (2015 to 2039)	Total potential change anticipated for 2050s (2040 to 2069)	Total potential change anticipated for 2080s (2070 to 2115)
Upper End	20%	30%	50%
Higher Central	15%	20%	30%
Central	10%	15%	20%

Peak river flow allowances for different assessments

2.7.7 For Flood Risk Assessments, the “flood risk vulnerability classification” (Table 2 in the NPPF) for the type of development and the “flood zone” (Table 1 in NPPF) should be used to decide which peak river flow allowances (allowance category) to use based on the lifetime of the Scheme (Table 2.3). The Scheme assessed in this FRA is considered essential infrastructure.

Table 2.3: Peak river flow allowances based on flood risk vulnerability classification and flood zone

Flood Zone 1
Essential infrastructure – use the central allowance Highly vulnerable – use the central allowance More vulnerable – use the central allowance Less vulnerable – use the central allowance **Water compatible – use none of the allowances**
Flood Zone 2
Essential infrastructure – use the higher central and upper end to assess a range of allowances Highly vulnerable – use the higher central and upper end to assess a range of allowances More vulnerable – use the central and higher central to assess a range of allowances Less vulnerable – use the central allowance Water compatible – use none of the allowances
Flood Zone 3a
Essential infrastructure – use the upper end allowance Highly vulnerable – development should not be permitted More vulnerable – use the higher central and upper end to assess a range of allowances Less vulnerable – use the central and higher central to assess a range of allowances Water compatible – use the central allowance
Flood Zone 3b
Essential infrastructure – use the upper end allowance Highly vulnerable – development should not be permitted More vulnerable – development should not be permitted Less vulnerable – development should not be permitted Water compatible – use the central allowance
If development is considered appropriate when not in accordance with flood zone vulnerability categories, then it would be appropriate to use the upper end allowance.

Peak river flow allowances for the Scheme

2.7.8 It is assumed that the lifetime of the Scheme is 100 years therefore the peak river flow climate change allowances for the lifetime of the Scheme should be assessed as shown in Table 2.4.

Table 2.4: Peak river flow allowances for the Scheme

Criteria	Scheme
River Basin District	Humber
Flood Zone	1, 2 and 3 (including 3b functional floodplain)
Flood Risk Vulnerability Classification	Essential Infrastructure (transport link)
Lifetime of Development	100 years
Climate Change Allowance to be Assessed	Upper End Allowance (50%)

Peak rainfall intensity allowance

2.7.9 Increased rainfall affects river levels and land and urban drainage systems. Table 2.5 shows anticipated changes in extreme rainfall intensity in small and urban catchments. For FRAs, both the central and upper end allowances need to be assessed to understand the range of impact.

Table 2.5: Peak rainfall intensity allowance

Applies across all of England	Total potential change anticipated for 2010 to 2039	Total potential change anticipated for 2040 to 2069	Total potential change anticipated for 2060 to 2115
Upper End	10%	20%	40%
Central	5%	10%	20%

3 Flood Risk to the Scheme

3.1.1 The NPPF requires site specific FRAs accompanying planning applications to assess the risk of all sources of flooding to and from the Scheme and to demonstrate how these flood risks would be managed so that the Scheme remains safe throughout its lifetime, taking climate change into account.

3.1.2 The following flood risk baseline is based on publicly available information including the South Staffordshire Council Level 1 SFRA and Environment Agency Interactive Flood Maps (Ref 4 and 5). In addition, HEC-RAS models have been created to understand flood risk as there were no existing models for most of the watercourses affected by the Scheme. The exception to this is the Latherford Brook (Watercourse 5), which did have JFLOW model results as part of the Environment Agency's Flood Map for Planning. However, as per recommendation of the Environment Agency, further modelling was undertaken to fully understand the fluvial flood risk impacts of the Scheme.

3.2 Fluvial flood risk

Existing fluvial flood risk

3.2.1 In accordance with the Environment Agency Long Term Flood Risk Mapping(Ref 5) (Figure 3.1) the Scheme is primarily located in Flood Zone 1 (less than 0.1% (1 in 1000-year) annual exceedance probability in any given year). In close proximity to Latherford Brook, in the northern portion of the Scheme, there is evidence of increased flood risk; Flood Zone 2 (between 1% and 3.33% (1 in 100-year to 1 in 30-year) annual exceedance probability in any given year) and Flood Zone 3 (greater than a 3.33% (1 in 30-year) annual exceedance probability in any given year).

3.2.2 Latherford Brook is the only Ordinary Watercourse near the Scheme which has been previously modelled. Other watercourses in the area, as shown in Figure 1.1, have not been modelled previously and so there is no fluvial flood risk mapping. The hydraulic modelling study would assess this fluvial flood risk.

3.2.3 According to the Environment Agency Long Term Flood Risk Mapping (Ref 5) Watercourses 7 and 8 have both flood zone 2 and 3 associated with them. However, neither of these watercourses are in the vicinity of any Scheme works. This means that the Scheme would not impact the floodplain for these watercourses.

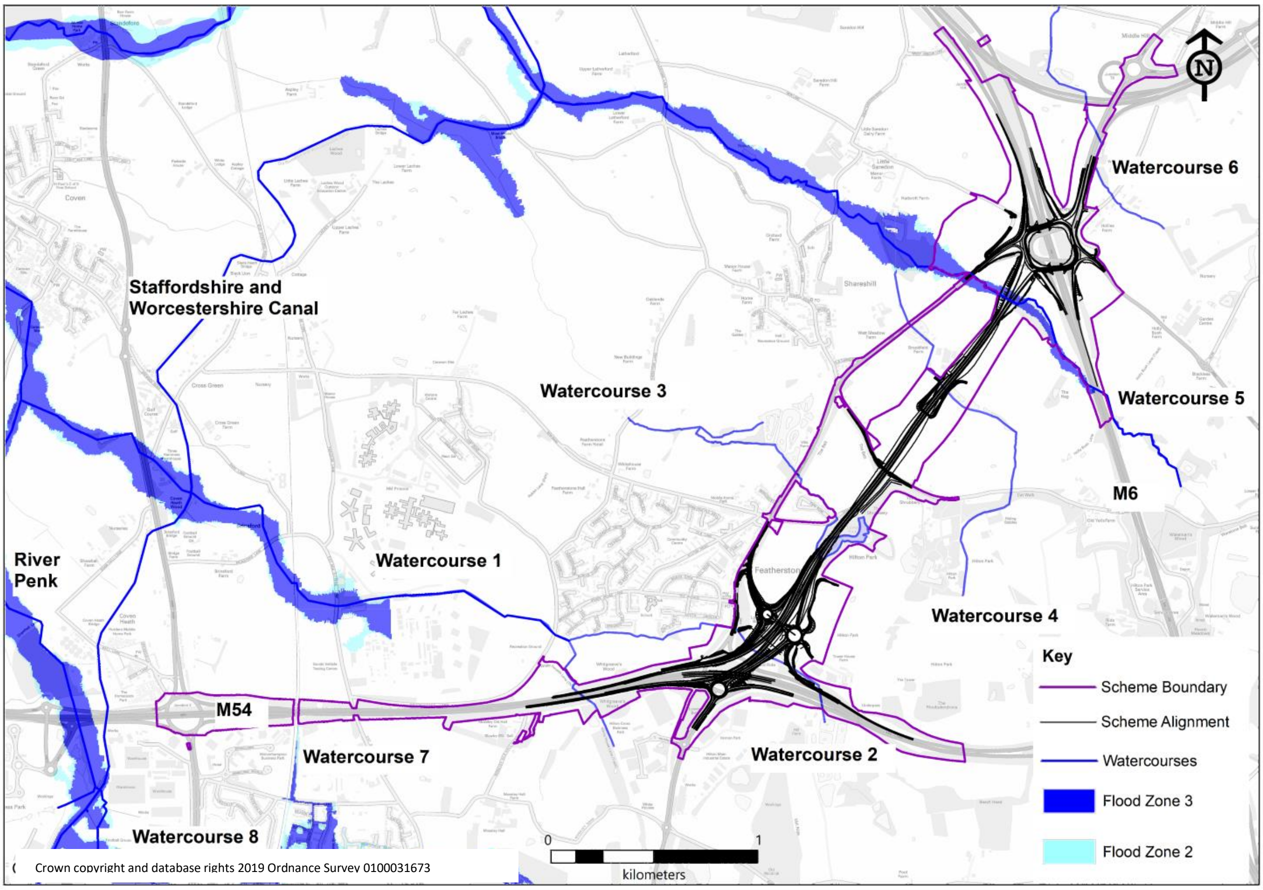


Figure 3.1: Fluvial flood risk supplied by the EA, long term flood risk mapping derived from JFLOW model

Modelled fluvial flood risk to the Scheme

3.2.4 A detailed Hydraulic model report for the 1D and 1D/2D hydraulic modelling undertaken to support this FRA is included in Annex B of this FRA.

3.2.5 To gather suitably detailed data to be able to construct hydraulic models, a river channel topographic survey was commissioned and undertaken by Storm Geomatics between February and April 2019. This survey was undertaken to the "Environment Agency National Standard Technical Specifications for Surveying Services". Four models were built to examine the existing fluvial flood risk to the area (as labelled in Figure 3.2).

3.2.6 Hydraulic models were deemed as not required for Watercourses 7, 8 or the Saredon Brook and River Penk, as the construction of the Scheme earthworks were not near these Watercourses. Therefore, the Scheme would not have impact on the areas located in Flood Zones 2 or 3 adjacent to these watercourses. In addition, EA flood mapping already exists for the Saredon Brook and the River Penk which has provided information for this FRA.

3.2.7 Four models were constructed for the six watercourses:

- Tower House Farm – Watercourse 1 and 2
- Hilton Park - Watercourse 3
- Latherford Brook – Watercourse 4 and 5
- Wheatsheaf Farm – Watercourse 6

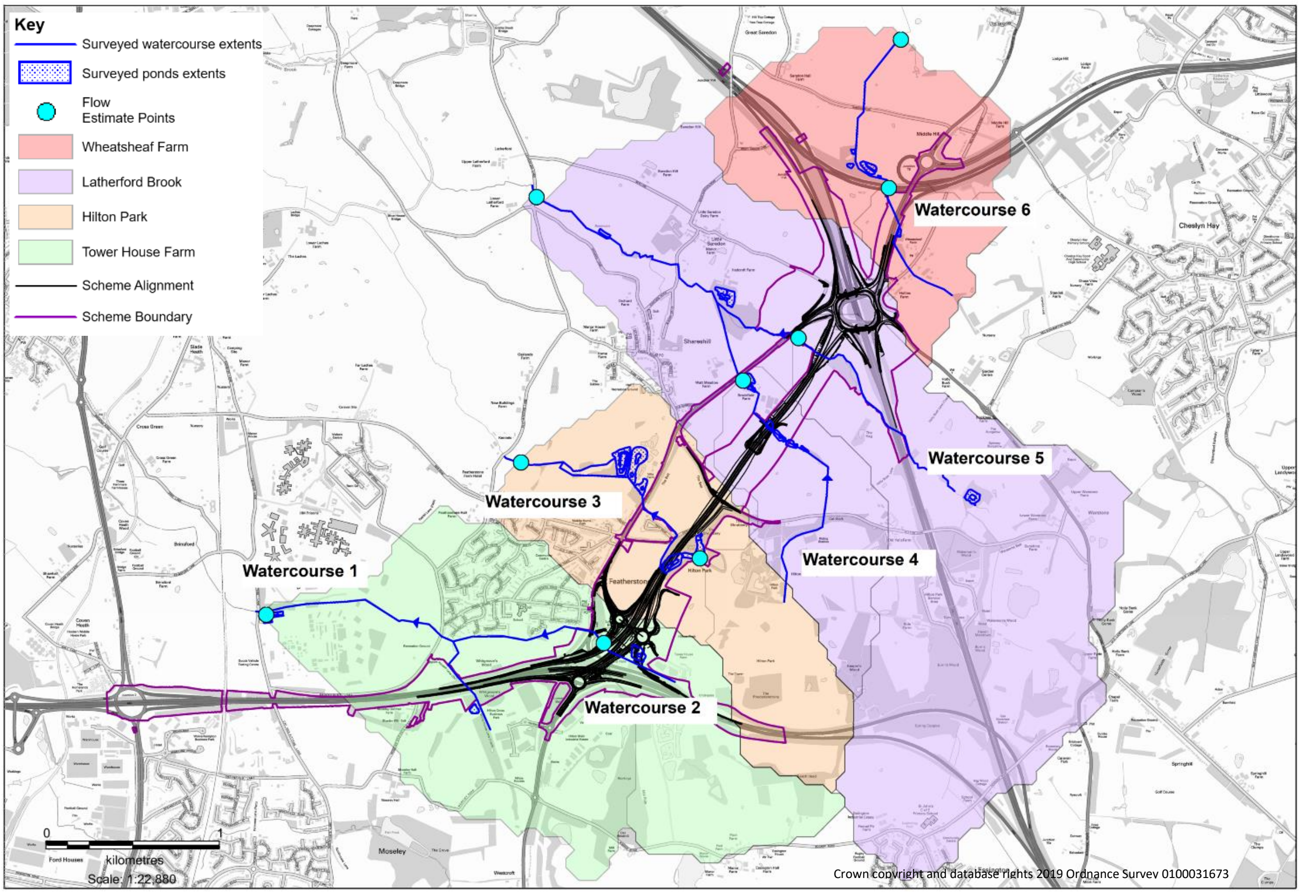


Figure 3.2: HEC-RAS modelling approach and flow estimation points

3.2.8 As per Environment Agency recommendation, simulations were undertaken for 5%, 1% and 0.1% Annual Exceedance Probability (AEP) events. In addition, an 1% AEP event was considered with a 50% climate change allowance. A 50% AEP simulation was undertaken for the Tower House Farm model to assist with the design of culvert crossings. Further details of model testing can be found in Annex B.

3.2.9 1D Model tests showed that Watercourses 1,2,3,6 did not flood out of bank in a 1% AEP event near the Scheme. Therefore, there is no new Flood Zone 2 or 3 to report to the Environment Agency. However, flooding did occur in locations during a 1% AEP event with the 50% climate change allowance, and during the 0.1% AEP event.

3.2.10 The existing Cat and Kittens Lane culvert on Watercourse 1 (see Figure 3.3) experiences out of bank flooding in the 1% AEP event with a 50% climate change allowance storm. Whilst this area is not near the Scheme, flood risk must not be exacerbated because of the Scheme. Although this site is derelict, the site has been identified as in the 2018 Site Allocation Document (Ref 15) for redevelopment as a strategic employment site.

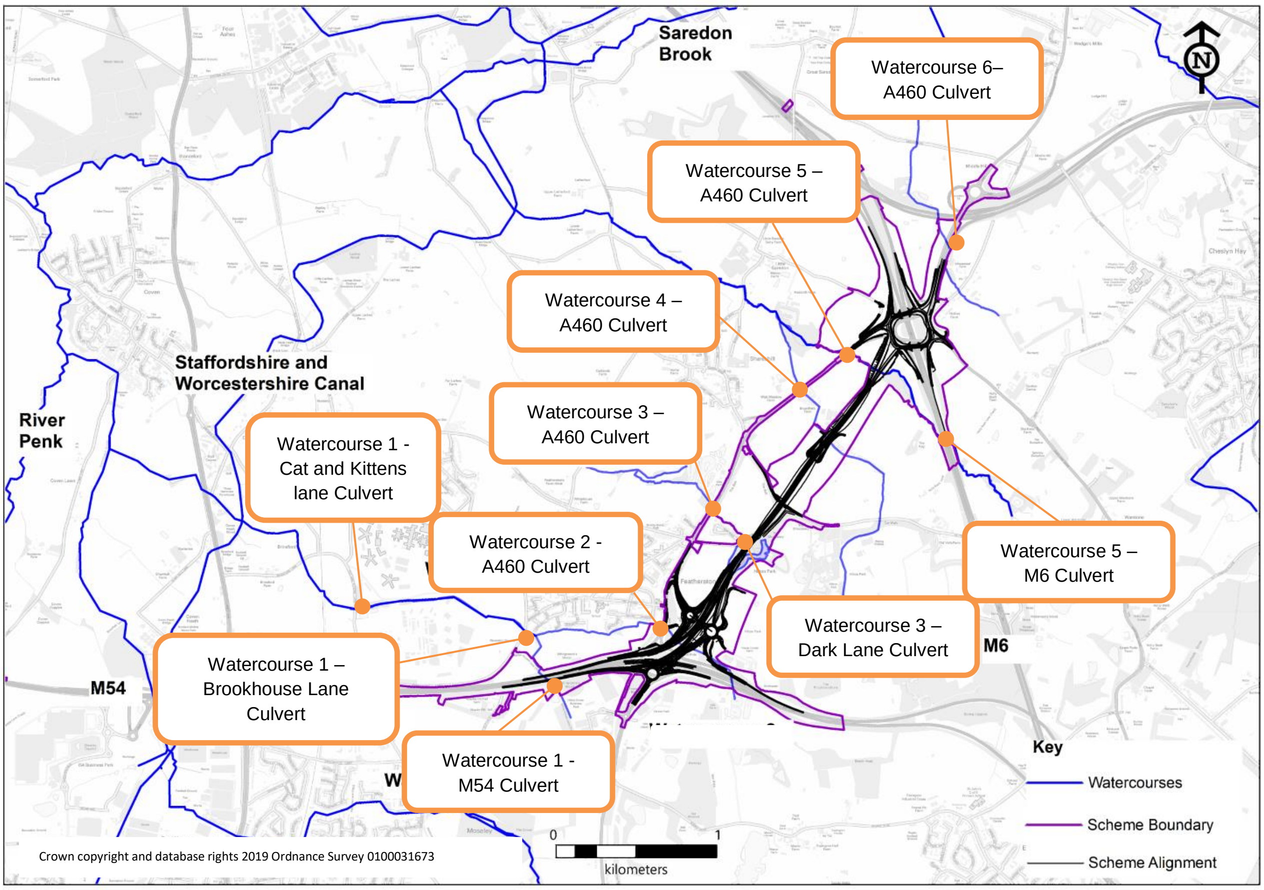


Figure 3.3: Existing culverts in the vicinity of the Scheme.

3.2.11 The A460 culvert on Watercourse 2 is shown to be at risk of flooding during the 1% AEP plus 50% climate change allowance storm. The surveyed road surface height is approximately 134.37m Above Ordnance Datum (AOD) where the culvert crosses Watercourse 2. However, the water level at the upstream side of the A460 culvert during the 1% AEP storm event with a 50% climate change allowance is 134.41 m AOD. This level creates potential flood risk at this return period. This is the main location the Scheme would need to ensure that flood risk is not worsened by the modification of the watercourse.

3.2.12 Model sensitivity testing for Watercourse 3 showed that the Lower Pool which feeds Watercourse 3 provides flood protection for the Dark Lane culvert and adjacent properties, as well as another culvert crossing the A460. The assessment of flood risk through modelling has been found to be highly sensitive to assumptions made with regard to the storage in Lower Pool. When peak flows are routed through Lower Pool, flooding does not occur in a 1% AEP with the 50% climate change allowance. However, if peak flows are applied downstream of Lower Pool (a highly conservative assumption), flood risk at the Dark Lane culvert and A460 culvert are significantly increased.

3.2.13 The Environment Agency has existing JFLOW model results for Watercourse 5, as seen in Figure 3.4. There were no previous model results available for Watercourse 4. The 1D-2D HEC-RAS Latherford Brook model was created to show the floodplain in higher resolution. The model results showed out of bank flooding occurs first in 5% AEP event for Watercourse 4 and 5. The model results also show that the Flood Zones 2 and 3 extents are less extensive than the JFLOW results, meaning there is less flood risk in this area than displayed on the Environment Agency Long Term Flood Risk Mapping service as shown on Figure 3.4.

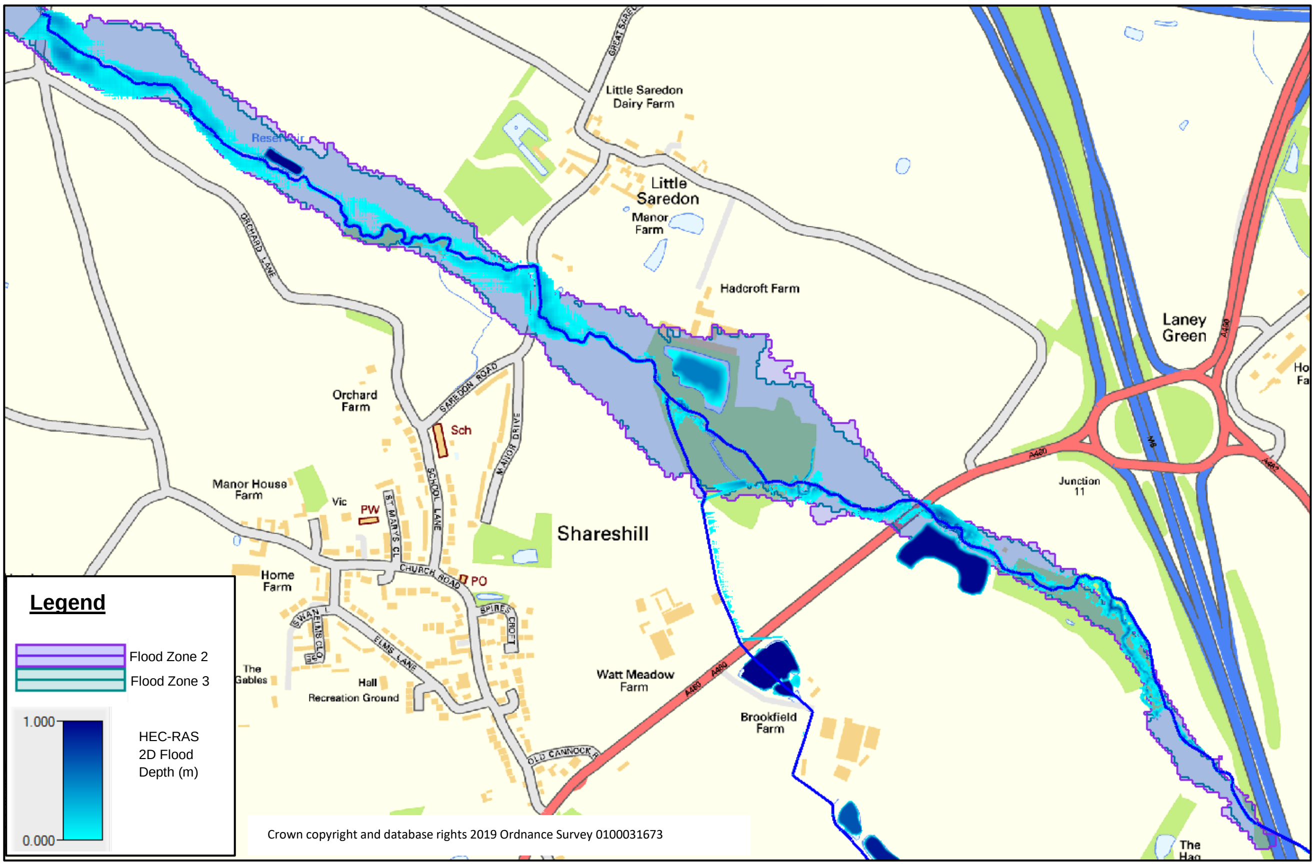


Figure 3.4: Environment Agency JFLOW model Flood Zone 2 and 3 outlines compared to Latherford Brook HEC-RAS model results for 1% AEP event

3.2.14 Watercourse 6 does not flood out of bank in the 1% AEP with the additional 50% climate change allowance scenario, assuming the culvert is cleared of a partial blockage, which is currently reducing the conveyance capacity of the culvert. Model results showed that if this blockage is not cleared, then out of bank flooding would occur in this scenario (Annex B – Hydraulic Model Report).

Summary of fluvial flood risk to Scheme

3.2.15 The table below summarises the fluvial flood risk to the Scheme posed by each watercourse considered as part of this FRA.

Table 3.1: Summary of fluvial flood risk to Scheme per watercourse

Watercourse number	Flood risk to Scheme
Watercourse 1	Low
Watercourse 2	Low
Watercourse 3	Low
Watercourse 4	Low
Watercourse 5	Low
Watercourse 6	Low
Watercourse 7	Low
Watercourse 8	Low

3.3 Tidal flood risk

3.3.1 There is no tidal influence in these catchments. Further investigation and specific mitigation for tidal flooding is therefore not required.

3.4 Surface water flood risk

3.4.1 In accordance with the Environment Agency Long Term Flood Risk Mapping (as replicated in Figure 3.5), the Scheme is at risk of surface water flooding in the following scenarios: 0.1%, 1% and 3.3% AEP. The sources of this risk are distributed across the Scheme. However, areas of high risk coincide with the watercourses which cross the Scheme. In addition, there are areas of high risk associated with areas, there are areas of hard standing in Shareshill and Featherstone, as well as the existing M54 and M6. Therefore, surface water flood risk to the Scheme is considered to be medium.

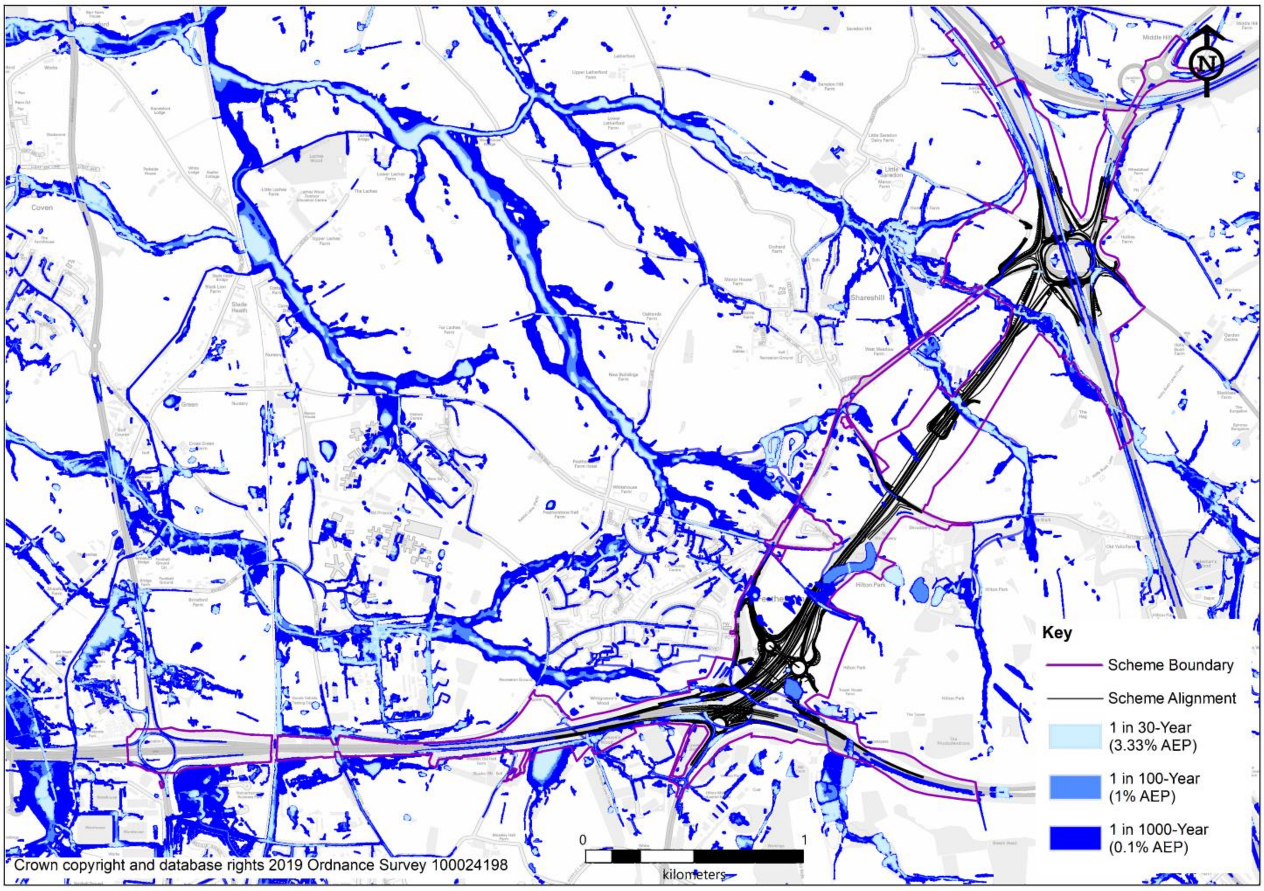


Figure 3.5: Surface Water Flood Risk supplied by the Environment Agency

3.5 Flooding from artificial sources

Reservoirs

3.5.1 The Environment Agency defines a reservoir as an artificial body of water which can hold 25,000 cubic meters or more of water, above ground level (Ref 18).

3.5.2 As illustrated by the Environment Agency's 'Long Term Flood Risk Map' the Scheme is not at risk from reservoir flooding.

Canals, ponds and lakes

3.5.3 There are several ponds which are with in the vicinity of the Scheme:

- Kings Pools Fishery Ponds;
- Lower Pool;
- Chubb Angling Club Fishing Ponds;
- Hilton Hall Pond;
- Brookfield Fishery;
- Fishing Ponds east of Brookfield Farm;
- Millride County Sports Fishery; and

- Former Sand and Gravel pits.

3.5.4 In addition to these ponds, the Staffordshire and Worcestershire Canal are also within 1 km of the Scheme boundary (please refer to Figure 13.1 of the ES [TR010054/APP/6.2].

3.5.5 A review of detailed OS mapping identifies there to be no canals or lakes within immediate proximity to the Scheme and therefore flood risk from these sources is deemed very low. Ponds are present within the Scheme boundary but due to their size and elevation, the risk from this source to the Scheme is considered low. Where appropriate, these ponds have been included in the hydraulic modelling, Figure 13.1 of the ES [TR010054/APP/6.2] for details.

3.6 Flooding from groundwater

3.6.1 Groundwater flooding occurs as a result of water rising from the underlying aquifer or from water flowing from springs. This tends to occur after long periods of sustained high rainfall, and the areas at most risk are often low-lying where the water table is more likely to be at shallow depth. Groundwater flooding is known to occur in areas underlain by major aquifers, although increasingly it is also being associated with more localised floodplain sands and gravels. It often occurs sporadically in both location and time, and because of the more gradual movement and drainage mechanisms tends to last longer than fluvial, pluvial or sewer flooding.

3.6.2 The British Geological Survey interactive mapping (Ref 12) identifies various types of superficial geology within the site boundary: Till, Devensian – Diamicton and Alluvium - Clay, Silt, Sand and Gravel. There are large areas near the Scheme in which have no recorded geology types. The Defra Magic (Ref 13) interactive mapping identifies the area to be located primarily within a Secondary (undifferentiated) Superficial Deposit Aquifer with pockets of Secondary A aquifer.

3.6.3 The British Geological Survey interactive mapping identifies various types of superficial geology within the site boundary: ‘Alveley Member - Mudstone and Sandstone’, ‘Chester Formation - Sandstone and Conglomerate, Interbedded’, ‘Chester Formation – Mudstone’ and ‘Clent Formation and Enville Formation (undifferentiated) - Mudstone and Sandstone’. The Defra Magic interactive mapping identifies the area to be located within a Principal and Secondary A Bedrock Aquifer.

3.6.4 The Environment Agency’s Areas Susceptible to Groundwater Flooding (AStGWF) map (Ref 7) illustrates that the site lies within 1 km grid squares of which >25-<50% of the area is susceptible to groundwater emergence. Groundwater flood risk in the area is due to permeable superficial deposits which tend to have a relatively high-water table.

3.6.5 Figure GW-SS of the South Staffordshire District Council Level 1 SFRA (Ref 8) identifies that most of the Scheme area is in an area classified as having a type ‘A’ susceptibility to groundwater flooding. This is defined as “having a limited potential for groundwater flooding to occur: based on rock type and estimated groundwater level during periods of extended intense rainfall”. Therefore, most of the Scheme is at low risk of ground water flooding.

3.6.6 However, the mapping also shows there are isolated pockets of land which is classified as type B (Potential for groundwater flooding of property situated below ground level) or C (Potential for groundwater flooding to occur at surface) with in the Scheme boundary, although the Scheme route does not directly intersect these areas.

3.6.7 Ground investigation surveys were undertaken during July and August 2019. As part of this survey, ground water strikes were logged, and ground water level monitoring was undertaken. The results are summarised in Table 3.2.

Table 3.2: Interim borehole water level monitoring results

Borehole reference	Water level monitoring – (Metres below ground level)										
	11/07/19	21/07/19	31/07/19	06/08/19	20/08/19	29/08/19	06/09/19	08/11/19	14/11/19	20/11/19	25/11/19
BH03	-	DRY	4.25	4.42	4.48	4.4	4.46	4.16	0.62	0.66	-
BH04	-	-	5.48	5.42	5.45	5.42	5.48	5.22	5.1	5.04	-
BH05	-	-	3.79	5.42	3.73	3.7	3.72	3.48	3.41	3.27	-
BH06	-	-	3.52	3.47	8.4	3.47	3.31	3.22	3.13	3.06	-
BH07	-	-	6.45	6.44	6.4	6.4	6.46	5.15	5.08	5.03	-
BH08a	3.55	3.65	3.64	3.65	3.6	3.79	3.65	3.1	2.06	3.01	-
BH09	9.28	9.25	9.25	9.21	9.22	9.17	8.21	8.91	8.85	8.83	-
BH10	5.63	5.8	5.77	5.73	8.69	5.67	7.7	5.16	5.01	4.89	-
BH11	4.59	4.6	4.33	4.88	4.92	4.87	4.9	4.64	-	4.43	4.13
BH12	-	-	-	1.19	0.27	1.26	1.4	0.62	-	0.62	0.6
BH16	-	-	-	-	8.68	7.7	7.77	6.99	6.92	6.77	-
BH18	-	3.48	3.50	3.53	3.5	3.5	3.55	2.24	1.96	1.55	-
BH20	-	12.8	12.2	12.96	12.87	12.23	12.46	11.18	11.12	10.74	-
BH21	-	-	-	-	1.83	1.99	1.98	1.15	1.03	1.35	1.16
BH24	-	4.05	4.06	4.13	4.1	4.12	4.06	3.28	3.11	3.01	-
BH25	7.41	9.28	8.62	9.03	9.03	8.94	9.03	7.18	7.06	7.02	-
BH26	-	-	-	4.75	4.84	4.94	4.87	4.76	4.83	5.01	-
BH27	-	-	12.86	12.83	12.99	13.06	13.1	12.53	12.48	12.41	

3.6.8 Water level monitoring showed groundwater levels varied across the Scheme area (Please refer to Annex A for Borehole locations). Ground water depths below ground level vary between 0.27 m and 12.96 m. Most boreholes show water levels far below ground, beyond the vertical impact of the Scheme, and therefore would indicate a low risk of flooding from ground water.

3.6.9 Groundwater was found nearest surface at BH12 which is to the southern edge of the Lower Pool. At this location water was found between 0.27 m and 1.4 m below surface, however the Scheme is designed to be set within a 1.5m cutting, approximately 5m to the west of this location. Whilst this borehole is not directly in the footprint of the Scheme, the water level here may indicate a higher local perched water table in the area, possibly due to the proximity of Lower Pool. The next borehole closest to this area is BH11, which shows depths between 4.33 m and 4.92 m below ground level. It is likely that the results for BH12 are therefore influenced by the close proximity to Lower Pool. The area will require de-watering as part of the construction process, as this section of Lower Pool is to be lost as a result of the Scheme. Therefore, it is considered that this isolated high groundwater does not pose a risk to the Scheme.

3.6.10 The preliminary design invert levels of the Highway Drainage are designed to be above the anticipated groundwater level. Therefore, no additional mitigation is proposed at this stage.

3.6.11 Overall, the risk from groundwater flooding to the Scheme is considered as low. Further information about ground conditions at the site and details regarding soakaway testing undertaken can be found in the Ground Investigation Report, Appendix 9.1 of the ES [TR010054/APP/6.3].

3.7 Flooding from sewers and drains

3.7.1 Data provided by Severn Trent Water shows that there are few sewers and drains near the Scheme. There is a foul combined sewer along Hilton Lane, which crosses the Scheme footprint. This will require a sewer diversion and will be addressed as part of the Scheme detailed design, in consultation with Severn Trent Water.

3.7.2 Table 5-4 of the South Staffordshire District Council Level 1 SFRA (Ref 7) identifies recorded incidents of sewer flooding within the vicinity of the Scheme from Severn Trent Water's DG5 register. The DG5 register shows that there are 3 incidents of flooding from sewers in the postcode area WV10 7, which covers the Featherstone area.

3.7.3 Given the rural nature of the area surrounding the Scheme and records of previous incidents, the current flood risk from sewers and drains is considered low.

3.8 Summary of flood risk to the Scheme

Fluvial and tidal flood risk

3.8.1 The existing fluvial flood risk in the Scheme area is primarily 'low' with the area surrounding Latherford Brook in the northern portion of site as having a 'medium' to 'high' fluvial flood risk. The area is not at risk of tidal flooding.

Surface water flood risk

3.8.2 The existing surface water flood risk to site is varied throughout the site. Where the Scheme is proposed to cross four watercourses, there is a 'low' to 'high' surface flood risk. There are also numerous pockets of risk along the Scheme alignment, often where there tends to be existing ponds or troughs in the topography. Therefore, surface water flood risk is considered to be medium.

Other sources of flood risk

3.8.3 Existing flood risk to site from artificial sources, such as canals, lakes and reservoirs, is considered as low. Existing flood risk from groundwater, sewers and drains is also considered to be low.

4 Flood Risk from the Scheme

4.1 Impact on fluvial flood risk

4.1.1 Following the development of baseline model scenarios in HEC-RAS, Scheme drawings were used to create a model to assess the impact of the Scheme on fluvial flood risk. Full details on model approach and detailed results analysis can be found in the Hydraulic Model Report, which is Annex B of this document.

Watercourse 1

4.1.2 The Scheme does not impact the fluvial flood risk for this watercourse. No modifications are being made to the existing culverts and given that no out of bank flooding is predicted to occur in the vicinity of the Scheme there is no impact of changing the floodplain.

Watercourse 2

4.1.3 The Scheme significantly reshapes the watercourse, diverting the watercourse approximately 80m north of its current position. In addition, a culvert of 182m is included in the design. The Scheme design does not include any changes to the existing A460 culvert, which is downstream of the Scheme.

4.1.4 The baseline model predicts that there is flood risk to the A460 during the 1% AEP plus 50% climate change storm, indicating that a flood depth of 4 cm could occur on the A460 road surface. The Scheme has been designed to not worsen flood risk to the A460 keeping flood depths the same as the baseline scenario. This has been achieved by ensuring the culvert underneath the Scheme along with the channel immediately downstream has been appropriately sized to store flows in this location and allowing water levels to remain the same as the baseline scenario.

4.1.5 The baseline model predicts that the first instance of flood risk to the A460 is as a result of a 1% AEP plus 50% climate change storm. The application of the Scheme design to the baseline model shows that there is no change in the return period of the first instance of flood risk, as flood risk in the vicinity of the Scheme first occurs during the 1% AEP plus 50% climate change storm event.

4.1.6 The existing A460 culvert throttles flows during larger magnitude events, holding flows upstream and consequently providing some flood risk benefits to properties downstream in the Featherstone estate. Improvements to the A460 culvert such as increasing diameter or conveyance would allow more flows to pass forward through the A460 culvert, which could put properties to the south of the Featherstone estate at risk of flooding during a 1% AEP plus 50% climate change storm. Therefore, no significant changes to the existing A460 culvert are proposed as part of the Scheme, to avoid this risk.

4.1.7 Different alignments of the watercourse were tested as part of the development of the design. Iterations of this have included the testing of a pond storage area between the main and minor culvert. Whilst this did have a minor impact on water levels at the existing A460 culvert, it was not deemed significant enough to include in the design given the increase in Scheme costs.

Watercourse 3

4.1.8 The Scheme reshapes the outline of Lower Pool and includes a culvert underneath the new carriageway. The dissection of Lower Pool will reduce its area from 13200 m^2 to 8723 m^2 (approximate values).

4.1.9 Despite the reduction in size of Lower Pool, the Scheme does not impact the fluvial flood risk for this watercourse if the pool is retained as an online pond. Water levels within the channel are increased in the section of watercourse between the culvert crossing and the Dark Lane culvert, as a result of reprofiling the upstream river reach. However, retaining part of the Lower Pool protects properties at Dark Lane, as well as the existing A460 from potential flood risk.

Watercourse 4

4.1.10 The Scheme does not impact flood risk at this location. There is some minor out of bank flooding in this location, however the depths and extents are comparable to the baseline scenario.

4.1.11 A fishing pond near to Brookfield Farm would be lost as a result of the Scheme, however this does not have an impact on fluvial flood risk as it is an offline pond.

Watercourse 5

4.1.12 Watercourse 5 (Latherford Brook) overtops its banks and floods in the 1% AEP event. The Scheme changes the shape and depth of the floodplain in this location in the vicinity of the proposed river crossing of the Latherford Brook. Please refer to Annex B - Hydraulic Model Report for full details. The potential impacts include:

- Natural flow paths bisected by the earthworks of the Scheme.
- Localised Increases in depths on flood plain.
- Effect of holding flows back – betterment to flood risk downstream.

4.1.13 The volumetric loss of floodplain as a result of the proposed embankment across Watercourse 5 (Latherford Brook) has been estimated from the model results. Figure 4.1 summarises these volumes at 0.5 m intervals. These volumes are based on a comparison between the baseline and Scheme models, and therefore represent the volume of flood water displaced as a result of earthworks and land raising within the 100 year plus climate change floodplain.

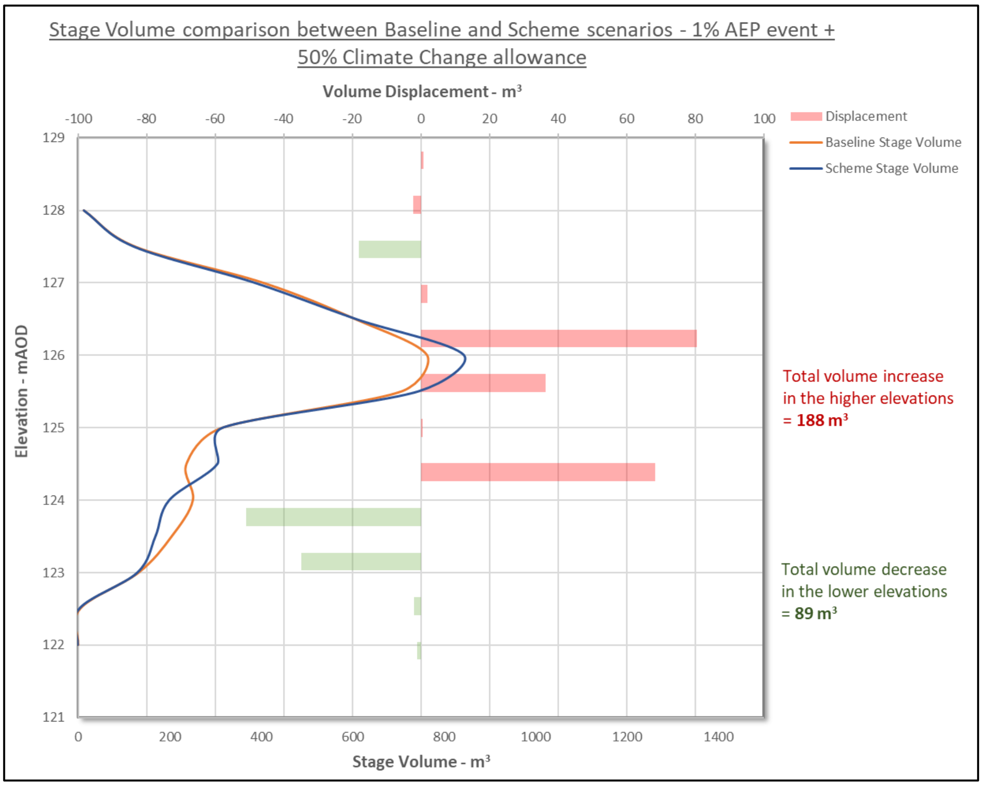


Figure 4.1 - Stage/volume displacement comparison between baseline and Scheme scenarios for a 1% AEP + 50% climate change allowance event

4.1.14 Despite the change in flood extents and depth as shown in Figure 4.1 and Figure 4.2, there is no significant change in flood risk. The areas at risk of inundation are open fields and woodland, which are already at risk of flooding under existing conditions. There is no change in flood risk to any vulnerable receptors, such as property and the road.

4.1.15 The only receptor to the change in flood risk is woodlands adjacent to the watercourse. The change in flood depths during the return periods modelled has been assessed as a minor impact to the existing woodland. During a 1% AEP event with a 50% climate change allowance, peak channel flood depths in this area are predicted to increase by 12cm, with flood extents widened as shown in Figure 4.2.

4.1.16 The impact of a 1% AEP event with 50% climate change allowance, may impact a wider area however a woodland receptor is generally resilient to the impacts of flooding. The impact of a high magnitude event is unlikely to significantly change the nature of the woodland, once recovery has taken place. However, the impact of frequent events is very likely to change the habitat of the woodland over time.

4.1.17 To assess the impacts of the Scheme on flooding in the woodland from more frequent and lower magnitude flood events, the 50% AEP event was modelled (See Annex B Hydraulic Model Report). Simulations show that there is very little out of bank flooding during this high frequency event, and extents and depths between the baseline and Scheme events are similar, with no new areas experiencing flooding. Therefore, the impacts of the Scheme on flood risk to these woodlands is predicted to be minimal.

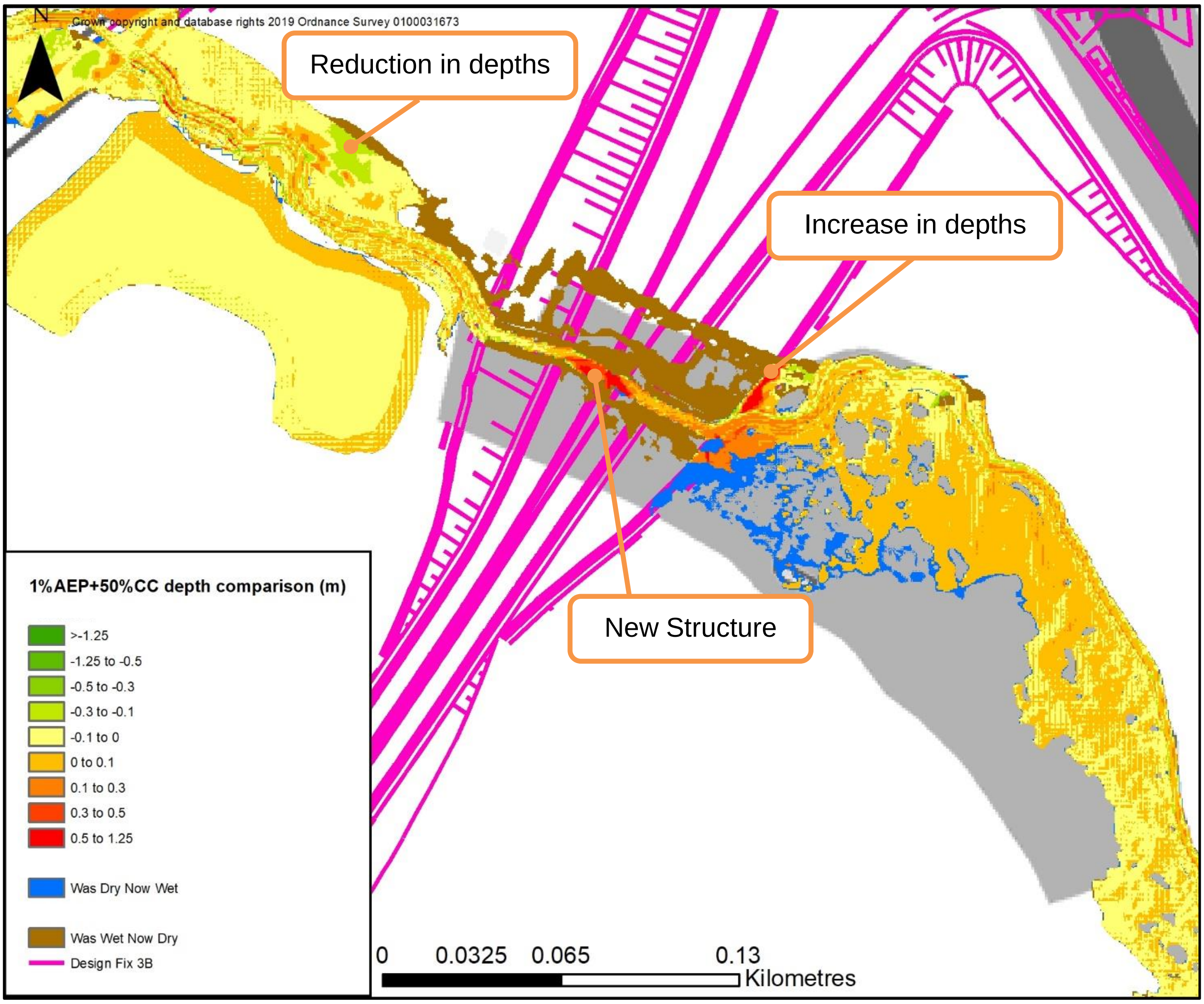


Figure 4.2 - Depth comparison between Baseline and Scheme scenarios for a 1% AEP + 50% climate change allowance event

Watercourse 6

4.1.18 The baseline modelling shows low flood risk from this watercourse and the Scheme does not impact the fluvial flood risk for this watercourse in any way. Whilst the watercourse intersects the Scheme boundary, no modifications are being made to the existing culverts and given that no out of bank flooding is predicted to occur in the vicinity of the Scheme in the baseline, there are no predicted impacts.

Watercourse 7

4.1.19 The Scheme does not impact flood risk at this location. Whilst the watercourse intersects Scheme boundary, there are no changes to this watercourse crossing or earthworks within the floodplain of this watercourse. Therefore, flood risk is not impacted by the Scheme.

Watercourse 8

4.1.20 The Scheme does not impact flood risk at this location. Whilst the watercourse is within 1 km of the Scheme boundary, there are no changes to this watercourse crossing or earthworks within the floodplain of this watercourse. Therefore, flood risk is not impacted by the Scheme.

Summary of fluvial flood risk from Scheme

4.1.21 The table below summarises the fluvial flood risk from the Scheme posed by each watercourse considered as part of this FRA.

Table 4.1: Summary of fluvial flood risk to Scheme per watercourse

Watercourse Number	Flood Risk from Scheme
Watercourse 1	Low
Watercourse 2	Low
Watercourse 3	Low
Watercourse 4	Low
Watercourse 5	Low – increased floodplain, minimal impact on receptors.
Watercourse 6	Low
Watercourse 7	Low
Watercourse 8	Low

4.2 Mitigation against fluvial flooding

4.2.1 NPPF states that developments should not increase the risk of flooding to the Site or elsewhere. In addition, feedback from the Environment Agency has stated that this FRA needs to include assessment of the floodplain compensation scheme, for any floodplain that may be lost as a result of development or land raising within the 100 year plus climate change floodplain. In order to mitigate the effects of raised ground levels within the floodplain resulting from construction of highway embankments, a like-for-like, volume-for-volume floodplain compensatory storage would need to be provided.

4.2.2 In addition, the updated DMRB[16] states that all projects on motorways and all-purpose trunk roads shall be designed 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.

4.2.3 Hydraulic modelling has shown that there is no loss of flood zone 2 or 3 for Watercourses 1, 2, 3, 4 and 6 as a result of the Scheme. Therefore, no flood plain mitigation would be required for these watercourses.

4.2.4 The Scheme includes earthworks in the floodplain for Watercourse 5. Hydraulic modelling has shown that the effect of these works is to redistribute flood risk within the immediate area as shown in Figure 4.2. All impacts are contained within 100 m upstream of the Scheme and 60m downstream of the Scheme, this is within the Scheme boundary.

4.2.5 There is a minor increase of peak flood levels up to 12 cm in the 1% AEP event with climate change allowance upstream of the Watercourse 5 crossing.

4.2.6 The new road carriageway at the Watercourse 5 crossing is at an elevation of 132.3 m AOD, compared to the peak flood level of 125.3 m AOD (1% AEP event + 50% climate change), would remain operational and safe for users in times of flood.

4.2.7 The change in floodplain would increase flood depths and frequency of flooding in the woodland area upstream of the Scheme, but this is not considered to have a negative impact on the habitat of the woodland. A 50% AEP event was modelled as the greatest impacts would be caused by the frequency of flooding which could have the potential to change the habitat over time. The flood extents for the Baseline compared to the Scheme scenario were very similar in extent and depths. Therefore, the impact of the Scheme to the existing woodlands would be negligible, and in consultation with ecologists in the design team, it has been agreed that no additional mitigation would be required.

4.2.8 The Environment Agency indicated during consultation that an increase in the extent of the flood plain is acceptable on Highways England owned land, and as long the flood risk for third parties is not increased. The land affected by the change in floodplain is within the Scheme boundary and is to be purchased to allow other environmental mitigation measures to be implemented. As a result, no mitigation or flood compensation measures are proposed to offset the changes in the floodplain, and the change in floodplain has a minimal impact on one receptor.

4.3 Impact on surface water runoff generation and overland flow

4.3.1 The alignment of the Scheme is largely on undeveloped (greenfield) land currently used for agricultural purposes.

4.3.2 Given that the proposed highway would increase the impermeable area along the entirety of its length, there is the potential for the surface water flood risk, both to the highway alignment and surrounding area, to significantly increase.

4.3.3 Regional and local planning policy indicates that Highway surface water runoff would need to be attenuated to greenfield runoff rates and that SuDS must be incorporated into the drainage design wherever practicable.

4.3.4 The surface water flows and highway drainage on the site have been assessed in detail and a surface water drainage strategy has been developed separately in order to manage the risk sensitively and sustainably.

4.3.5 Refer to surface water Drainage Strategy (Appendix 13.2 of the ES [TR010054/APP/6.3]) for the pre- and post-development impermeable areas, greenfield run-off rates, proposed discharge rates, proposed attenuation volumes and other details of the proposed drainage design.

4.4 Mitigation against surface water flooding

4.4.1 The impact on surface water flooding mechanisms due to the Scheme is low provided all the overland surface water runoff and highway drainage generated by the Scheme is captured and attenuated in the proposed drainage network to prevent flooding up to a 1% AEP + Climate Change event as described below.

4.4.2 The principles for the disposal of surface water in order of preference and general acceptability are summarised below:

- infiltration into the ground;
- discharge to a watercourse;
- discharge to a surface water sewer; and
- discharge to a combined sewer.

4.4.3 The surface water Drainage Strategy (Appendix 13.2 of the ES [TR010054/APP/6.3]) indicates that due to the volume of attenuation required this would be provided with the use of balancing ponds.

4.4.4 The SuDS features such as ponds have been designed to accommodate a 1% AEP storm event with 40% allowance for climate change as per the requirements of SCC's Flood Risk Management team (LLFA). Discharge from the ponds would be at greenfield runoff rates to nearby watercourses as shown on the drawings.

4.4.5 Hydraulic design of the proposed drainage network would be such that the system is designed not to flood in a 1 in 5 year (5% AEP) return period storm event with climate change allowance of 20%, as per the DMRB[16] specification.

4.4.6 The design achieves a 5l/s/ha greenfield runoff rate which has been agreed with SCC.

4.4.7 Details of the proposed carriage way drainage arrangements can be found in the Drainage Strategy (Appendix 13.2 [TR010054/APP/6.3]).

4.4.8 Surface water flows from areas upstream of the Scheme would be managed via interception gullies and drainage channels. The proposed drainage arrangement drawings provided in the Drainage Strategy (Appendix 13.2 of the ES [TR010054/APP/6.3]) use schematic arrows to illustrate surface water flow routes adjacent to the road and the proposed drainage ditch locations.

4.4.9 The proposed highway drainage system for the Scheme would be maintained by Highways England.

4.4.10 With all of the mitigation measured proposed as part of the Drainage Strategy and drainage design, there would be no impact on surface water flood risk from the Scheme.

4.5 Impact on groundwater flooding

4.5.1 As stated previously, the risk of groundwater flooding in baseline conditions is low.

4.5.2 The Drainage Strategy (Appendix 13.2 of the ES [TR010054/APP/6.3]) outlines proposals to discharge runoff to watercourse or existing drainage network. None of the proposed drainage is connected to groundwater, therefore the Scheme has no impact on flood risk from groundwater as the water table in the area would not be altered by the Scheme.

4.5.3 During construction, cutting excavations may liberate groundwater in the form of seepages from any higher permeability zones of relatively granular material. The impact of the construction phase of the Scheme on groundwater should be considered as part of the Construction Environmental Management Plan, complying with CIRIA guidance for Ground Water Control (Ref 19). In order to mitigate ground water flooding during construction, adequate drainage and dewatering facilities should be provided.

4.5.4 The cutting beneath Hilton Lane Overbridge would be up to 5.8 m below ground level (bgl). The proposed road level will fall to the north east from approximately 137.6 m AOD to approximately 133.3 m AOD. Based on the results of groundwater level monitoring up to November 2019, it is considered that the groundwater level is close to the proposed road level and it is likely that the road drainage will intercept groundwater. Currently, there is no information on the maximum winter groundwater levels, which would be expected to be higher than those recorded to date. Accordingly, drainage of the cutting will needed to lower the groundwater level and maintain the groundwater below the road level.

4.5.5 Preliminary calculations indicate that very small groundwater inflows will occur during operation, as the drawdown required is only less than 0.5 m. The calculated groundwater inflow to the cutting during operational drainage is small, being less than 1.5 m^3/day.

4.5.6 These results are based on groundwater level observations, which has taken place with in a specific time frame. Sensitivity testing shows that if peak groundwater levels were to be raised by 1m, inflows to the cutting could be 5 m^3/day and 8m^3/day. If peak groundwater levels were to be raised by 2 m, inflows to the cutting varies between approximately 11 m^3/day and 18 m^3/day. Additional information is provided in Appendix 13.8 of the ES [TR010054/APP/6.3]).

4.5.7 The groundwater in the area of the proposed Hilton Lane Overbridge cutting currently flows in a northerly direction towards watercourse 4, where it provides baseflow discharge to the stream and the associated ponds. The drains alongside the cutting will intercept the groundwater, reducing the flow towards watercourse 4. However, as the road drains along the cutting will discharge to watercourse 4 maintaining the input of water to the stream, it is considered that the impact on the flow in the stream would be minor.

4.5.8 Overall, the risk from groundwater flooding as a result of the Scheme is considered as low.

4.6 Mitigation against groundwater flooding

4.6.1 The Drainage Strategy (Appendix 13.2 of the ES [TR010054/APP/6.3]) suggests installation of combined (surface water and groundwater) filter drains that will convey the combined flows into the proposed drainage network where the flowrates will either be attenuated back to greenfield run-off rates via balancing ponds and/or attenuated back to the existing discharge rate. The attenuated flows will subsequently be discharged to a nearby watercourse or connect to the existing drainage network, not discharging to groundwater.

4.6.2 Use of combined surface water and groundwater surface drains is common practice for highway drainage and the alternate of carrier pipes with separate fin/narrow filter drains still results in the highway surface water flows and groundwater flows in the vicinity of the road pavement being combined in the same drainage system. After initial draw down of groundwater levels long term groundwater flow rates adjacent to the road pavement will be negligible in comparison to peak surface water storm flows. Where adjacent ground falls towards the proposed road earthworks drains/ditches will be provided which will take a proportion of groundwater and surface water flows and these will be keep separate from the highway surface water drainage system in most cases.

4.6.3 Proposed earthwork drainage would be located at the top of cuttings or toe of embankment to capture surface flows from natural catchments.

4.6.4 Thus, the impact on groundwater flooding mechanisms due to the Scheme is low as appropriate mitigation strategies are implemented as designed into the Drainage Strategy.

4.7 Impact on flooding from artificial sources

4.7.1 The pond referred to as Lower Pool is to be dissected by the Scheme. However, flood risk modelling of Watercourse 3 has shown that the partial loss of an area of this pond will have a negligible impact on flood risk.

4.7.2 A fish pond near to Brookfield Farm will be lost as a result of the Scheme. However, flood risk modelling of Watercourse 4 has shown that the loss of this pond will have a negligible impact on flood risk.

4.7.3 The proposed drainage strategy is to discharge through attenuation basins into watercourses at an agreed rate via a dedicated highway drainage network. The impact on flood risk from artificial sources as a result of the Scheme is low.

4.8 Summary of flood risk impacts from the Scheme

Table 4.2: Summary of risk from the Scheme

Flood risk	Summary of risk from the Scheme	Notes	Mitigation required
Fluvial	Low	Hydraulic modelling has shown localised increase (12cm in 1% AEP + 50% Climate change event) in flood levels upstream of the proposed Latherford Brook (Watercourse 5) crossing. However, it should be noted that no properties are in the affected area, and there are minimal changes to the flood extents and depths. The only receptor to the change in flood extents is the existing woodland, for which the impacts of this change will be low. The impact of the Scheme on the fluvial flood risk from Watercourse 1,2,3,4 and 6 is low as modelling has shown no change in flood risk to receptors.	No
Surface Water	Low	Given that the proposed highway will increase the impermeable area along the entirety of its length, there is the potential for the surface water flood risk, both to the highway alignment and surrounding area, to significantly increase. The impact on surface water flooding mechanisms due to the Scheme is low provided all the overland surface water runoff and highway drainage to be generated by the Scheme is captured and attenuated by the proposed drainage network to prevent flooding up to a 1%+ 40% climate change event as described in the surface water Drainage Plan.	Yes
Groundwater	Low	The impact on groundwater flooding mechanisms due to the Scheme is low provided appropriate mitigation strategies are implemented as described in the surface water Drainage Plan.	Yes
Sewer and Water Supply Infrastructure	Low	Given the rural nature of the route alignment and the proposed surface water drainage strategy, the current risk from sewers and drains is considered low.	No
Artificial Sources	Low	Despite the loss of an area of the Lower Pool and a fishing pond near Brookfield Farm, the flood risk impact from the Scheme is low.	No

5 Residual Risk

5.1.1 There is residual fluvial risk associated with the Latherford Brook (Watercourses 4 and 5) in the 1% AEP storm event. However, risk to properties, land, third parties and the Scheme is low. There is also some existing residual risk at Watercourses 1, 2, 3 and 6 in the 0.1% AEP storm event, however to address this risk is beyond the scope of the Scheme and the Scheme is not expected to affect flood risk on these watercourses.

5.1.2 There is residual risk associated with failure of the highway drainage system through blockage or build-up of sediment as a result of the shallow gradient of the pipes, both of which may cause the capacity of the drainage system to become reduced. The risk of blockage and sedimentation can be reduced by undertaking regular inspection of the drainage system and ensuring that serviceability is maintained. A maintenance plan will need to be developed at detailed design stage to describe the ownership, frequency of and techniques for site drainage maintenance.

5.1.3 In the event of failure of the drainage system through either blockage or exceedance of flows, excess surface water will be managed within the local topography without putting the road itself or other receptors at risk of flooding. This will be achieved by landscaping the topography to ensure no flooding to third party land and reducing flood risk to the road. This landscaping will be included as part of the detailed design process.

6 Sequential and Exception Test

6.1.1 It is considered that there will be no significant increase in fluvial flood risk to the neighboring land uses, or an increase in surface water runoff as a result of the Scheme based on application of identified mitigation measures.

6.1.2 The Scheme alignment passes through Flood Zone 3, and therefore does not automatically pass the Sequential test. Owing to the nature of the Scheme, it is not viable to relocate the works in a zone with a lower probability of flooding. The Scheme alignment has been developed following a comprehensive assessment of different alignment options, which considered all environmental impacts (inclusive of flood risk). The Scheme is classed as Essential Infrastructure and passes through Flood Zone 3. Therefore, the Scheme must be assessed against the Exception Test.

6.1.3 For the Exception Test to be passed the development must demonstrate that:

- it provides wider sustainability benefits to the community that outweigh flood risk; and
- it will be safe for the lifetime of the development.

6.1.4 Since the Scheme is also classed as a Nationally Significant Infrastructure Project (NSIP), it is considered that the Exception Test would also be passed. The evidence of the wider sustainability benefits to the community is provided as part of the wider DCO submission. The information presented within this report demonstrates that mitigation measures have been incorporated into the design to ensure that the new road will be at low risk of flooding and will be safe for the lifetime of the development.

7 Conclusions

7.1.1 As required by the DMRB LA 113 (Ref 17), this FRA has been completed in accordance with the NPSNN and NPPF and the accompanying PPG. The following conclusions can be made:

- The Scheme would be situated largely on a greenfield site.
- The flood risk to the Scheme from fluvial, tidal, surface water, artificial sources, drainage infrastructure and groundwater is low.
- Hydraulic modelling has shown a localised increase of flood levels immediately upstream of the proposed Latherford Brook (Watercourse 5) crossing. However, it should be noted that no properties are in the affected area, and there is no risk to the Scheme. The only receptor which will experience a minor impact is the existing woodland which already experiences flooding for the storm events tested. Model results show that the Scheme does not significantly increase the flood risk to any properties in the vicinity of the proposed Latherford Brook crossing, and therefore no additional mitigation is required.
- The drainage strategy demonstrates that it is possible to safely and sustainably manage surface water volumes from the site up to the 1% AEP + 40% for climate change flows.
- The Scheme is also as a NSIP, and given the evidence in this FRA it is considered that the Exception Test would also be passed.

8 Reference

Ref 1 Department for Communities and Local Government (2019) National Planning Policy Framework

Ref 2 Department for Communities and Local Government (March 2014) National Planning Practice Guidance. Flood risk and coastal change. [Online] Accessed: 28.06.2019

Ref 3 Department for Transport (December 2014) National Policy Statement for National Networks

Ref 4 Environment Agency Flood Map for Planning. [Online] Accessed: 25.07.2019

Ref 5 Environment Agency Long term Flood Risk[Online] Accessed: 25.07.2019

Ref 6 Staffordshire County Council (2011) Staffordshire Preliminary Flood Risk Assessment. [Online] Accessed: 28.07.2019

Ref 7 Southern Staffordshire Councils Level 1 Strategic Flood Risk Assessment Final Report October 2019. [Online] Accessed: 28.11.2019

Ref 8 Cannock Chase Council, Lichfield District Council, Stafford Borough Council and South Staffordshire Council (2014) South Staffordshire, Cannock Chase, Lichfield & Stafford Strategic Flood Risk Assessment. [Online] Accessed: 28.06.2019

Ref 9 Staffordshire Local Flood Risk Management Strategy. [Online] Accessed: 25.07.2019

Ref 10 Staffordshire County Council (2015) Shropshire and Staffordshire Local Flood Risk Management Strategy – Part 3: Strategic Environmental Assessment for Staffordshire. [Online] Accessed: 01.07.2019

Ref 11 Environment Agency (2010) River Trent Catchment Flood Management Plan

Ref 12 British Geological Survey records [Online] Accessed: 27.06.2019

Ref 13 Department for Environment, Food and Rural Affairs, MAGIC Mapping [Online] Accessed: 03.07.2019

Ref 14 Department for Environment, Food and Rural Affairs (2015) Sustainable Drainage Systems: Non-statutory technical standards for sustainable drainage systems. [Online] Accessed: 28.06.2019

Ref 15 South Staffordshire Council (December 2012) A Local Plan for South Staffordshire: Core Strategy Development Plan Document [Online] Accessed 16.08.2019

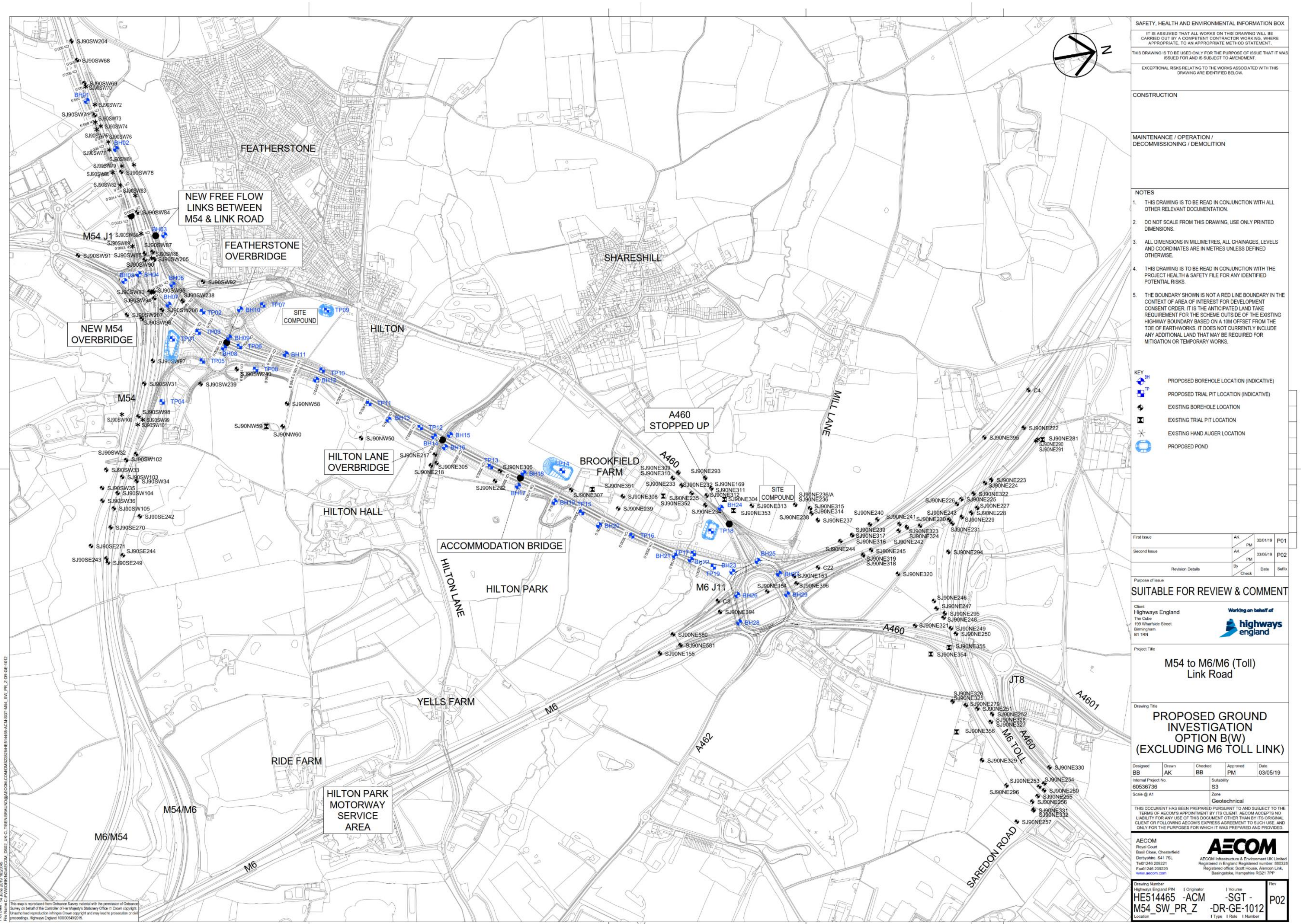
Ref 16 Environment Agency (2019) Flood risk assessments: climate change allowances. [Online] Accessed: 28.06.2019

Ref 17 Highways England (2019) Design Manual for Roads and Bridges LA 113 Road Drainage and the Water Environment

Ref 18 Department for Environment, Food & Rural Affairs and Environment Agency. (2016). Guidance: Reservoirs: owner and operator requirements. [Online] Accessed: 23.09.2019

Ref 19 Ciria (2016) Groundwater control: design and practice (second edition) (C750) [Online] Accessed 27.09.2019

Annex A: Site Investigation drawing


FEATHERSTONE
NEW FREE FLOW LINKS BETWEEN M54 & LINK ROAD
M54 J1
FEATHERSTONE OVERBRIDGE
SHARESHILL
NEW M54 OVERBRIDGE
SITE COMPOUND
HILTON
M54
A460 STOPPED UP
MILL LANE
HILTON LANE OVERBRIDGE
BROOKFIELD FARM
A460
HILTON HALL
ACCOMMODATION BRIDGE
HILTON LANE
HILTON PARK
M6 J11
A460
JT8
A4601
YELLS FARM
M6
A462
M6 TOLL
RIDE FARM
HILTON PARK MOTORWAY SERVICE AREA
M54/M6
M6/M54
M6
SAREDON ROAD
SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX
CONSTRUCTION
MAINTENANCE / OPERATION / DECOMMISSIONING / DEMOLITION
NOTES
KEY
PROPOSED BOREHOLE LOCATION (INDICATIVE)
PROPOSED TRIAL PIT LOCATION (INDICATIVE)
EXISTING BOREHOLE LOCATION
EXISTING TRIAL PIT LOCATION
EXISTING HAND AUGER LOCATION
PROPOSED POND
SUITABLE FOR REVIEW & COMMENT
M54 to M6/M6 (Toll) Link Road
PROPOSED GROUND INVESTIGATION OPTION B(W) (EXCLUDING M6 TOLL LINK)
AECOM
HE514465 -ACM -SGT -
M54_SW_PR_Z -DR-GE-1012
P02

Annex B: Hydraulic Modelling Report

Annex B – Hydraulic Model Report

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1 Introduction

1.1 Aims and Objectives

1.1.1 A Scheme alignment for a link road between the M54 and M6 has been proposed by Highways England. There are six known locations where watercourses intersect the Scheme. Hydraulic modelling of the watercourses has been undertaken as part of the Flood Risk Assessment (FRA) for the Environmental Statement (ES). The purpose of this report is to describe the processes, data and assumptions undertaken for the four hydraulic models constructed to support the FRA.

1.2 Overview of Study Area

1.2.1 Highways England have assessed highway options to address congestion issues on the A460 Cannock Road, through the villages of Shareshill and Featherstone with the aim of diverting through traffic away from the villages onto a more suitable link road between the M54, M6 and M6 Toll. The Scheme is located between the M54, M6 and M6 Toll to provide a link from Junction 1 of the M54, M6 North, M6 Toll to the A460 to Cannock. 'Chapter 3: Assessment of Alternatives' [TR010054/APP/6.1] of the ES describes the various options that have been developed and considered; ultimately resulting in the definition of the Scheme. The design for the Scheme can be seen below in Figure 1.1.

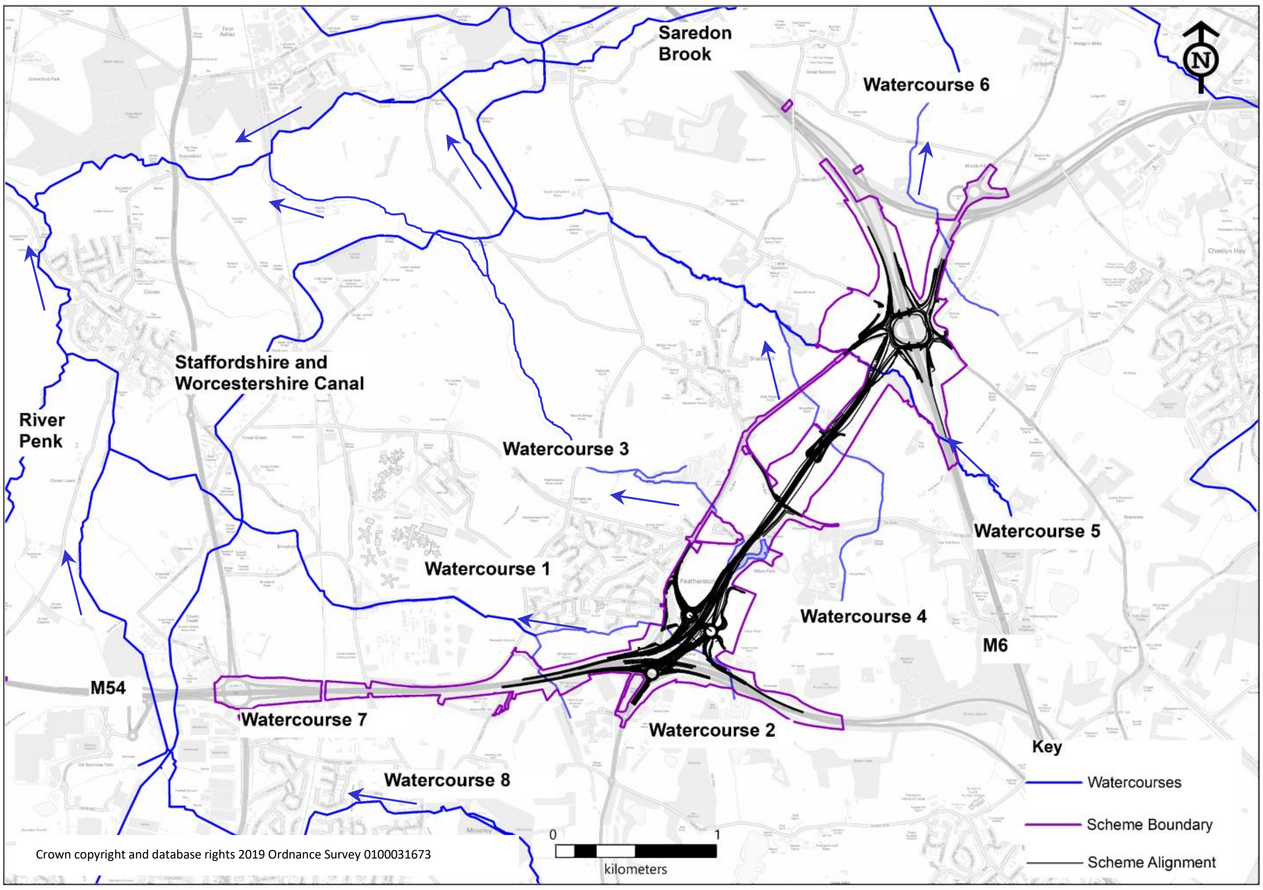


Figure 1.1: A map of the Scheme area showing watercourses. Arrows indicate direction of flow.

1.2.2 There are six ordinary watercourses near to the Scheme, which required hydraulic modelling to understand flood risk. Hydraulic models were deemed as not required for Watercourses 7, 8 or the Saredon Brook and River Penk, as the construction of the Scheme earthworks were not in the vicinity of these Watercourses. As a result, these Watercourses have been scoped out of the FRA.

1.2.3 Four models were built to examine the existing fluvial flood risk to the area. Throughout this report, the models are referred to as: Latherford Brook, Tower House Farm, Wheatsheaf Farm and Hilton Park (Figure 3.1).

2 Data Collection

2.1 Survey & Site Visits

2.1.1 To gather suitably detailed data to be able to construct hydraulic models, a river channel topographic survey was commissioned by AECOM and undertaken by Storm Geomatics between February and April 2019. This survey was undertaken to the 'Environment Agency National Standard Technical Specifications for Surveying Services v4'[1].

Table 2.1: Survey Summary

Model Name	Number of River Channel Cross sections	Number of Structures surveyed
Tower House Farm	33	11
Hilton Park	25	9
Latherford Brook	59	12
Wheatsheaf Farm	24	10

2.1.2 These cross-sections were generally spaced at 100m, unless otherwise specified by the survey scope. The survey scope included additional sections in areas of interest. Additional sections were included in the scope in the vicinity of the footprint of the proposed scheme.

2.1.3 Issues surrounding permissions to access private land meant that some areas were not surveyed. In these locations modelling assumptions have been made and therefore there is lower confidence in the model results in reaches where interpolation has been exercised. This issue was most prevalent for the Tower House Farm model and is discussed in section 4.2.

2.1.4 In addition to the topographic survey, the modelling team from Highways England attended a site visit on the 11th of February 2019. The purpose of this site visit was to help refine the scope of the topographic survey and to gather additional information to aid modelling structures and the river channel at key locations of interest.

[1] Environment Agency (2017) National Standard Technical Specifications for Surveying Services Version 4

Figure 2.1: Site visit to Latherford Brook (Watercourse 5) where the Scheme will dissect the river

2.2 LiDAR Data

2.2.1 The main component of any 1D-2D linked hydraulic model is the ground model data which is used to represent natural flow paths which exist outside of the river network. All models were developed as 1D, and where out of bank flooding occurred, the model then incorporated 2D elements. The Latherford Brook (Watercourses 4 & 5) is the only 1D-2D model created as part of this study. The 'Baseline' terrain is a composite of the best available LiDAR data resolutions from various sources:

- 5m, 2m, 1m - Environment Agency data
- 2m Airborne Fixed Wing LiDAR – Survey commissioned by Highways England
- 1m Airborne Rotary Wing LiDAR - Survey commissioned by Highways England

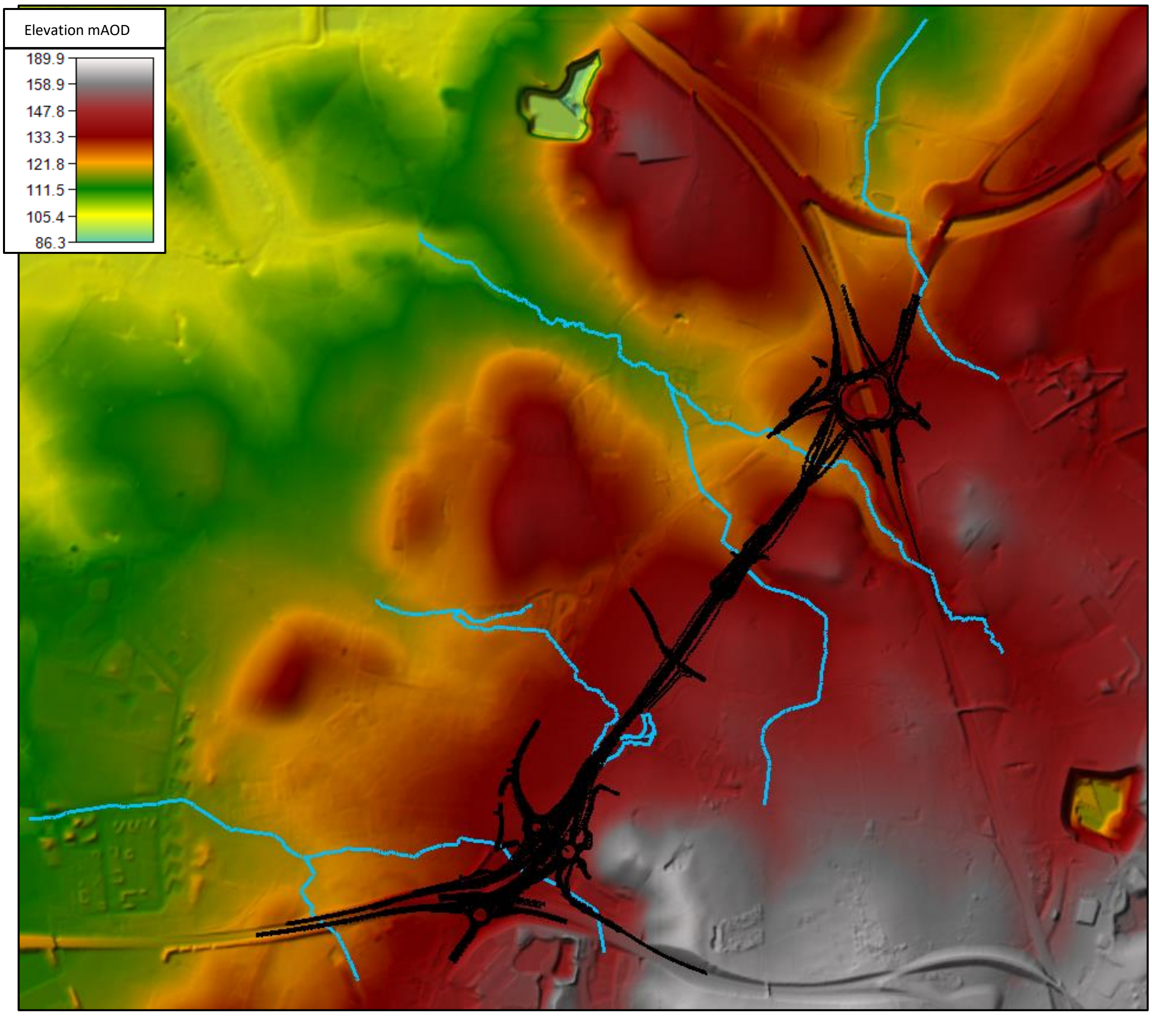


Figure 2.2: Baseline terrain developed

2.3 Hydrometric Data

2.3.1 Hydrometric Data for this project was requested from the Environment Agency. The nearest river level gauges to the study area are the Deepmore Farm Level Gauge on Saredon Brook which is approximately 2km downstream of the Latherford Brook model boundary, and the Coven Level Gauge on the River Penk which is downstream of Watercourse 1 and 2. The data from these gauges was assessed, however due to the distance from the study area the data has not been used to calibrate the models.

2.4 Previous Modelling Studies

2.4.1 Previous JFLOW modelling has been undertaken by the Environment Agency for a section of the Latherford Brook (Watercourse 5). This JFLOW modelling has been used to indicate Flood Zone 2 and 3 and is incorporated to the Environment Agency's Long-Term Flood Risk Mapping.[2]

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

2.4.2 No previous modelling or studies has been undertaken for Watercourses 1, 2, 3, 4 and 6.

3 Model Approach

3.1 Catchment Hydrological Analysis

3.1.1 A hydrological analysis has been undertaken of the six watercourse catchments in order to generate design event inflow hydrographs for the hydraulic modelling. Based on the nature of the catchments and informed by the availability and quality of hydrometric data for the catchment, the ReFH2 method[3] has been adopted.

3.1.2 Throughout this report, the models are referred to as: Latherford Brook, Tower House Farm, Wheatsheaf Farm and Hilton Park (as labelled in Figure 3.1).

Subcatchment Definition

3.1.3 The fluvial catchments of the six watercourses were selected using the FEH (Flood Estimation Handbook) Web Service. Table 3.1 summarises the locations and catchment areas, as well as the catchment descriptors from the FEH Website. The catchment boundaries are also shown in Figure 3.1.

Table 3.1: Details of the six watercourses intersecting the Scheme

Location	Watercourse	Estimated watercourse gradient at crossings 4	Area of upstream catchment (km^2)	Grid reference (Easting, Northing)	
Tower House Farm	1	0.01	1.1	393662	304087
Tower House Farm	2	0.01	1.0	394950	304250
Hilton Park	3	0.02	0.7	395275	304700
Latherford Brook	4	0.01	0.9	395425	305475
Latherford Brook	5	0.01	3.4	396350	305100
Wheatsheaf Farm	6	0.02	0.5	396175	306950

[3]ReFH2: In Depth. https://www.hydrosolutions.co.uk/software/refh-2/in-depth-2/ (Accessed October 2019)
[4] Slope estimated from contours derived from LiDAR

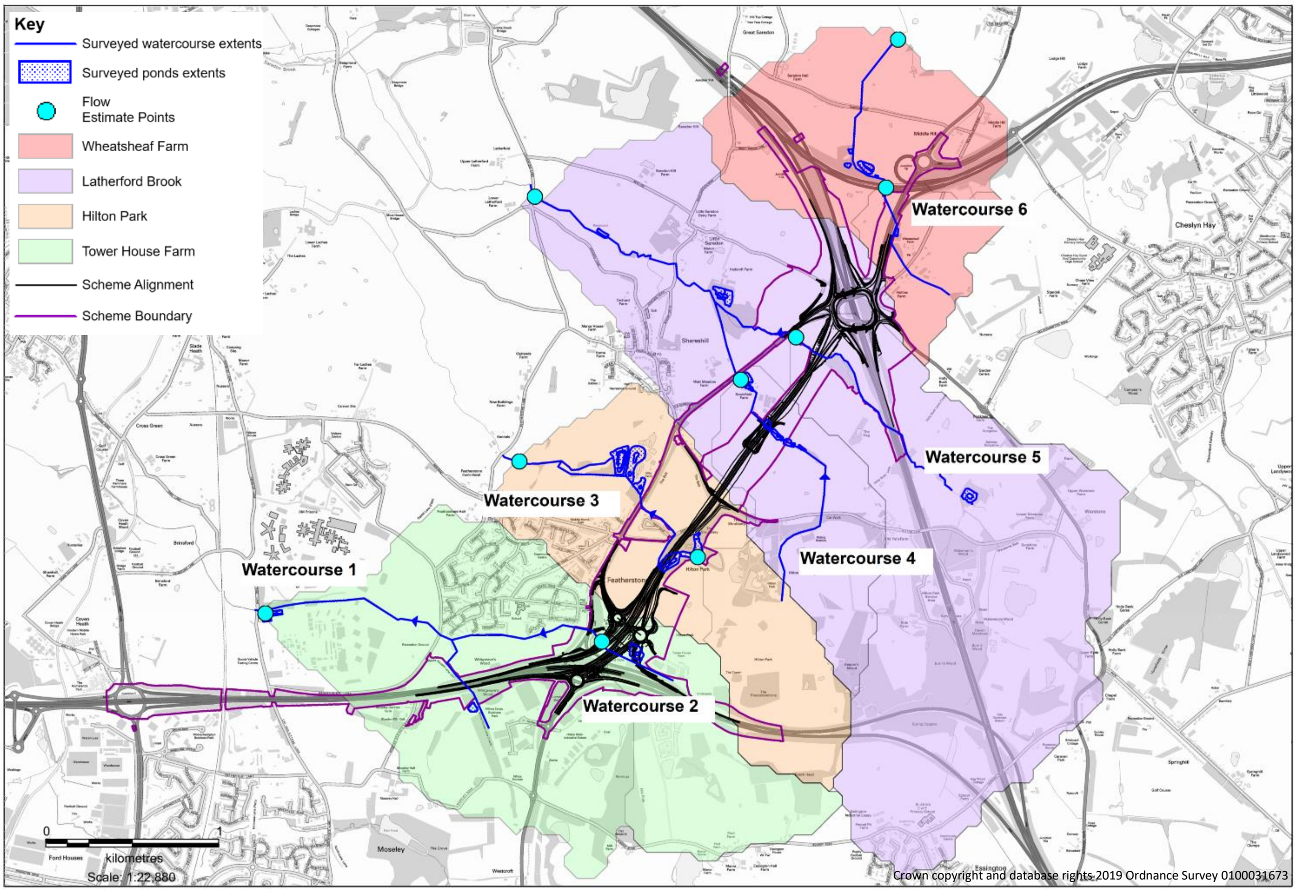


Figure 3.1: Six catchments where watercourses intersect with the Scheme

3.2 Hydrometric Data and Event Analysis

FEH Statistical Method

3.2.1 The FEH statistical method calculates peak flows as a product of a QMED (the median annual flow) estimate and a flood growth curve. Wherever possible, local data should be used to improve the QMED estimate.

QMED

3.2.2 None of the tributary watercourses are gauged, and a suitable donor catchment could not be found for the target sites; this is because there are few gauged small watercourses within the vicinity. As such, QMED has been estimated from catchment descriptors for each site. The $URBEXT_{2000}$ (catchment descriptor) values were reviewed to determine if the catchments were classified as predominantly urban, (when the $URBEXT_{2000} > 0.3$). All the catchments were identified as rural.

Pooling Group and Growth Curve

3.2.3 For the six watercourses, the catchment descriptors were similar enough that the same pooling group could be used for each. The pooling group was based on the largest of the catchments Latherford Brook. WINFAP-FEH (hydrological modelling software package) was used to create an initial pooling group for the site, which was then refined to remove sites with poor quality data and to improve the homogeneity of the group for growth curve estimation.

3.2.4 Data from the pooling group was used to then generate growth curve and associated flood frequency curves, using the Generalised Logistic distribution to generate peak flows for the required return period design events.

3.2.5 To calculate the flood frequency curves / fittings (or peak flow estimates) for the sites, the QMED values for the six catchments were multiplied by their associated growth curves.

ReFH2 Method

3.2.6 ReFH2 (The Revitalised Flood Hydrograph Model) rainfall-runoff boundaries were generated for each site, based on parameters calculated from catchment descriptors. The critical storm durations were identified and set (based on the standard FEH approximation formula). For each site, the ReFH2 boundaries were used to calculate peak flows for the same return periods as for the FEH statistical method, (refer to Table 3.2).

Table 3.2: Estimated peak flows (m^3/s) FEH statistical method and ReFH2 method

% AEP (Annual Event Probability)	TowerHouseFarm_estimate		TowerHouseFarm_US		HiltonParl_DS		LatherfordBrook-Trib		Latherford Brook-US		WheatsheafFarm_DS	
	Watercourse 1 (estimated)		Watercourse 2		Watercourse 3		Watercourse 4		Watercourse 5		Watercourse 6	
	Statistical	RefH2	Statistical	RefH2	Statistical	RefH2	Statistical	RefH2	Statistical	RefH2	Statistical	RefH2
50	0.3	0.3	0.2	0.2	0.6	0.7	0.3	0.4	1.2	1.3	0.5	0.6
5	0.7	0.7	0.3	0.5	1.2	1.4	0.7	0.8	2.2	2.4	1.0	1.1
1.33	0.9	0.9	0.5	0.7	1.6	1.9	1.0	1.1	2.9	3.4	1.3	1.6
1	1.0	1.0	0.5	0.7	1.7	2.1	1.0	1.2	3.1	3.6	1.4	1.7
0.5	1.1	1.2	0.6	0.9	1.9	2.5	1.1	1.5	3.5	4.3	1.6	2.1
0.1	1.5	1.7	0.7	1.3	2.6	3.6	1.5	2.2	6.8	6.2	2.1	3.0

3.2.7 A comparison of flows indicated that the FEH statistical flows were generally lower than the ReFH2 flow estimates for all subcatchments. Up to the 1000 year return period event, the peak flow estimates from the two methods are relatively comparable but the difference between methods becomes significantly greater for the more extreme events.

3.2.8 Although the Statistical FEH flows are based on a pooling group of actual gauged data, these stations are located outside the catchment boundary of the subject sites and have a much bigger catchment area than the M54 sub-catchments. Therefore, these gauged sites do not represent the characteristics of our small study catchments well.

3.2.9 The ReFH2 method employs the most up-to-date FEH2013 DDF rainfall model and improves the representation of the impact of urbanisation within the rainfall-runoff model through an explicit urban model. In this case, it has been concluded that the ReFH2 method is the most appropriate methodology because:

- ReFH2 uses the most up-to-date rainfall modelling, data and methods.
- ReFH2 specifically models urban runoff by considering the actual urban extent.
- ReFH2 tends to better estimate flows for very small catchments with uniform hydrological characteristics.
- There is less confidence in the pooled statistical estimates because they are based on much larger donor stations that lie outside the study area.

Therefore, the ReFH2 peak flows and hydrographs were taken forward to the hydraulic modelling. Catchment descriptors can be seen in Figure 6.1: Summary of scheme impacts on flooding

3.2.10 Annex 1 - Catchment descriptors.

Design Event inflows

3.2.11 A summary of the design flows from the ReFH2 method for the downstream extent of each model is included in Table 3.3 below. The time to peak (Tp) of each catchment has been calculated in ReFH2 and then used to estimate the critical storm duration for each catchment.

Table 3.3: Design event inflows (RefH2) for all watercourses (no climate change considered)

Sub-catchment name	Tp (hours) from catchment descriptors	Critical Storm duration (hr) applied	Design event inflow: 5% AEP (m^3/s)	Design event inflow: 1% AEP (m^3/s)	Design event inflow: 0.1% AEP (m^3/s)
Tower House Farm Watercourse 1&2	3.38	5.5	2.07	3.08	5.27
Hilton Park Watercourse 3	2.96	5.0	1.40	2.09	3.61
Latherford Brook Watercourse 4 &5	2.45	7.5	3.23	4.77	8.07
Wheatsheaf Farm Watercourse 6	2.53	4.5	1.15	1.75	3.03

Limitations

3.2.12 As noted throughout the proceeding sections, limitations in the ReFH2 urban methodology and limitations in the hydrometric data quality and availability of events mean that uncalibrated models are being used for this assessment. Using uncalibrated models limits confidence in the outputs but to mitigate this risk, additional sensitivity testing has been undertaken to ensure that the results of the appraisal are not unacceptably sensitive to the assumptions and parameters in the hydrological modelling. By adopting consistent methods and assumptions across the six catchments, the methods used are justified and repeatable.

Climate Change Assumptions

3.2.13 The Environment Agency published climate change guidance in February 2016, which has been updated in 2019. The guidance indicates that climate change is likely to increase river flows, sea levels, rainfall intensity, and wave height and wind speed. The Environment Agency are undergoing more updates to their climate change guidance, based on the UKCP 2018 updates. Consultation with the Environment Agency has been undertaken prior to the publication of this FRA, to agree climate change parameters for hydraulic modelling. However, they may need to be reviewed before detailed design to ensure that future changes in guidance are reflected in the final design.

3.2.14 The Environment Agency, as part of the engagement undertaken for this FRA, has indicated that a climate change allowance of 50% should be used to assess flood risk and design appropriate mitigation for the Scheme. This would be the Upper End value anticipated for the 2080s which means that there is a 90% chance that the increase in flows from climate change would be less than 50% in this region.

4 Baseline Model development

4.1 General Assumptions

HEC-RAS

4.1.1 The survey data for the six watercourses collected was imported to HEC-RAS as four model databases. Model logs were created and maintained to keep an auditable trail of decisions and assumptions made as part of the model construction.

1D or 2D

4.1.2 Tower House Farm, Hilton Park and Wheatsheaf Farm catchments are all 1D models, whereas the Latherford Brook catchment is a 1D-2D model. All catchments were initially constructed as a 1D model[5], and if the 1D model showed a potential for significant out of bank flooding, the choice was then made to incorporate 2D elements in to the model in order to get more detailed flood risk results on the floodplain.

Lateral Flows

4.1.3 Lateral flows have generally been calculated using the difference in estimated peak flows between the upstream and downstream FEH estimation points. This intervening catchment flow has then been distributed along the river reach at suitable points based on survey information and site photographs, where lateral flows have been observed.

Roughness

4.1.4 Manning's (n) roughness values have been applied to the channel, structures and 2D surface. The general approach was to apply generalised roughness values during the build stage with a view to stabilising the model. Once the model had been stabilised, Manning's (n) roughness values were adjusted to more accurately represent survey data based on site visit observations and surveyor's photographs[6].

Storage Areas

4.1.5 Storage areas and ponds have been included in the models where they are thought to have a potential impact on flood risk. This includes ponds which are 'online' and ponds which are thought to have a benefit to flood risk. Ponds which are offline or do appear to impact flood risk have not been included within the models.

Initial Conditions

4.1.6 Initial conditions are applied to the model flow data to enable stability of the model. Generally, these initial conditions reflect the surveyed water level in the storage areas. For the river reach, initial conditions reflect a stable state of the river before a storm occurs. In some cases, a minimum base flow was applied to the models to

[5] Desktop review of 2D hydraulic modelling packages (2009) http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/SC080035_Desktop_review_of_2D_hydraulic_packages_Phase_1_Report.sflb.ashx
[6] Chow, V.T. (1959) Open Channel Hydraulics. McGraw-Hill, New York.

ensure stability throughout the run, but this does not increase the maximum peak or duration of the storm hydrograph.

Calibration

4.1.7 Models have not been calibrated, as there are no long term local hydrometric sites. This is noted as a limitation of the modelling process but the risk of proceeding with an uncalibrated model will be mitigated to some extent through sensitivity testing.

4.2 Tower House Farm

Model Build

4.2.1 In addition to the general approach outlined in section 4.1 of this document, specific assumptions and decisions were made for the Tower House Farm Model.

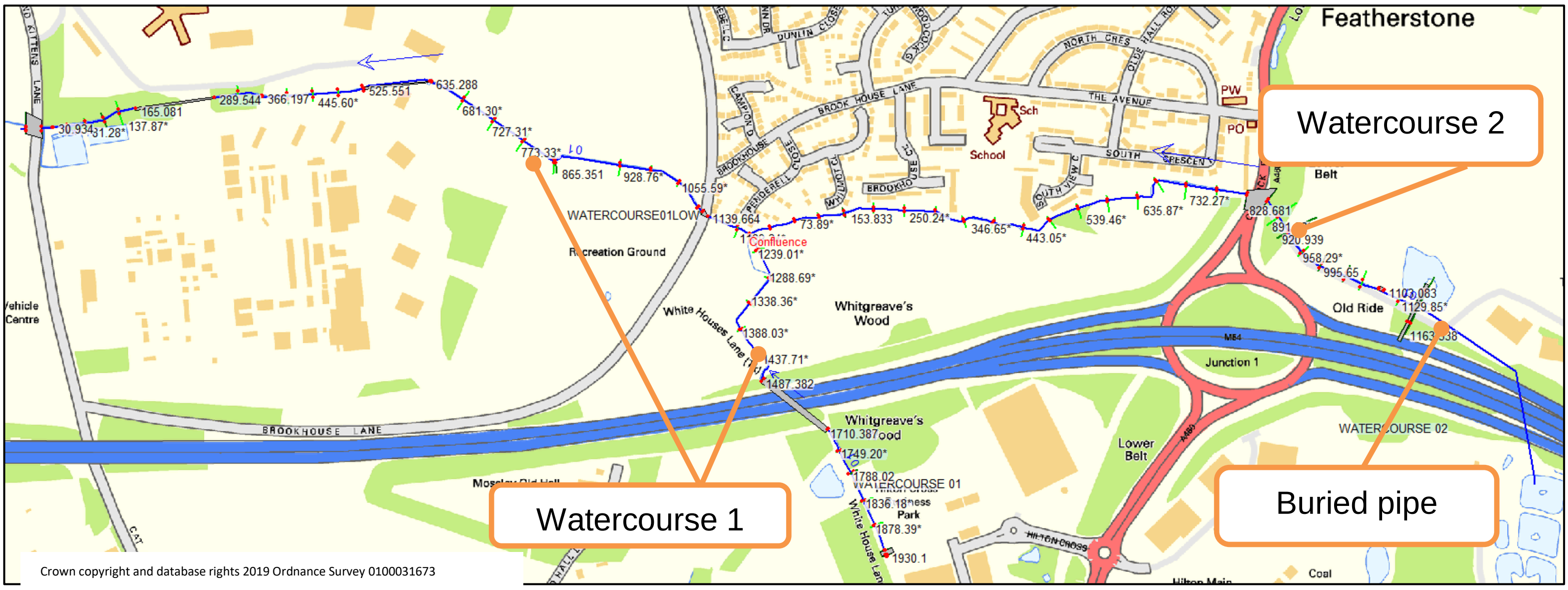


Figure 4.1: Overview of Tower House Farm model extents

4.2.2 The Tower House Farm model was built as a HEC-RAS 1D model. After an assessment of peak flows during a 1% AEP (annual exceedance probability) storm, it was decided not to convert the model to 2D as no out of bank flooding was predicted.

4.2.3 The model extents can be seen in Figure 4.1. The downstream boundary for Watercourse 1 was set at Cat and Kittens Lane, where EA flood mapping of Flood Zone 2 and 3 already exists.

Survey Data

4.2.4 The survey scope for topographic channel survey included a cross-section every 100m, or more in areas of specific interest. However due to difficulty in obtaining permission from land owners concerning land access, this meant some areas were not surveyed. In these locations, HEC-RAS interpolation tools have been used to create the model, however this means there is lower confidence in these areas of the model. As depicted as green cross-sections in Figure 4.2, cross-sections 33.913 to 780.48 of Watercourse 2 have been interpolated in the model for this reason, except for cross-section 153.833 which was surveyed from publicly accessible common ground.

4.2.5 The survey team found that Watercourse 2 emerges from a buried pipe (which was included in the survey, see Figure 4.1), which is located part way through where the feeder road is in the current design. This pipe is fed from fishing ponds approximately 360m upstream on the southern side of the M54. These ponds were not included in the survey scope as they are not directly impacted by the Scheme. Given that these ponds have not been included in the model, and are the source of Watercourse 2, it is therefore considered that the model results will be conservative. Including the ponds in the model and applying the upstream hydrograph would have a dampening effect on peak flows. Not including these ponds in the model creates a potentially exaggerated peak flow, and therefore the model results provide a worst-case scenario.

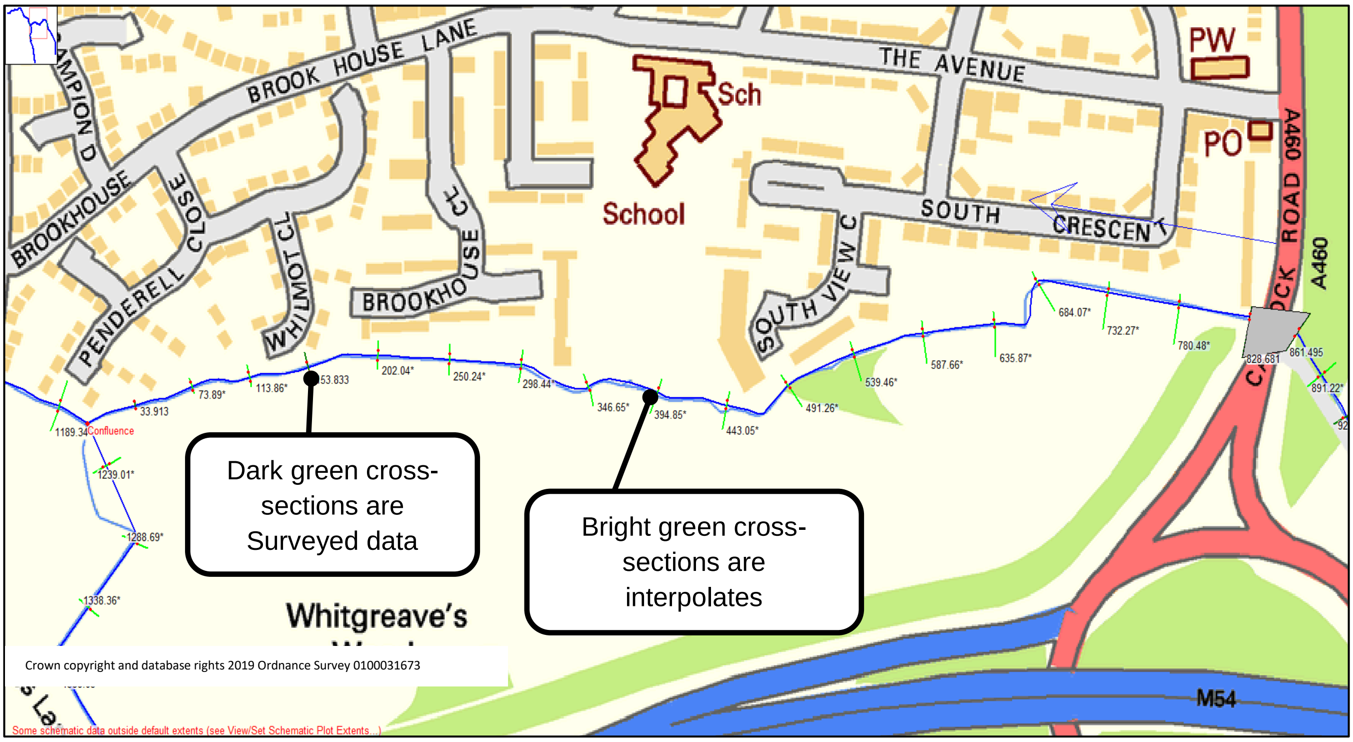


Figure 4.2: Interpolated reach of Watercourse 2

Manning's Roughness

4.2.6 A starting Manning's (n) roughness value of 0.05 for the river banks, and 0.03 has been applied[7]. Manning's values have been adjusted where necessary based on survey photographs.

Boundary Conditions

4.2.7 Boundary conditions were applied to the model, including lateral inflows. A summary of model boundary conditions and Lateral flows is included in Table 4.1.

[7] Chow, V.T. (1959) Open Channel Hydraulics. McGraw-Hill, New York.

Table 4.1: Summary of Boundary Conditions

Reach	Chainage	Boundary Condition type	Assumptions
WATERCOURSE 02	1163.338	Upstream inflow hydrograph	Upstream REFH2 hydrograph used for inflows to this cross section
WATERCOURSE 01	1930.100	Upstream inflow hydrograph	Upstream REFH2 hydrograph used for inflows to this cross section
WATERCOURSE 01	1788.020	Lateral inflow hydrograph	Based upon calculations between Upstream and Downstream REFH2 calculations. Survey photos inform positioning of lateral inflows.
WATERCOURSE01LOW	1119.000	Lateral inflow hydrograph	Based upon calculations between Upstream and Downstream REFH2 calculations. Survey photos inform positioning of lateral inflows.
WATERCOURSE01LOW	525.000	Lateral inflow hydrograph	Based upon calculations between Upstream and Downstream REFH2 calculations. Survey photos inform positioning of lateral inflows.
WATERCOURSE01LOW	0.000	Downstream boundary	Normal depth. Assumed, based on gradient.

Baseline Model Results

5% AEP

4.2.8 Figure 4.3 shows the long profile of the Tower House Farm model with the 1D model results for the 5% AEP event. There is a low risk of flooding in this part of the catchment. There is no out of bank flooding in close vicinity to the proposed scheme.

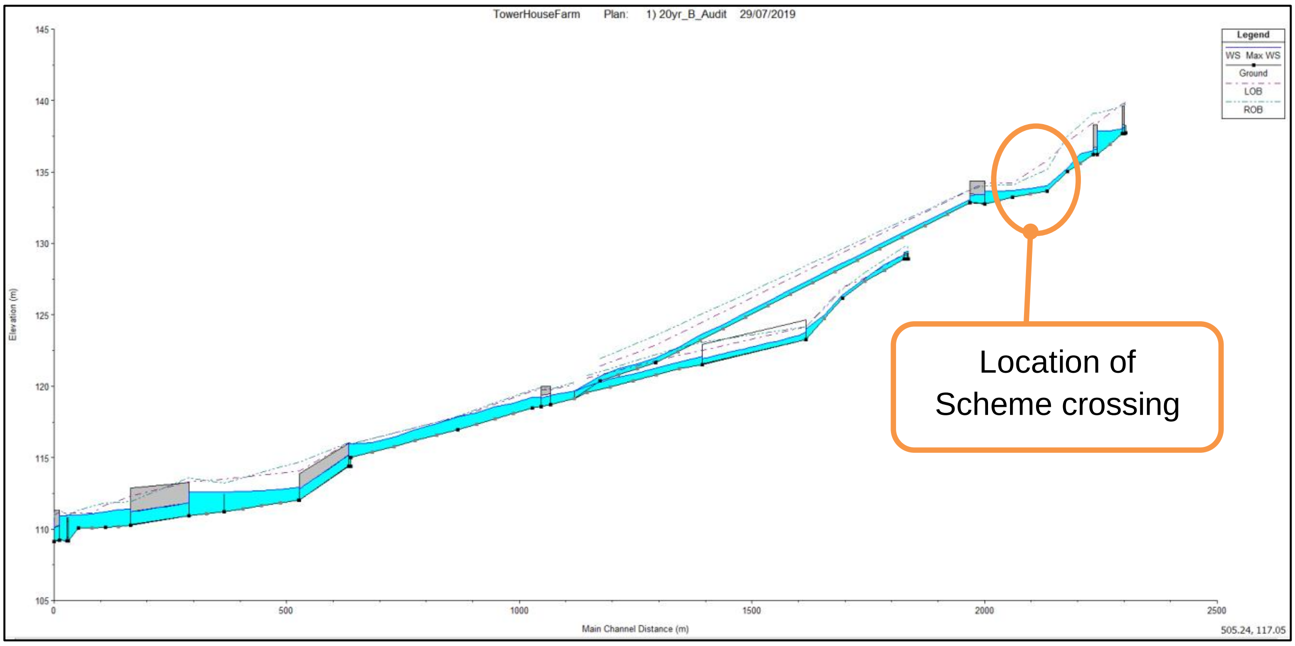


Figure 4.3: Tower House Farm model 5% AEP maximum water levels[8]

[8] LOB= Left Overbank, ROB = Right Overbank

1% AEP

4.2.9 The 1D model shows very low flood risk in the 1% AEP event, as there is no out of bank flooding in close vicinity to the proposed scheme.

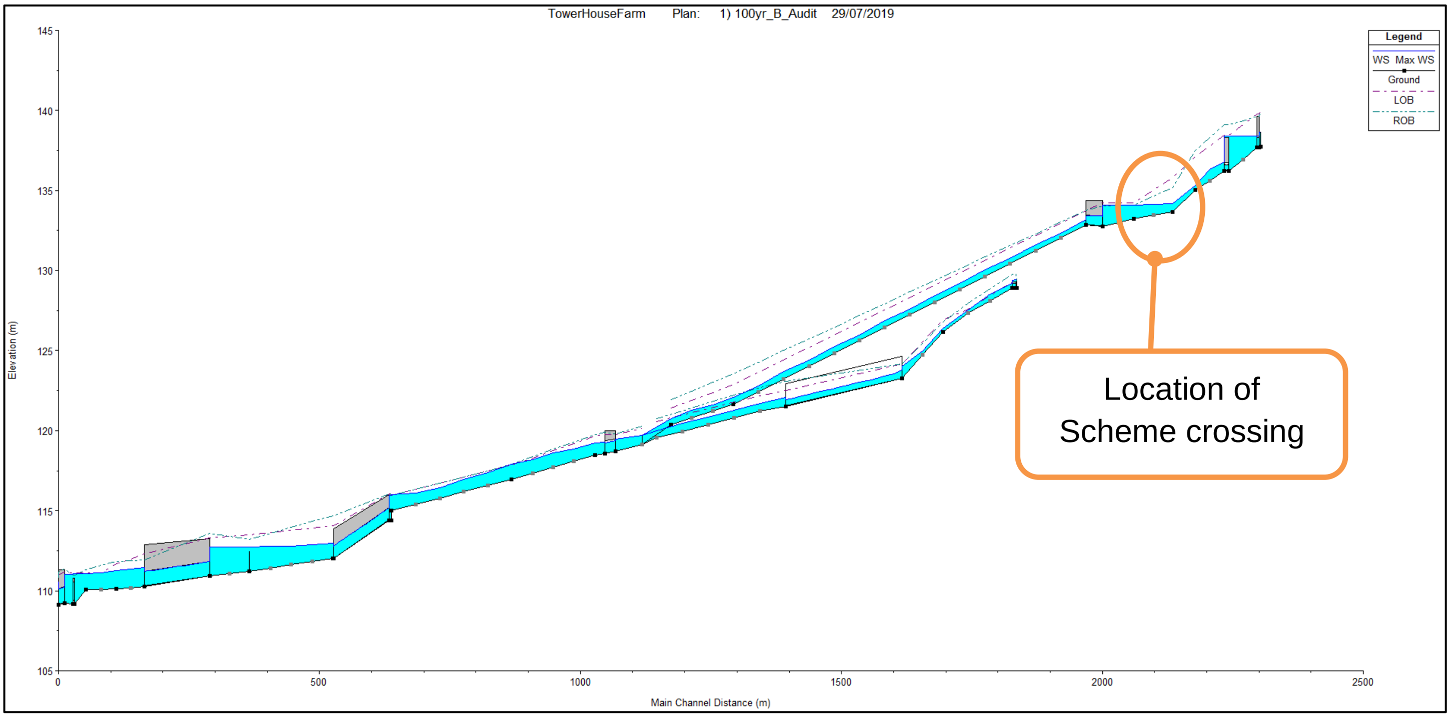


Figure 4.4: Tower house Farm model 1% AEP maximum water levels

1% AEP + 50% climate change allowance

4.2.10 When a 50% increase in runoff for climate change is added to the 1% AEP storm event there is a higher risk of flooding, as shown in the long profile in Figure 4.5.

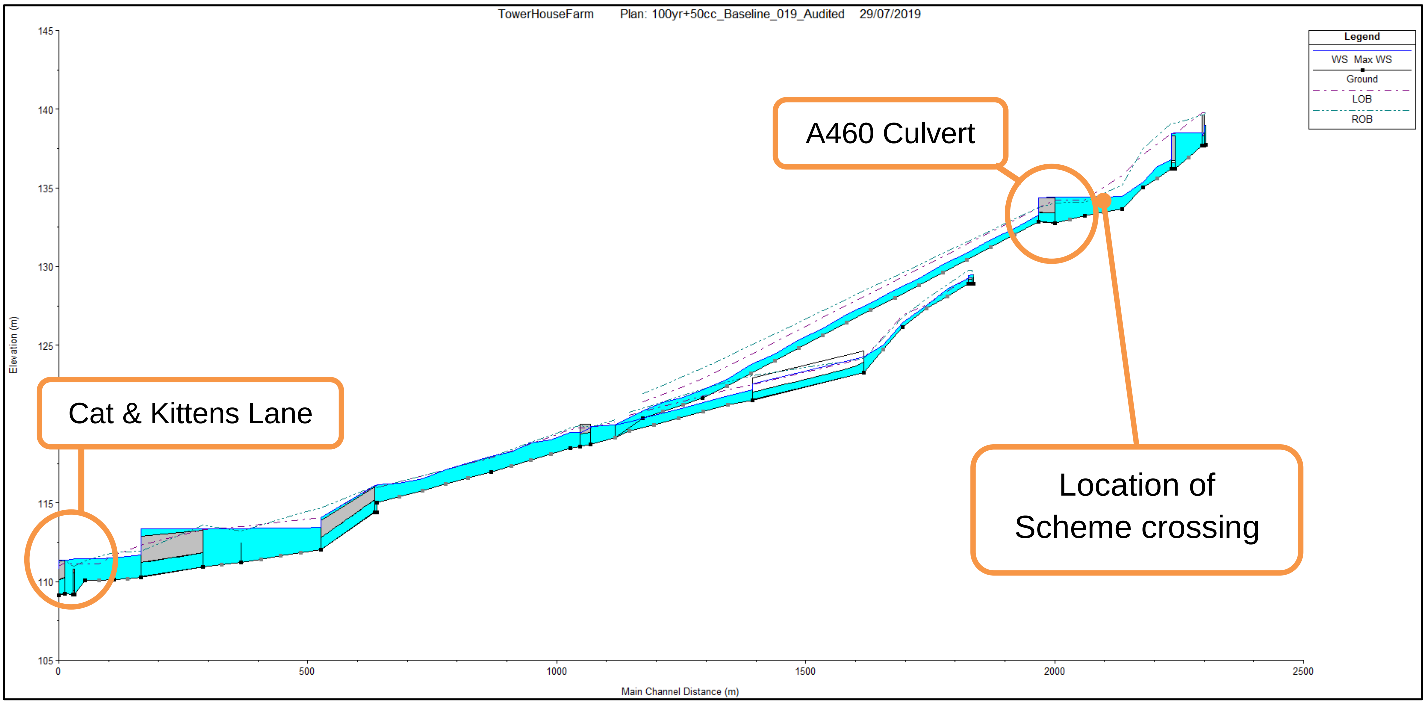


Figure 4.5: Tower House Farm model 1% AEP + 50% climate change allowance maximum water levels

4.2.11 Cross-section 861.495 shows some flood risk to the A460. The surveyed road surface height is approximately 134.37mAOD where it crosses Watercourse 2. However, the water level at the upstream side of the A460 culvert during the 1% AEP storm event with a 50% climate change allowance is 134.41mAOD. This level creates potential flood risk in this event. This is the main location where mitigation may be required to ensure that flood risk is not worsened by the modification of the watercourse.

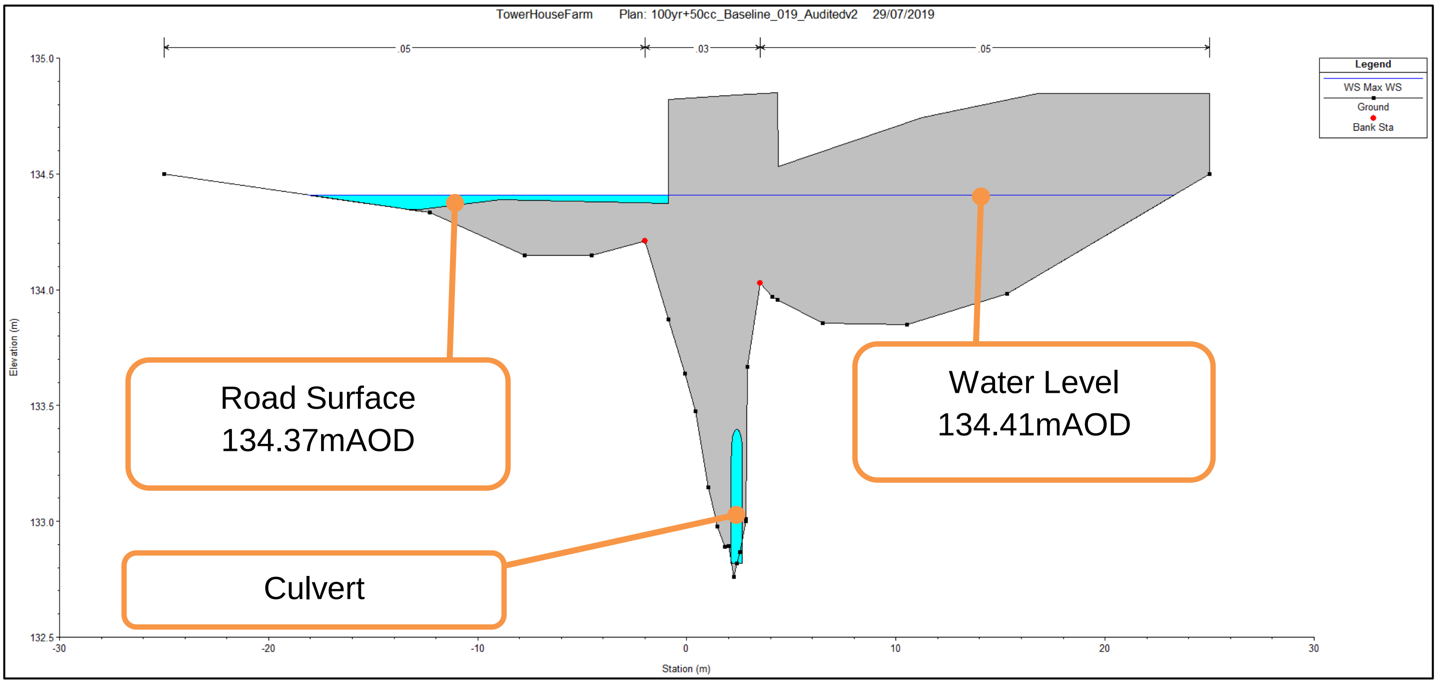


Figure 4.6: Water levels on upstream side of A460 culvert. Cross-section 861.495.

4.2.12 At the downstream end of the Watercourse 1, in the 1% AEP event with a 50% climate change allowance, the 1D model shows out of bank flooding between cross-sections 12.365 and 51.885 to the east of Cat and Kittens Lane. Whilst this area is not in the vicinity of the Scheme, flood risk must not be exacerbated as a result of the Scheme, as this area is part of the Core Strategy for development[9].

0.1% AEP

4.2.13 Modelled flood risk in the 0.1% AEP storm event is similar to the results of the 1% AEP event with the 50% climate change allowance. Out of bank flooding is predicted upstream of the culvert which passes beneath the A460. The surveyed road surface height is approximately 134.37mAOD where it crosses Watercourse 2. The modelled water level in the 0.1% AEP event is 134.43mAOD at this location. This level creates a potential flood risk at this return period.

4.2.14 At the downstream end of the Watercourse 1, as the 1D model shows out of bank flooding between cross-sections 12.365 and 51.885 to the east of Cat and Kittens Lane in the 0.1% AEP event.

[9] South Staffordshire Council Adopted Core Strategy https://www.sstaffs.gov.uk/planning/the-adopted-core-strategy.cfm (Accessed August 2019)

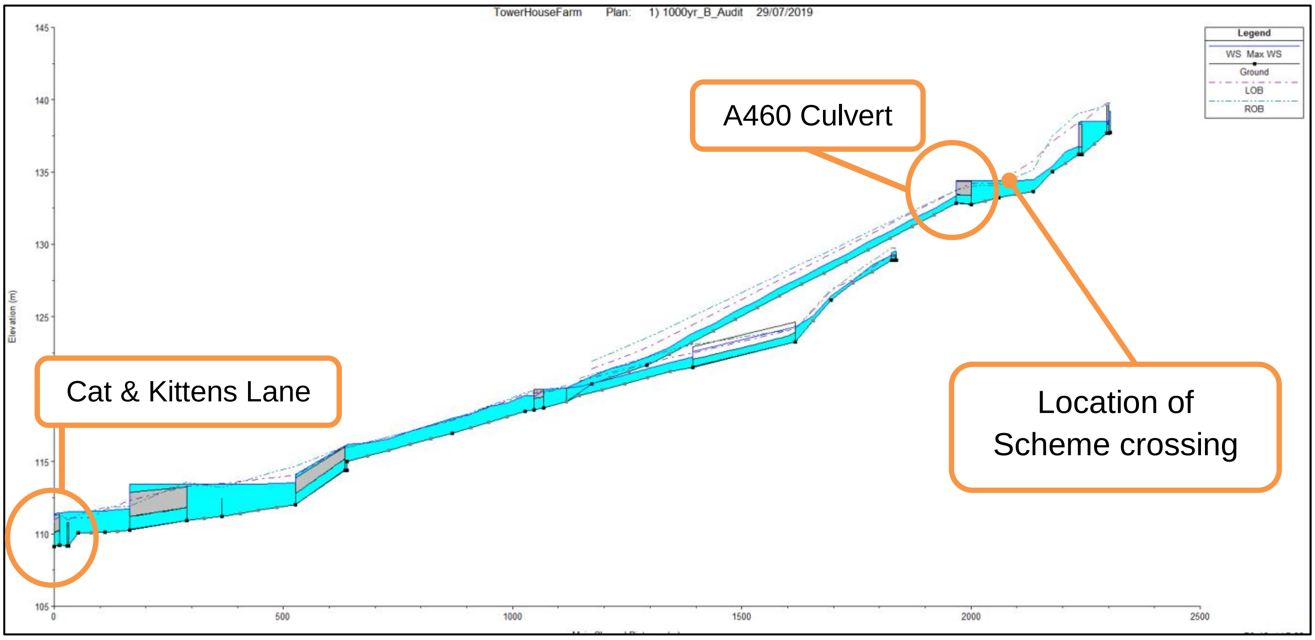


Figure 4.7: Tower House Farm model 0.1% AEP maximum water levels

Summary of Baseline results

4.2.15 Flooding does not occur in the model in the 5% or 1% AEP storm events. Model results show that some out of bank flooding does occur in the 1% AEP+50% climate change event, and the 0.1% AEP event. The main areas at risk of flooding are the A460 culvert, and the area around Cat and Kittens Lane.

4.3 Hilton Park

Model Build

4.3.1 In addition to the general approach outlined in section 4.1 of this document, specific assumptions and decisions were made for the Hilton Park model.

4.3.2 The Hilton Park model was built as a HEC-RAS 1D model. After an assessment of peak flows during a 1% AEP storm with the inclusion of the Lower Pool, it was decided not to convert the model to 2D as no out of bank flooding was predicted.

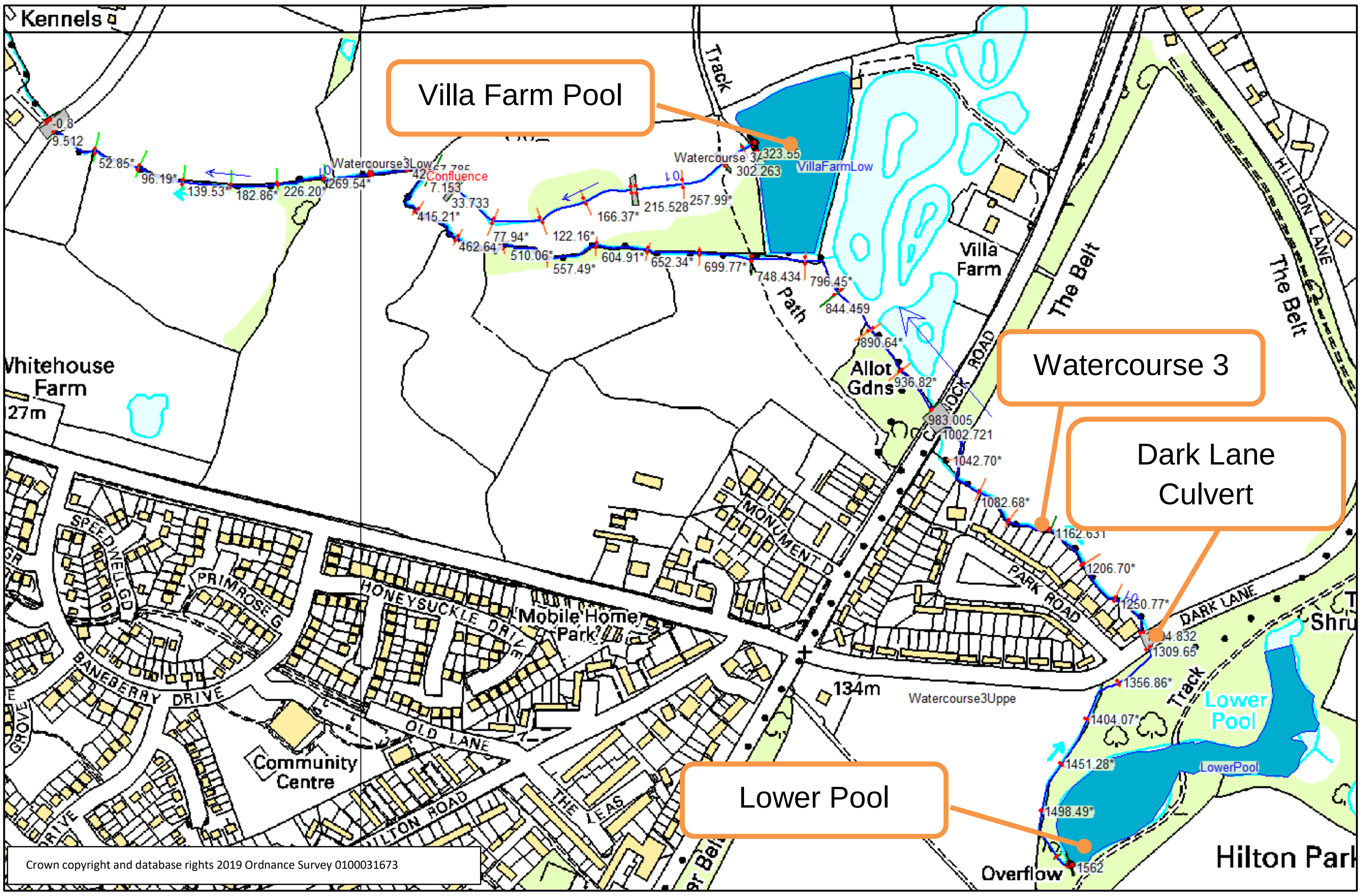


Figure 4.8: Overview of Hilton Park model extents

4.3.3 The model extents can be seen in Figure 4.8. There is no EA flood mapping available for this watercourse.

Survey Data

4.3.4 The survey scope for topographic channel survey included a cross-section every 100m, or more frequently in areas of specific interest. There were no difficulties in obtaining permission from land owners concerning land access for the survey of this entire watercourse.

4.3.5 The survey scope included the Lower Pool as this feeds Watercourse 3 directly and is an online pond. There are other ponds within the Hilton Park grounds which are linked to the Lower Pool. However, these were not included in the survey scope as they would not necessarily improve the understanding of flood risk.

Manning's Roughness

4.3.6 A starting Manning's n roughness value of 0.05 for the river banks, and 0.03 in-channel has been assumed[10]. Manning's (n) values have then been adjusted where necessary based on survey photographs.

Boundary Conditions

4.3.7 Boundary conditions were applied to the model, including lateral inflows. A summary of model boundary conditions and Lateral flows is included in the Table 4.2.

Table 4.2: Summary of Boundary Conditions

Reach	Chainage	Boundary Condition type	Assumptions
Watercourse3Upper	1559.9	Upstream inflow hydrograph	Upstream REFH2 hydrograph used for inflows to this cross section.
Watercourse3Upper	1250.77	Lateral inflow hydrograph	Based upon calculations between Upstream and Downstream REFH2 calculations. Survey photos confirm locations of lateral inflows.
Watercourse3Low	-0.08	Downstream boundary	Normal depth. Assumed, based on gradient.
LowerPool	N/A	Lateral inflow hydrograph	Baseflow applied to the pond which is at the top of the river reach.
VillaFarmLow	N/A	Lateral inflow hydrograph	Upstream REFH2 hydrograph applied to this pond, at the top of the river reach.

Sensitivity Testing of Lower Pool

4.3.8 Sensitivity testing was undertaken with regards to the Ponds which are at the beginning of the river reach on "Watercourse3Upper" and "Watercourse3A".

4.3.9 Survey data showed that these ponds were the source of these watercourse reaches. Initial model tests applied the calculated upstream REFH2 hydrograph to the ponds and routed it through the ponds to the downstream watercourse. In this setup, the ponds provided a significant attenuation impact and there was no obvious peak flow passed into the downstream watercourse.

4.3.10 Whilst the survey data showed that the ponds were the source of these reaches, a more conservative approach was taken for Lower Pool, by applying a baseflow to the modelled storage area and the calculated peak flow hydrograph was then applied as an inflow to the modelled watercourse downstream of the pond. This approach was considered more conservative to be able to aid the design of culvert crossings, and therefore gives a worst-case scenario for flood risk in the areas adjacent to the Scheme.

[10] Chow, V.T. (1959) Open Channel Hydraulics. McGraw-Hill, New York.

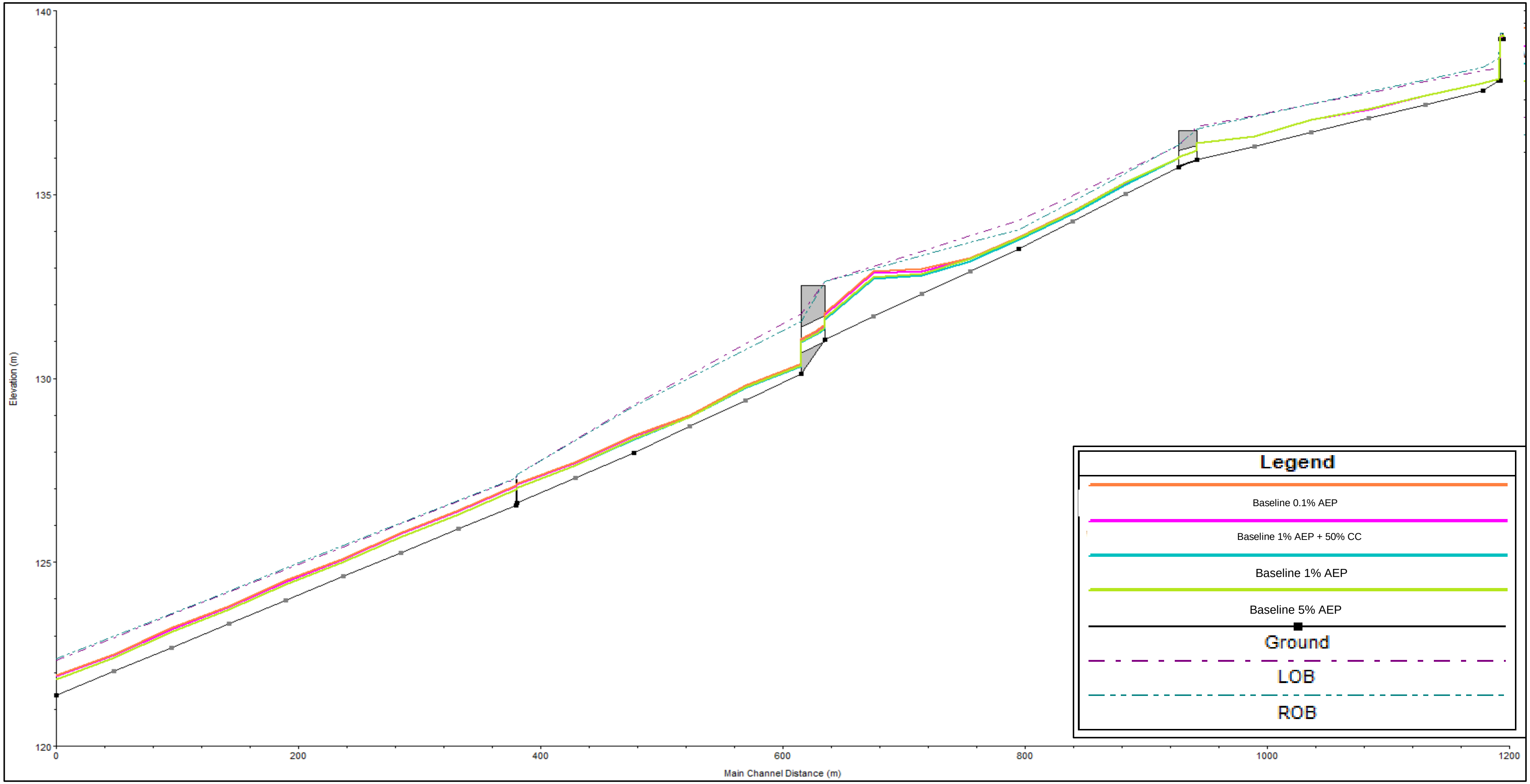
4.3.11 As a result, the model has simulations for both scenarios – the inclusion of Lower Pool at the upstream of the river reach (Baseline), and the exclusion of Lower Pool as the main source of flows for the river reach (conservative).

Baseline Model Results

4.3.12 The following model results are based upon the more conservative scenario with inflow hydrographs applied downstream of the pond, as discussed in the section on 'Sensitivity Testing'.

4.3.13 Figure 4.9Figure 4.9 shows a long profile of 1D model results on the Hilton Park watercourse. The 1D model shows low flood risk in the 5%, 1%, 1% + 50% Climate Change and the 0.1% AEP events, as there is no out of bank flooding in close vicinity to the proposed scheme.

Figure 4.9: All AEP maximum baseline water levels – Hilton Park watercourse



Sensitivity test

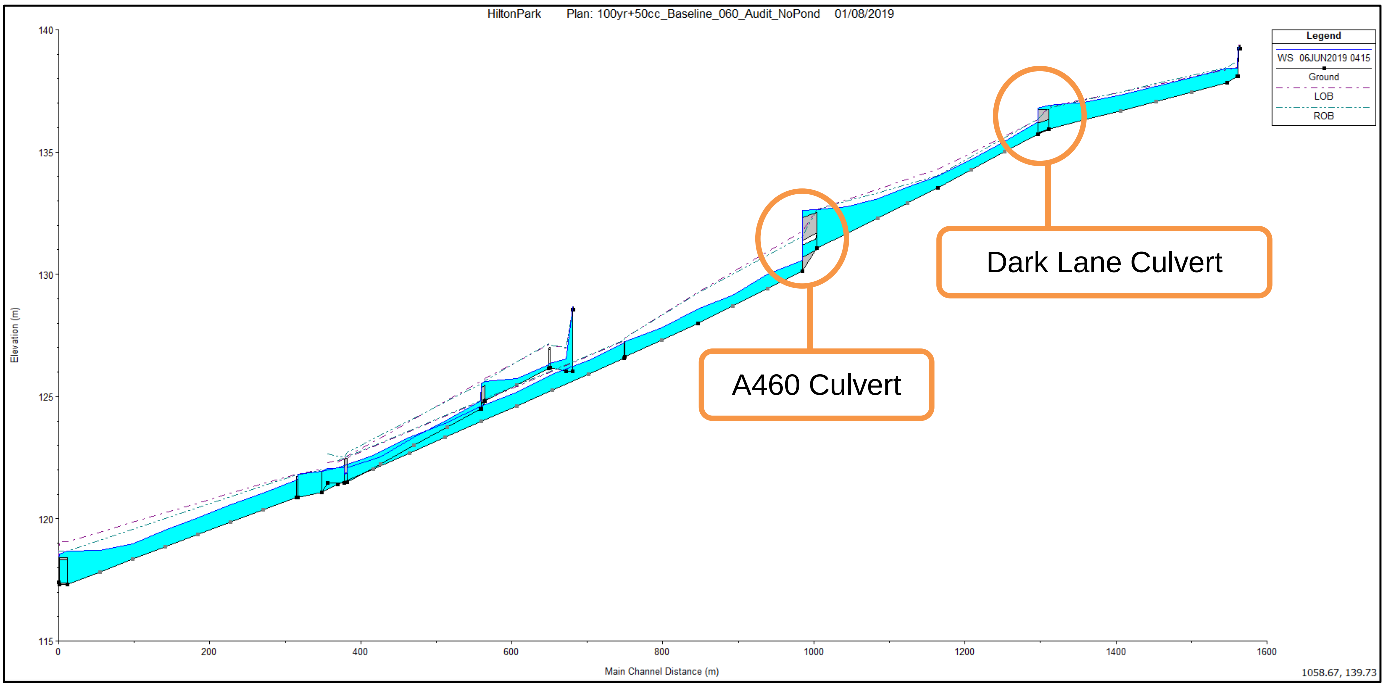


Figure 4.10: 1% AEP + 50% Climate Change event sensitivity test maximum water levels (inflow applied downstream of Lower Pool)

4.3.14 The model sensitivity test shows the impact of applying the hydrograph directly to the upstream reach. This is different to the Baseline approach, where the flows are applied directly to the Lower Pool (Figure 4.10).

4.3.15 In this scenario, modelled water levels are significantly higher at the upstream end of the model between the Lower Pool and the Dark Lane Culvert (Figure 4.11), resulting in out of bank flooding (Figure 4.10). There is also flooding at the A460 culvert. This sensitivity test shows how the Lower Pool benefits flood risk downstream.

4.3.16 This sensitivity test was used as an aid to culvert design for the Scheme, as it is considered a more conservative approach with regards to potential flows.

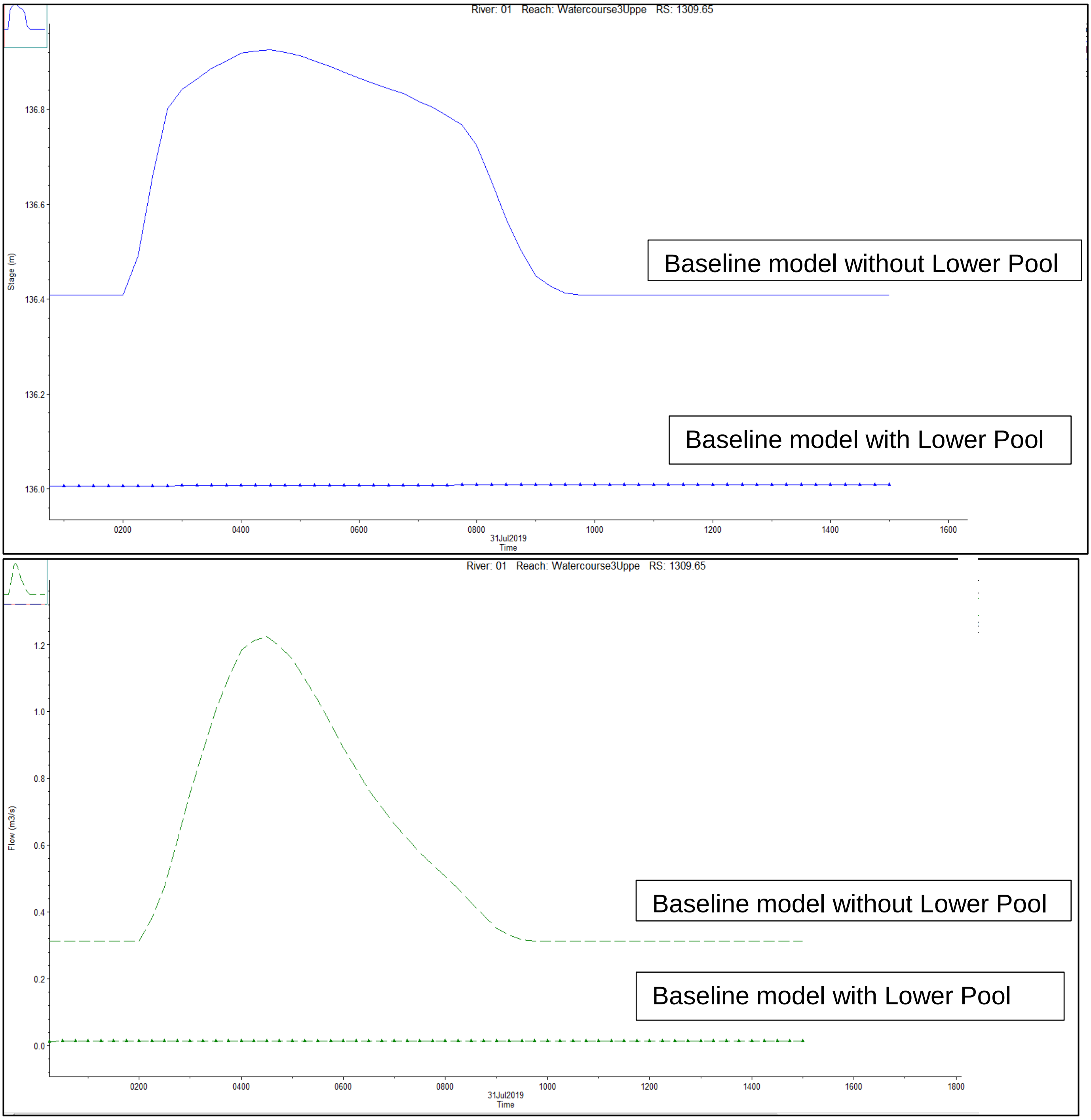


Figure 4.11: Sensitivity test stage and flow results for 1% AEP + 50% climate change allowance event showing the impact of exclusion of Lower Pool from the model.

Summary of Baseline results

4.3.17 Flooding does not occur in the model during any of the storm events tested.

4.3.18 However, sensitivity testing shows by applying upstream flows to the upstream cross-section rather than to Lower Pool, flood risk is increased, causing out of bank flooding.

4.3.19 The more conservative approach was taken forward for the sizing of scheme culverts, to allow minimum culvert sizes to be calculated based upon a worst case scenario.

4.3.20 However, the less conservative approach was taken forward for FRA as the arrangement of the Lower Pool at the head of the watercourse reflects the survey data.

4.4 Latherford Brook

Model Build

4.4.1 In addition to the general approach outlined in section 4.1 of this document, specific assumptions and decisions were made for the Latherford Brook model.

4.4.2 The model extents can be seen in Figure 4.12. There is already Environment Agency flood mapping available for Watercourse 5, however there is none available for Watercourse 4.

4.4.3 The Latherford Brook model was built as a HEC-RAS 1D-2D model, due to the presence of known Flood Zone 2 and 3 from the Environment Agency flood mapping.

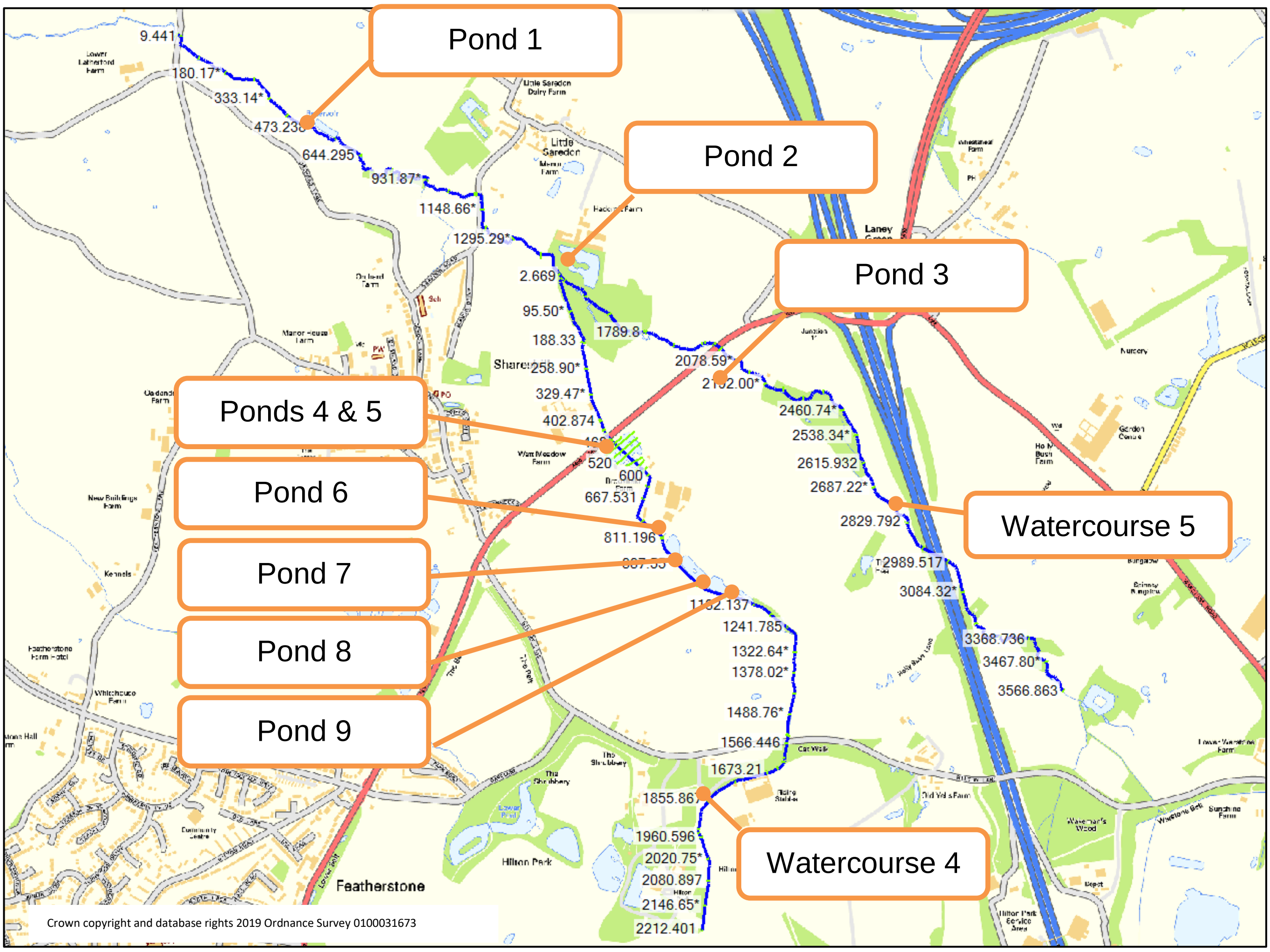


Figure 4.12: Overview of Latherford Brook model

Survey Data

4.4.4 The survey scope for topographic channel survey included a cross-section every 100m, or more frequently in areas of specific interest. There were no difficulties in obtaining permission from land owners concerning land access for the survey of this watercourse.

Manning's Roughness

4.4.5 A starting Manning's n roughness value of 0.05 to 0.06 for the river banks, and 0.035 to 0.04 in-channel has been applied[11]. Manning's (n) values have been adjusted where necessary based on the survey photographs.

Boundary Conditions

4.4.6 Boundary conditions were applied to the model, including lateral inflows. A summary of model boundary conditions and Lateral flows is included in Table 4.3.

Table 4.3: Summary of Boundary Conditions

Reach/Feature	Chainage	Boundary Condition type	Assumptions
Trib	2212.401	Upstream inflow hydrograph	Upstream REFH2 hydrograph used for inflows to this cross section.
Main_Upper	3566.863	Upstream inflow hydrograph	Upstream REFH2 hydrograph used for inflows to this cross section.
Main_Lower	851.697	Lateral inflow hydrograph	Baseflow applied to the pond which is at the top of the river reach.
Main_Lower	0000	Downstream Boundary	Normal depth. Assumed, based on gradient.
POND02	N/A	2D boundary condition line	Initial value of 1.9m^3/s
POND03	N/A	2D boundary condition line	Initial value of 5.75m^3/s
POND06	N/A	2D boundary condition line	Initial value of 1.0m^3/s
POND07	N/A	2D boundary condition line	Initial value of 1.7m^3/s
POND08	N/A	2D boundary condition line	Initial value of 1.2m^3/s
POND09	N/A	2D boundary condition line	Initial value of 0.2m^3/s

[11] Chow, V.T. (1959) Open Channel Hydraulics. McGraw-Hill, New York.

4.4.7 Hydrographs were also applied to six 2D storage areas which represent ponds adjacent to the watercourses. However, these hydrographs have an initial value at the first interval (see Table 4.3 for initial values), and after this has elapsed flow values applied are reduced to $0m^3/s$. This allows the ponds to begin the simulation with an initial volume of water contained within them, and replaces the requirement of an initial water level, if these storage areas had been modelled in 1D. After this, whilst the watercourse may interact with the ponds, however there are no additional flow applied by these 2D storage areas.

Baseline Model Results

5% AEP

4.4.8 Model results indicate that there is some out of bank flooding during the 5% AEP event. Most of this flooding occurs on the downstream reach of Watercourse 5.

4.4.9 In addition, a secondary channel is activated on Watercourse 5 through woodland close to Junction 11. It is in this area where the Scheme will cross the watercourse.

4.4.10 Aside from the secondary channel being activated, there is no out of bank flooding within proximity to the proposed scheme for Watercourse 5.

4.4.11 There is very little out of bank flooding for Watercourse 4 where the Scheme will cross the watercourse. The model is showing ponding in fields which are downstream of the proposed Watercourse 4 crossing. Changes to the terrain in this area as a result of the Scheme must not worsen flood risk.

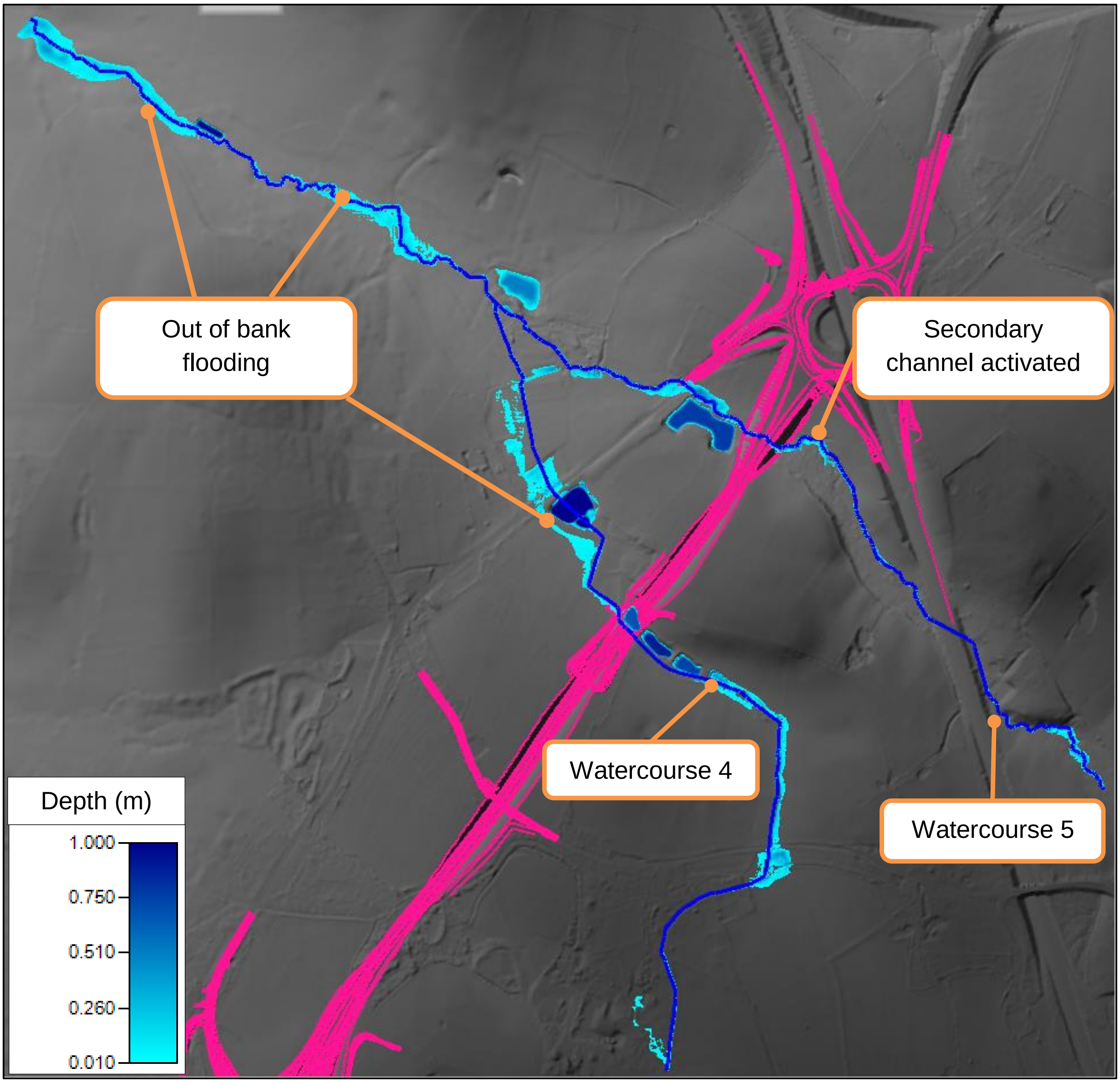


Figure 4.13: Latherford Brook - 5% AEP maximum water depth (m)

1% AEP

4.4.12 There is out of bank flooding during the 1% AEP event. Most of this flooding occurs on the downstream reach of Watercourse 5.

4.4.13 The area between the primary and secondary channel Watercourse 5 through woodland close to Junction 11 becomes inundated during this event, however depths are generally below 10cm. It is in this area where the Scheme will cross the watercourse.

4.4.14 In this scenario, a new flow path to the north of the channel is evident. This flow path does not reconnect with the main channel, and depths are less than 1cm.

4.4.15 There is very little out of bank flooding for Watercourse 4 where the Scheme will cross the watercourse. The model is showing ponding in fields which are downstream of the proposed Watercourse 4 crossing. Changes to the terrain in this area as a result of the Scheme must not worsen flood risk.

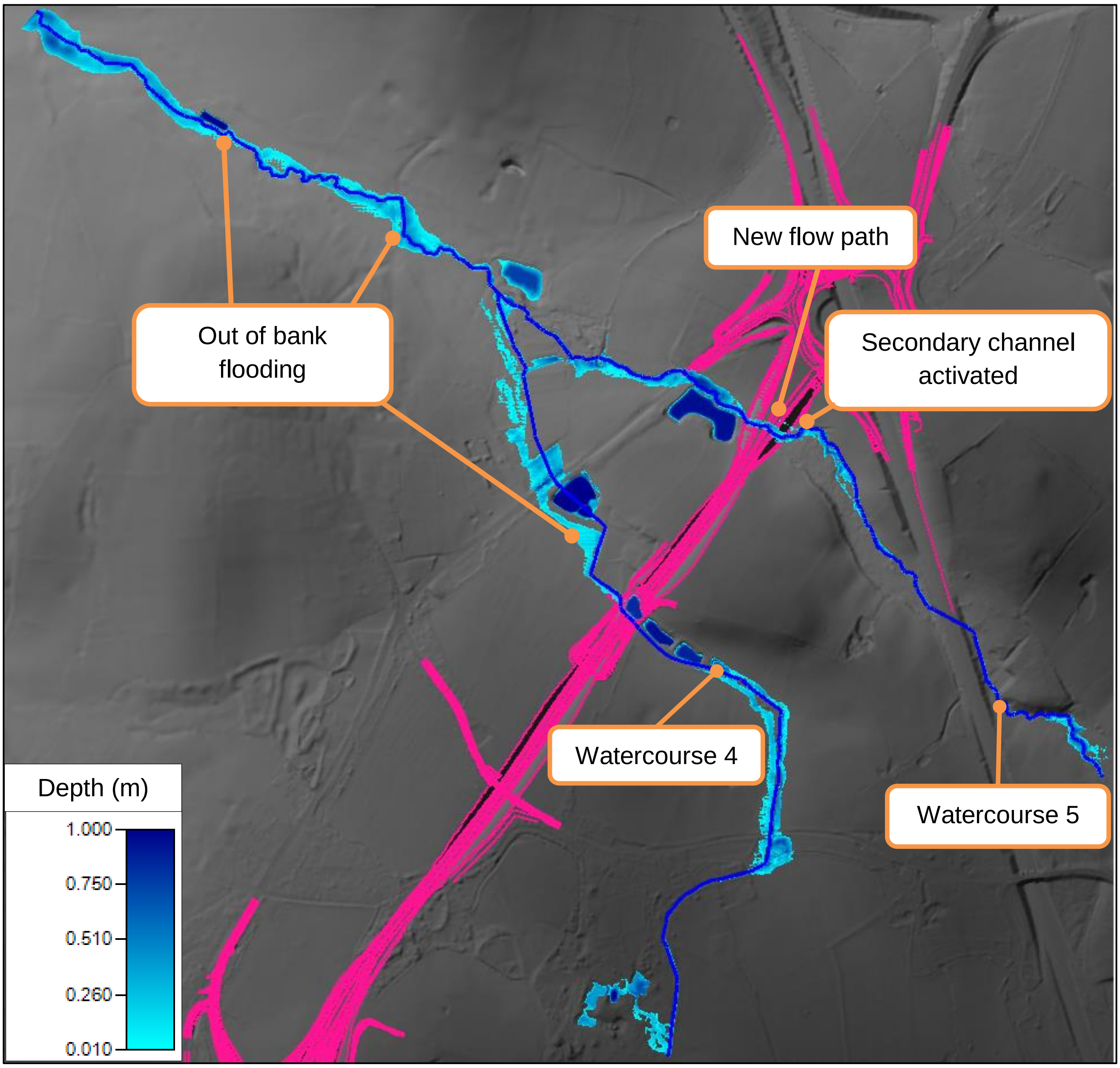


Figure 4.14: 1% AEP maximum water depth (m)

1% AEP + 50% climate change allowance

4.4.16 There is out of bank flooding during the 1% AEP + 50% climate change event. Most of this flooding occurs on the downstream reach of Watercourse 5. The extents of this flooding are noticeably wider than the 1% AEP event. However, Watercourse 5 out of bank flood depths upstream of the proposed alignment vary between 3cm and 10cm, in the 1% AEP + 50% climate change allowance event.

4.4.17 The new flow path which emerged in the 1% AEP event is more established during the 1% AEP + 50% climate change allowance event, however depths are on average 1cm.

4.4.18 The area between the primary and secondary channel Watercourse 5 through woodland close to Junction 11 becomes inundated during this event with depths between 1 cm and 30 cm. It is in this area where the Scheme will cross the watercourse.

4.4.19 There is very little out of bank flooding for Watercourse 4 where the Scheme will cross the watercourse. The model is showing ponding in fields which are downstream of the proposed Watercourse 4 crossing. Changes to the terrain in this area as a result of the Scheme must not worsen flood risk.

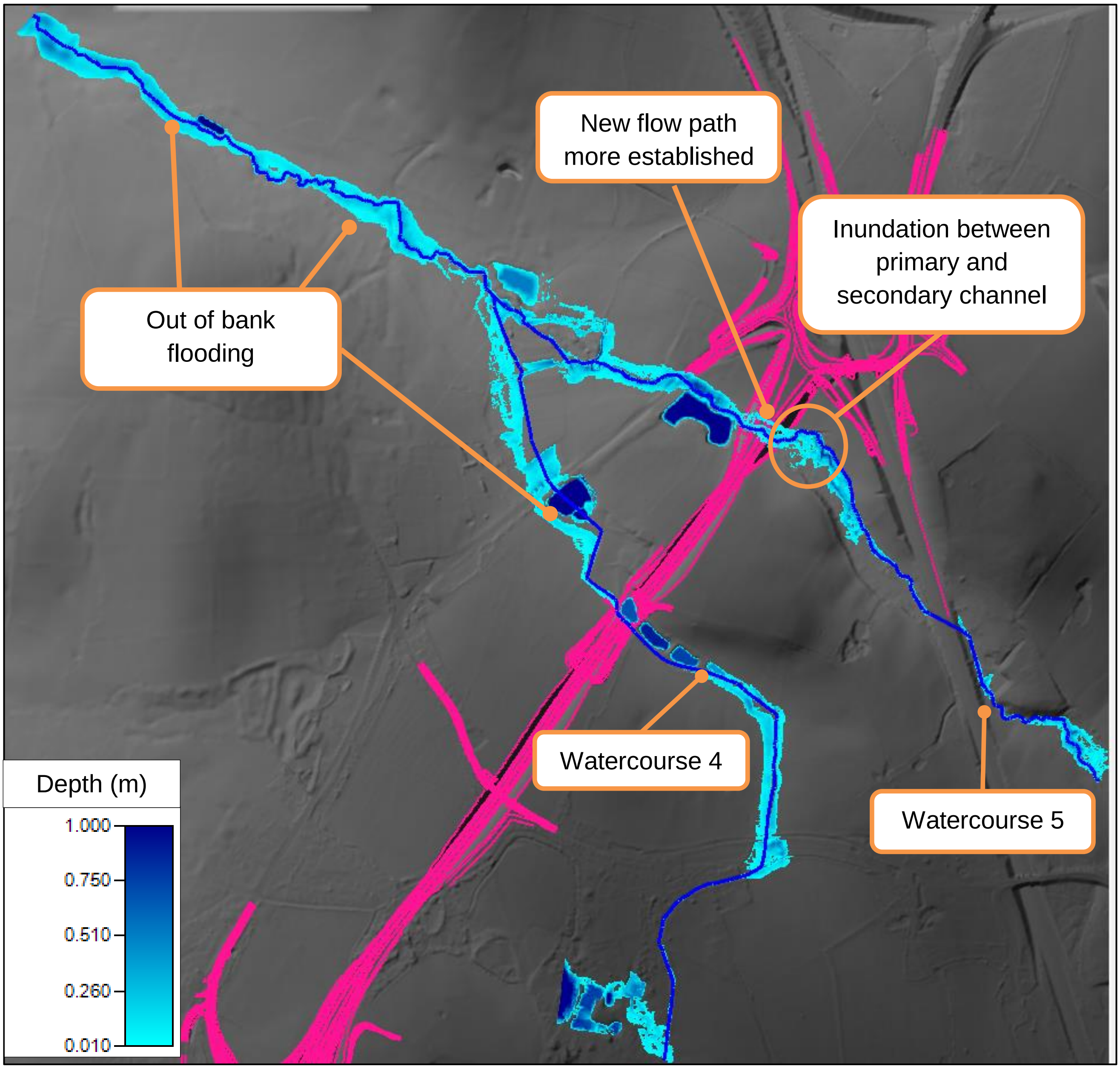


Figure 4.15: 1% AEP + 50% climate change allowance maximum water depth (m)

0.1% AEP

4.4.20 There is out of bank flooding during the 0.1% AEP event. Most of this flooding occurs on the downstream reach of Watercourse 5. The extents of this flooding are very similar to the 1% AEP + 50% climate change event. However, Watercourse 5 out of bank flood depths upstream of the proposed alignment vary between 4 cm and 10cm in the 0.1% AEP event.

4.4.21 The new flow path mentioned in the 1% AEP event is more established during the 0.1% AEP event, however depths are on average 1cm.

4.4.22 The area between the primary and secondary channel Watercourse 5 through woodland close to Junction 11 becomes inundated during this event with depths between 1 cm and 3cm. It is in this area where the Scheme will cross the watercourse.

4.4.23 There is very little out of bank flooding for Watercourse 4, and none where the Scheme will cross the watercourse.

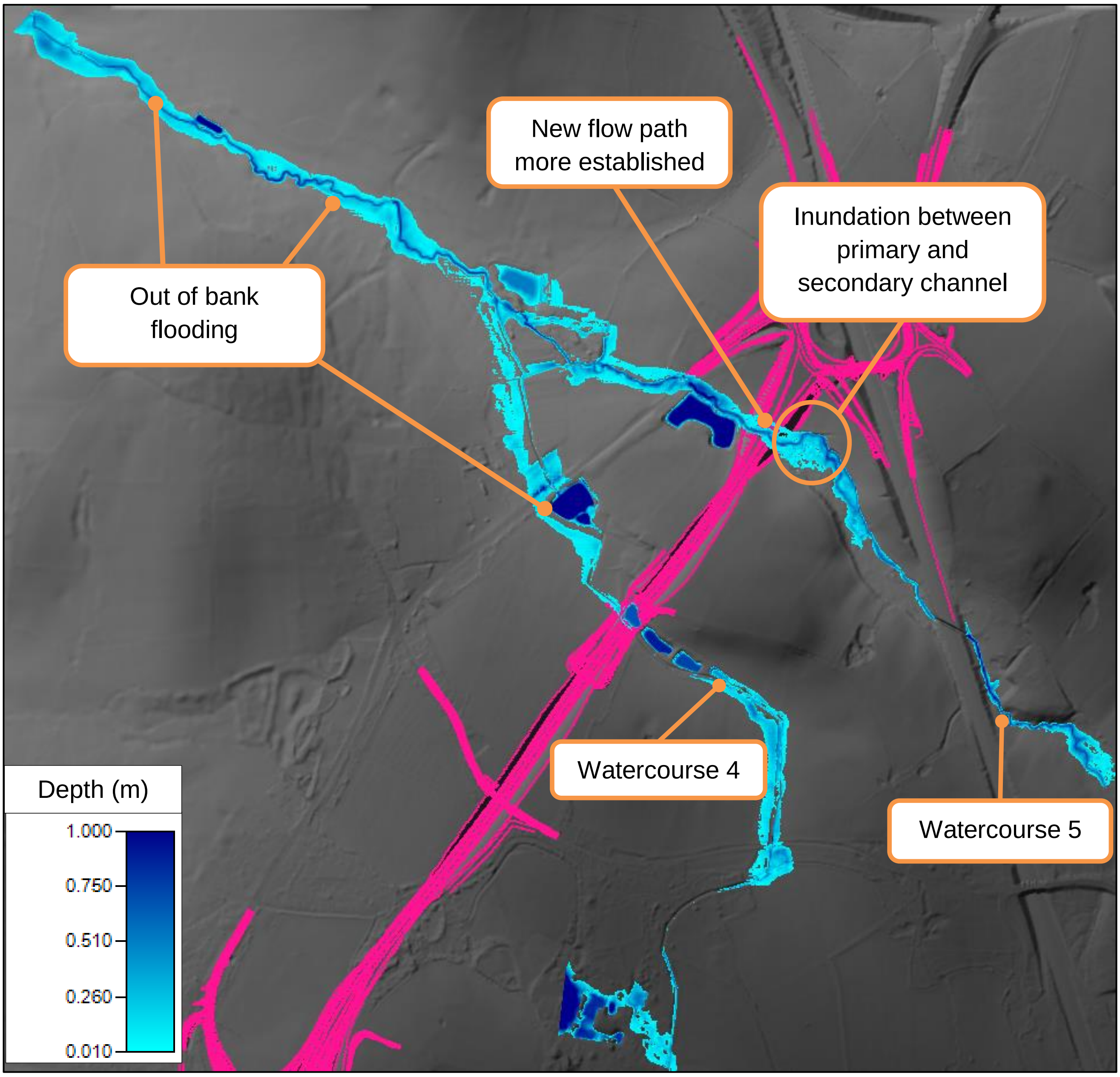


Figure 4.15: 0.1% AEP maximum water depth (m)

JFLOW Flood Zone 2 and 3 comparison

4.4.24 The flood extents indicated by the Latherford Brook HEC-RAS model for the 1% AEP event is significantly less extensive than the JFLOW modelling results. Consequently, the HEC-RAS modelling undertaken has reduced the number of receptors which need to be considered as part of the FRA. There are buildings at Hadcroft farm which were with in Flood Zone 2, which are not shown to flood in the 1% AEP or 0.1% AEP events in the HEC-RAS model. There is more confidence in the outputs of the Latherford Brook HEC-RAS modelling than the JFLOW modelling results used for the Environment Agency Flood Zones as this is more detailed flood modelling, including channel survey and LiDAR data and with flows calculated by the latest ReFH2 methodology.

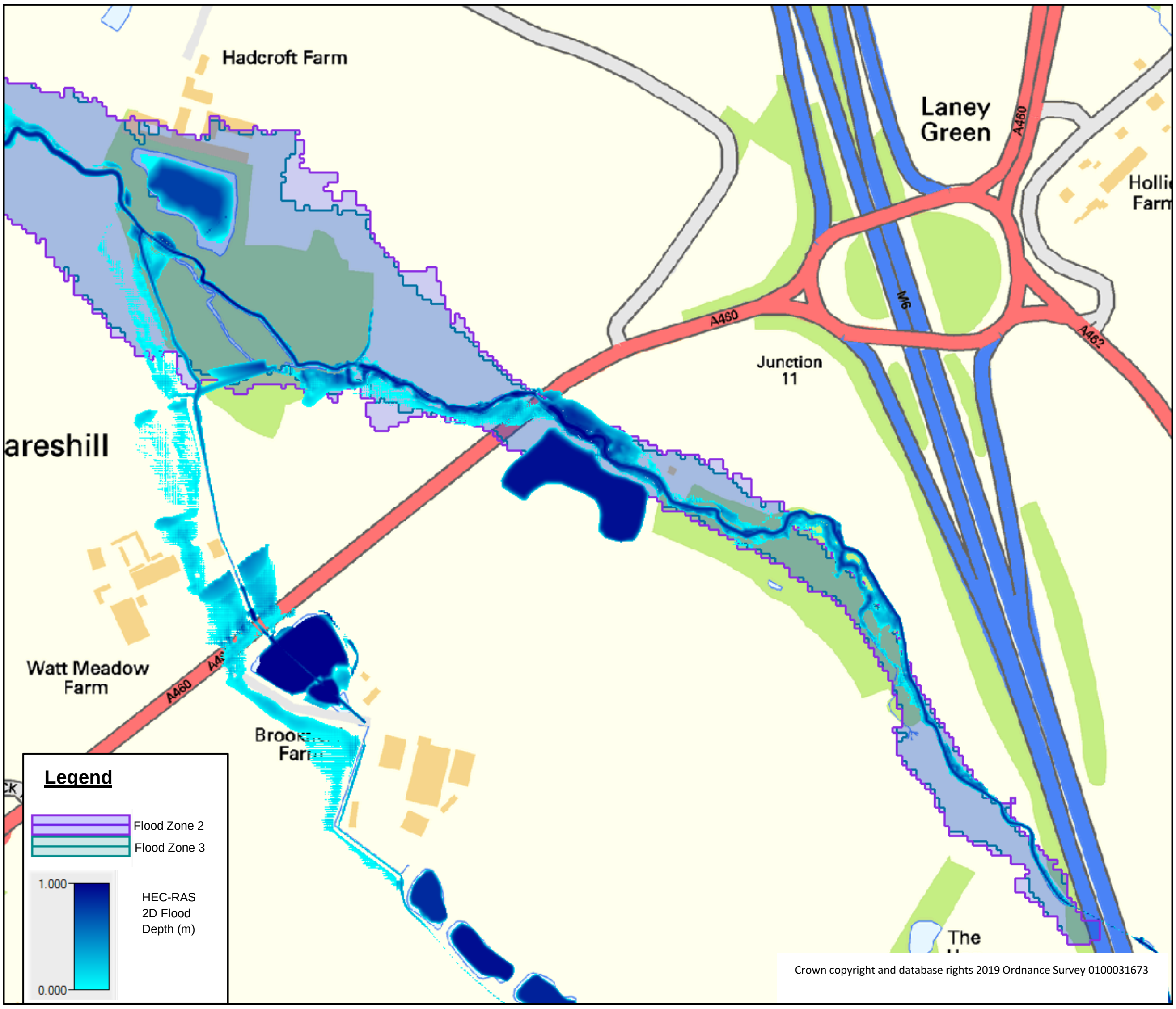


Figure 4.16: Environment Agency JFLOW model Flood Zone 2 and 3 outlines compared to Latherford Brook HEC-RAS model results for 1% AEP event

Summary of Baseline results

4.4.25 The model shows out of bank flooding in all the design storms tested.

4.4.26 The flood extents for the 1% AEP + 50% climate change allowance are similar to the 0.01% AEP event flood extents.

4.4.27 Watercourse 5 out of bank flood depths upstream of the proposed alignment vary between 3cm and 10cm in the 1% AEP + 50% climate change allowance event.

4.4.28 In channel velocities where the Scheme will dissect watercourse 5 peak at 1.26m/s in the 1% AEP + 50% climate change allowance event

4.4.29 The flood extents for the 1% AEP event is significantly less extensive than the JFLOW modelling results.

4.5 Wheatsheaf Farm

Model Build

4.5.1 In addition to the general approach outlined in section 4.1 of this document, specific assumptions and decisions were made for the Wheatsheaf Farm model.

4.5.2 The Wheatsheaf Farm model was built as a HEC-RAS 1D model. After an assessment of peak flows during a 1% AEP + 50% climate change allowance event, it was decided not to convert the model to 2D as out of bank flooding was not predicted in the vicinity to the Scheme. In addition, there are no scheme works which will directly affect the watercourse, so the primary purpose of building the model was to ascertain whether there were any new areas of Flood Zone 2 or 3 which may impact the Scheme.

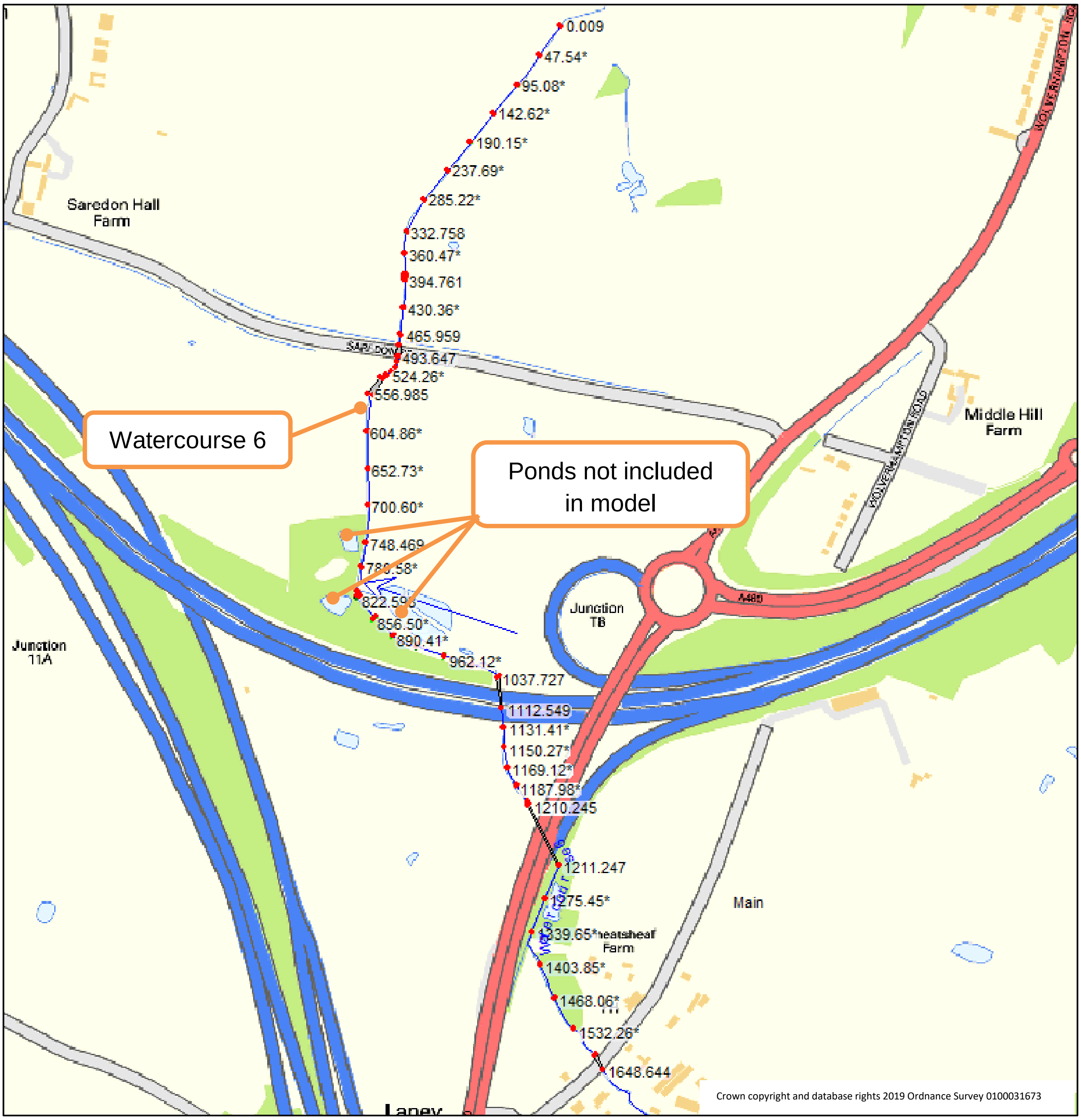


Figure 4.17: Overview of Wheatsheaf Farm model extents

4.5.3 The model extents can be seen in Figure 4.17. There is no Environment Agency flood mapping available for this watercourse.

Survey Data

4.5.4 The survey scope for topographic channel survey included a cross section every 100m, or more frequently in areas of specific interest. There were difficulties in obtaining permission from land owners concerning land access for survey, particularly at the upstream of this watercourse. Where access was unavailable, model interpolation tools have been used to create cross-sections.

4.5.5 Ponds were initially included in the model however given a lack of evidence from survey data as to whether these ponds were online, these ponds were removed from the model. This provides a more conservative approach to flood risk.

Manning's Roughness

4.5.6 An initial Manning's n roughness of between 0.035 to 0.05 for the river banks, and 0.03 to 0.045 in-channel was applied[12]. Manning's (n) values have then been adjusted where necessary based on the survey photographs.

Boundary Conditions

4.5.7 Boundary conditions were applied to the model, including lateral inflows. A summary of model boundary conditions and Lateral flows is included in Table 4.4.

Table 4.4: Summary of Boundary Conditions

Reach	Chainage	Boundary Condition type	Assumptions
Watercourse6	1691	Upstream inflow hydrograph	Upstream baseflow applied to cross section
Watercourse6	1648.644	Upstream inflow hydrograph	Upstream REFH2 hydrograph used for inflows to this cross section.
Watercourse6	465.959	Lateral inflow hydrograph	Based upon calculations between Upstream and Downstream REFH2 calculations. Survey photos confirm locations of lateral inflows
Watercourse6	0.009	Downstream Boundary	Normal depth. Assumed, based on gradient.

Baseline Model Results

5% AEP

4.5.8 As shown in the long profile in Figure 4.18, the 1D model shows low flood risk in the 5% AEP event, as there is no out of bank flooding within close proximity to the proposed scheme.

[12] Chow, V.T. (1959) Open Channel Hydraulics. McGraw-Hill, New York.

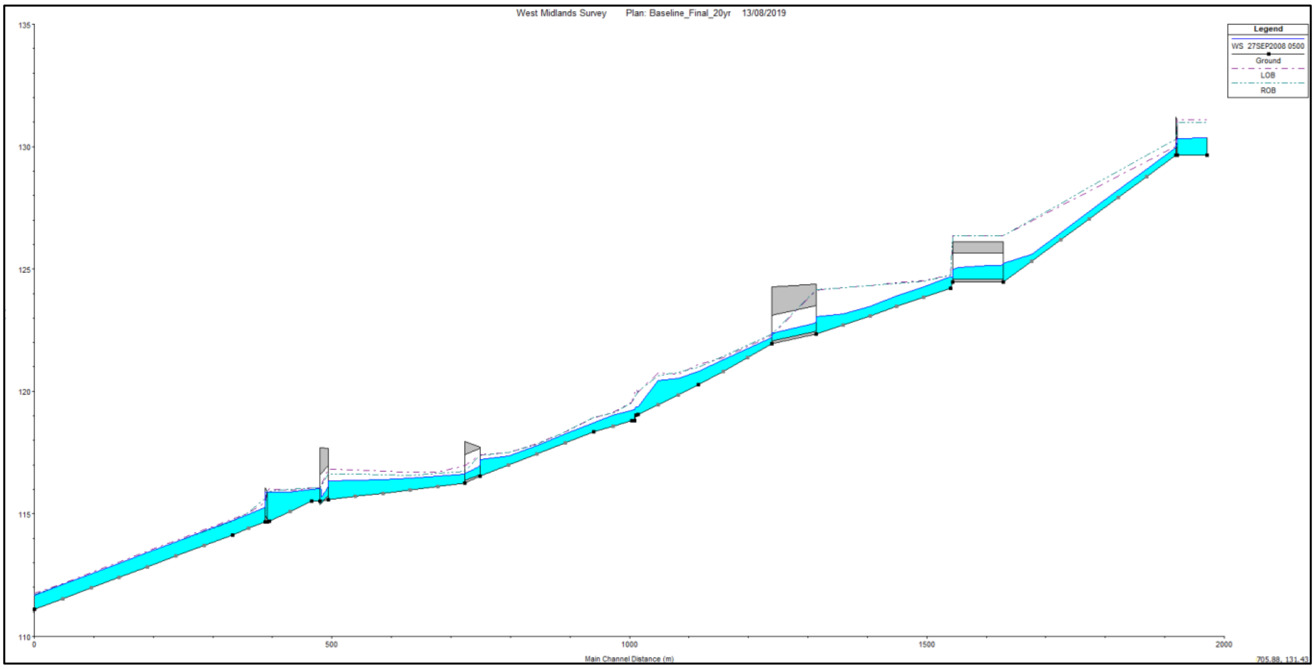


Figure 4.18: 5% AEP maximum water levels

1% AEP

4.5.9 Again, the modelled long-profile results shows low flood risk in the 1% AEP event, as there is no out of bank flooding within close proximity to the proposed scheme.

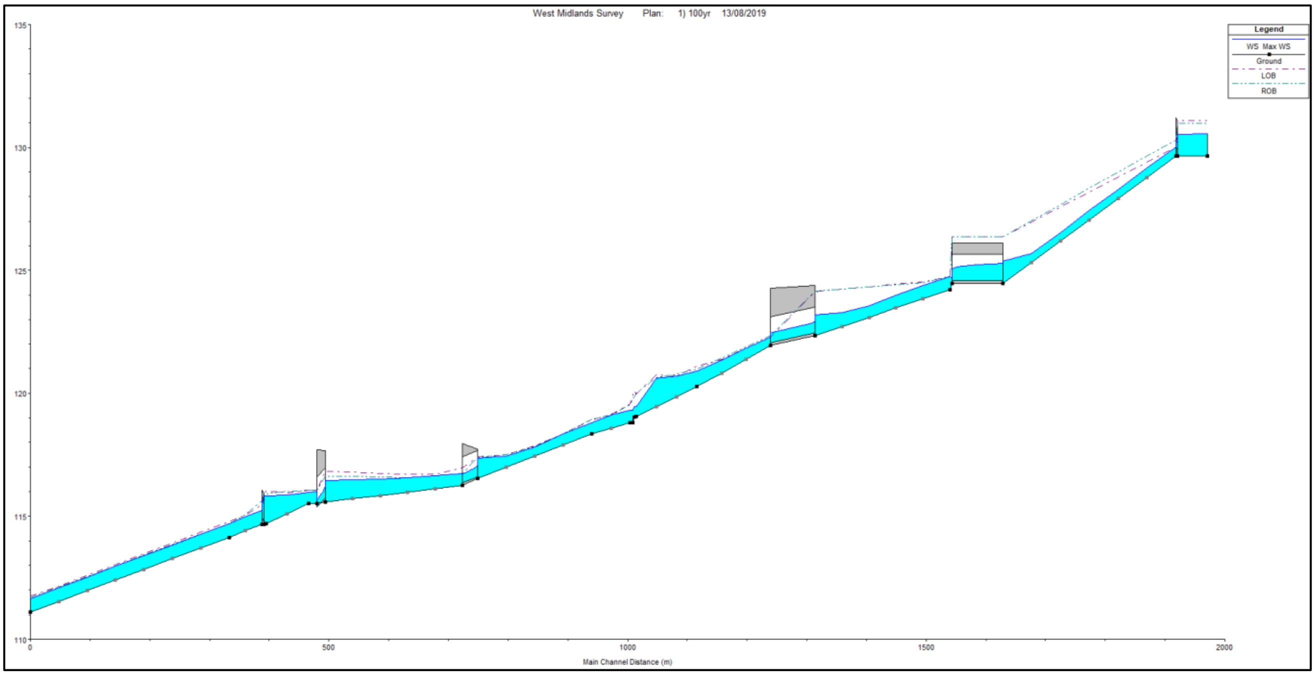


Figure 4.19: 1% AEP maximum water levels

1% AEP + 50% climate change allowance

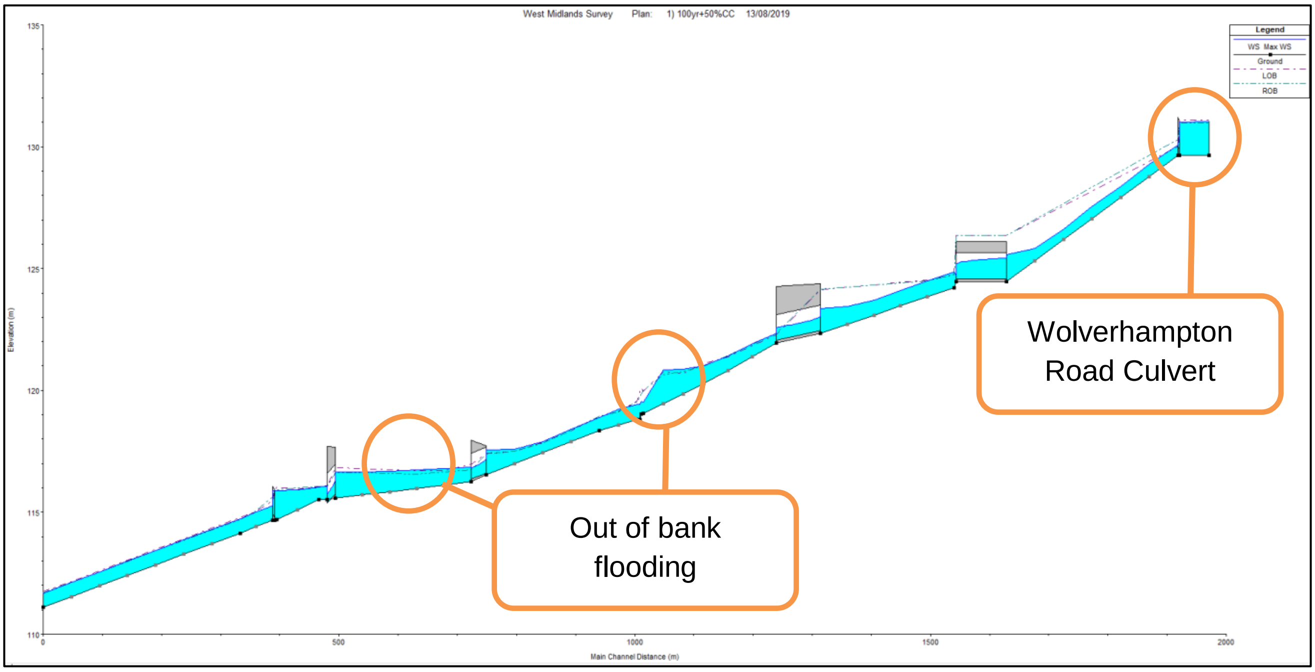


Figure 4.20: 1% AEP +50% climate change allowance maximum water levels

4.5.10 Figure 4.20 shows the 1D model results as a long profile for the climate change scenario.

4.5.11 The upstream cross-section of the Wolverhampton Road Culvert at the upstream of the model experiences out of bank flooding in the 1% AEP + 50% climate change event. This culvert has two barrels, and the 2019 survey found that the second barrel was blocked to a depth of 31cm, significantly reducing the capacity of the culvert. This means that the water upstream of the culvert achieves a level of 131.2mAOD, putting the Wolverhampton Road at risk of flooding, see cross-section in Figure 4.21. This instance of out of bank flooding is not in close vicinity to the proposed Scheme and therefore is not considered as a threat to the Scheme.

4.5.12 In addition to this, out of bank flooding is predicted between cross-sections 856.50 and 890.41, as well as 508.96 and 604.86. These areas of out of bank flooding are in areas where the cross-sections have been interpolated because of inaccessibility at the time of the survey. Therefore, whilst the model predicts out of bank flooding in these areas, there is lower confidence in these sections of the model.

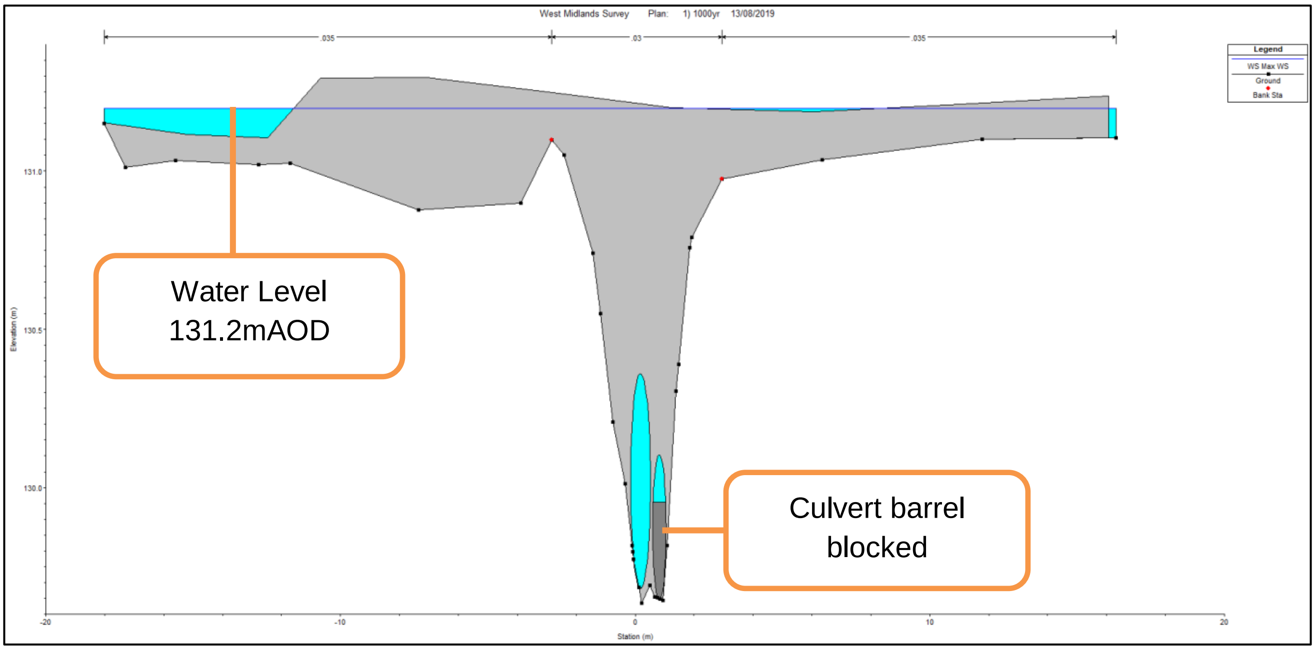


Figure 4.21: 1% AEP + climate change allowance maximum water levels with culvert blockage

4.5.13 However, model tests show that removing the blockage will eliminate this flood risk without causing increases to flood risk downstream in the 1% AEP + 50% climate change event as shown in the cross-section in Figure 4.22 and the long profile in Figure 4.23.

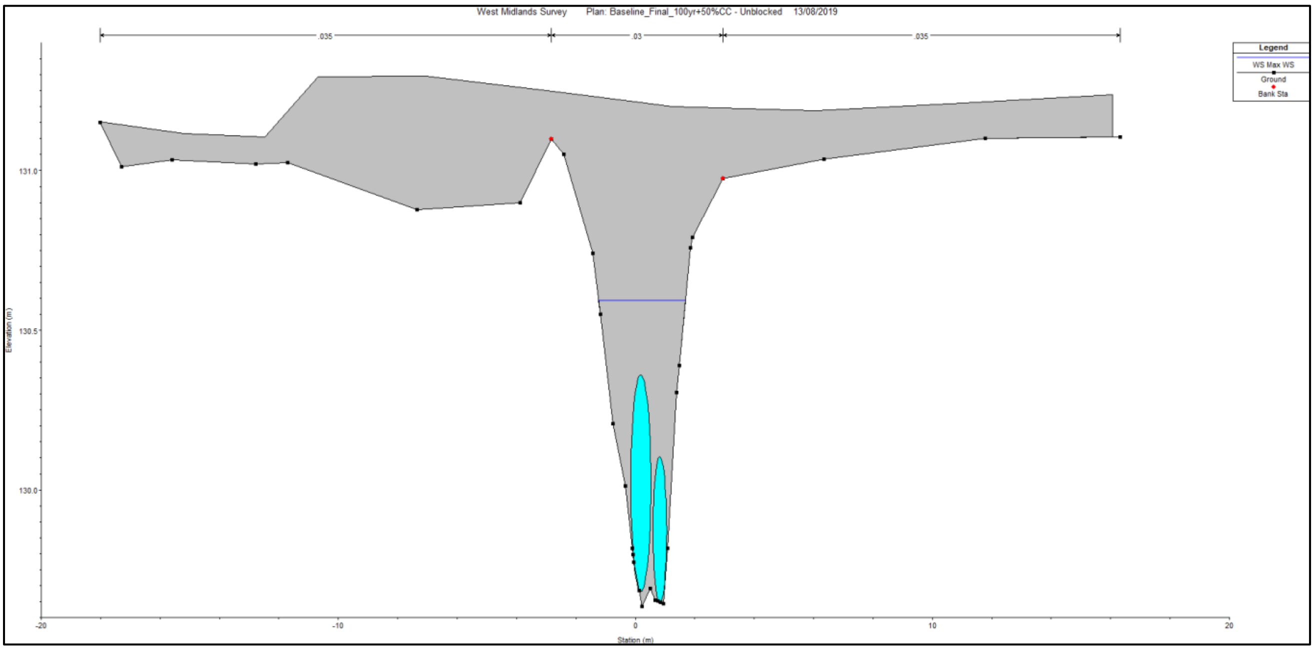


Figure 4.22: 1% AEP + 50% climate change allowance maximum water levels without culvert blockage

4.5.14 Whilst this area would not be affected by the Scheme, it would be beneficial to flood risk locally for maintenance to be undertaken on this existing culvert by the LLFA to restore its full capacity.

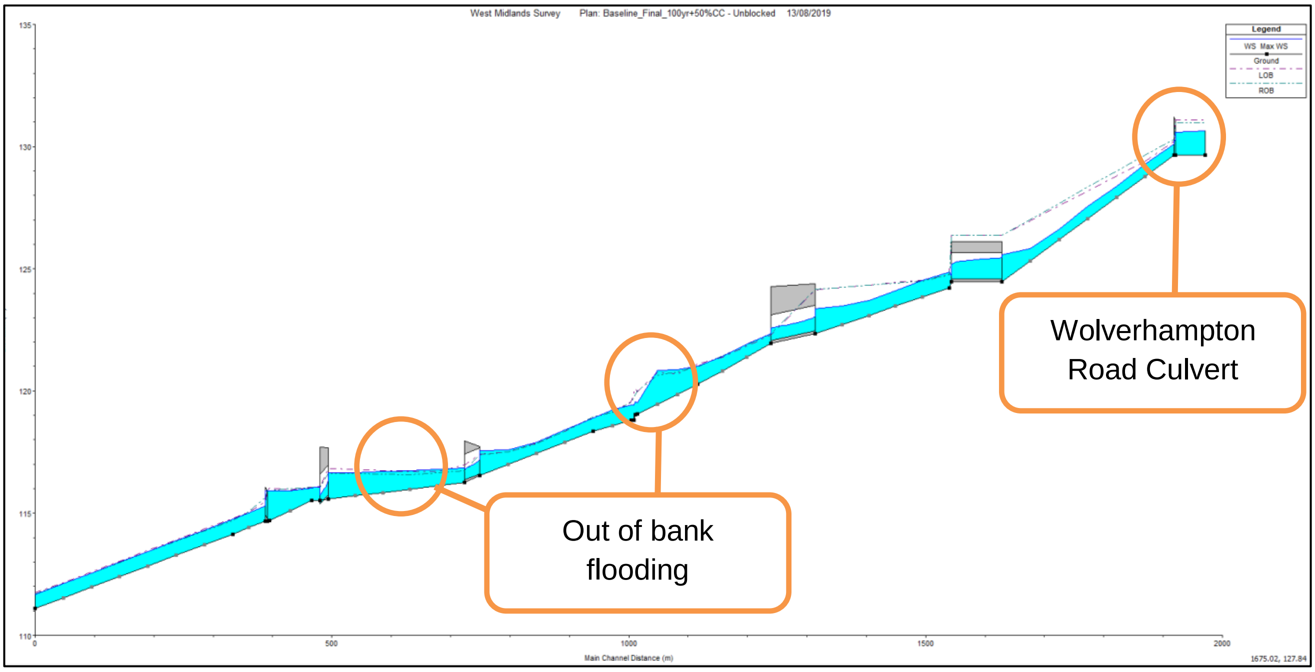


Figure 4.23: 1% AEP + 50% climate change allowance maximum water levels without culvert blockage long section

0.1% AEP

4.5.15 In a similar pattern to the 1% AEP + 50% climate change event, the upstream cross-section of culvert 1598.643 at the Wolverhampton Road culvert experiences out of bank flooding in the 0.1% AEP.

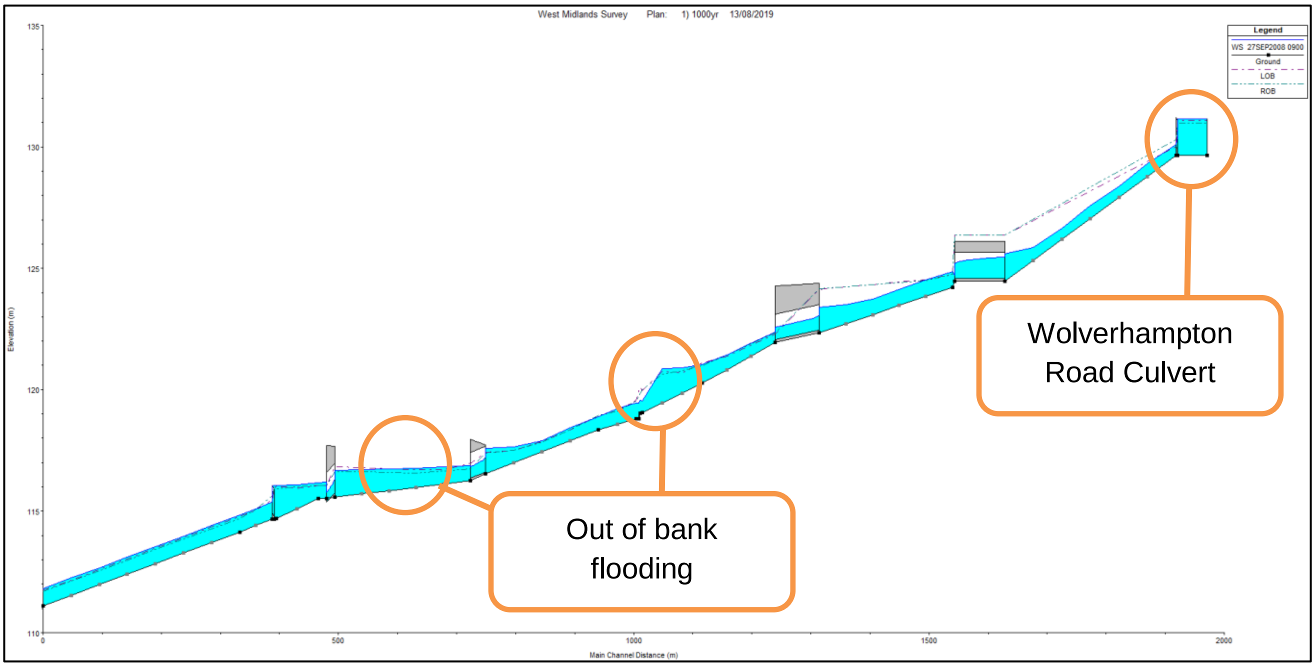


Figure 4.24 - 0.1% AEP maximum water levels

4.5.16 As in the climate change scenario, model tests show that this flood risk is alleviated by removing the blockage from the culvert in the 0.1%AEP event

Summary of Baseline results

4.5.17 Out of bank flooding does not occur in the 5% or 1% AEP events according to the model.

4.5.18 The model results show that out of bank flooding does occur in the 1% AEP event with a` climate change allowance of 50%, and in the 0.1% AEP flood event. This flooding is not within the vicinity of the proposed scheme. Flood risk during these events would be reduced if the Wolverhampton Road culvert was cleared of the silt currently causing a blockage.

4.5.19 Other areas which demonstrate out of bank flooding in the model are areas which were inaccessible due to land access permissions. In these reaches, cross sections have been interpolated and there is less confidence in the model. These areas are not with in the vicinity of the proposed Scheme.

4.5.20 There are no new areas of Flood Zone 2 or 3 which will impact the Scheme.

5 Option Development

5.1.1 Following an audit of each baseline model, the Scheme design drawings (The General Arrangement Scheme Layout Plans as shown in Application Document 3.2 [TR010054/APP/3.2]) were obtained and built in to the model to assess flood risk to the Scheme and the potential impacts of the Scheme on flood risk from these watercourses. Once the model had been stabilised, the same probability flood events were simulated.

5.2 Tower House Farm

5.2.1 The Scheme design for this location includes:

- Diversion of the watercourse approximately 80m to the north of its current channel. It has been assumed that similar channel dimensions to the existing watercourse would be implemented. Therefore, the route was interpolated from the geometry of existing cross sections.
- A new 1.2m diameter circular culvert ('minor' culvert shown in Figure 5.1) to the east of the new carriage way which will pass underneath the feeder road for a new with a length of approximately 58m.
- A new 2m wide x 1m high box culvert ('main' culvert shown in Figure 5.1) passing underneath the new carriageway, with a length of approximately 182m. This has been assumed to be made of concrete, and a Manning's n of 0.011 applied. Cross-sections to the downstream of this new culvert are widened to provide some additional storage during large storm events.

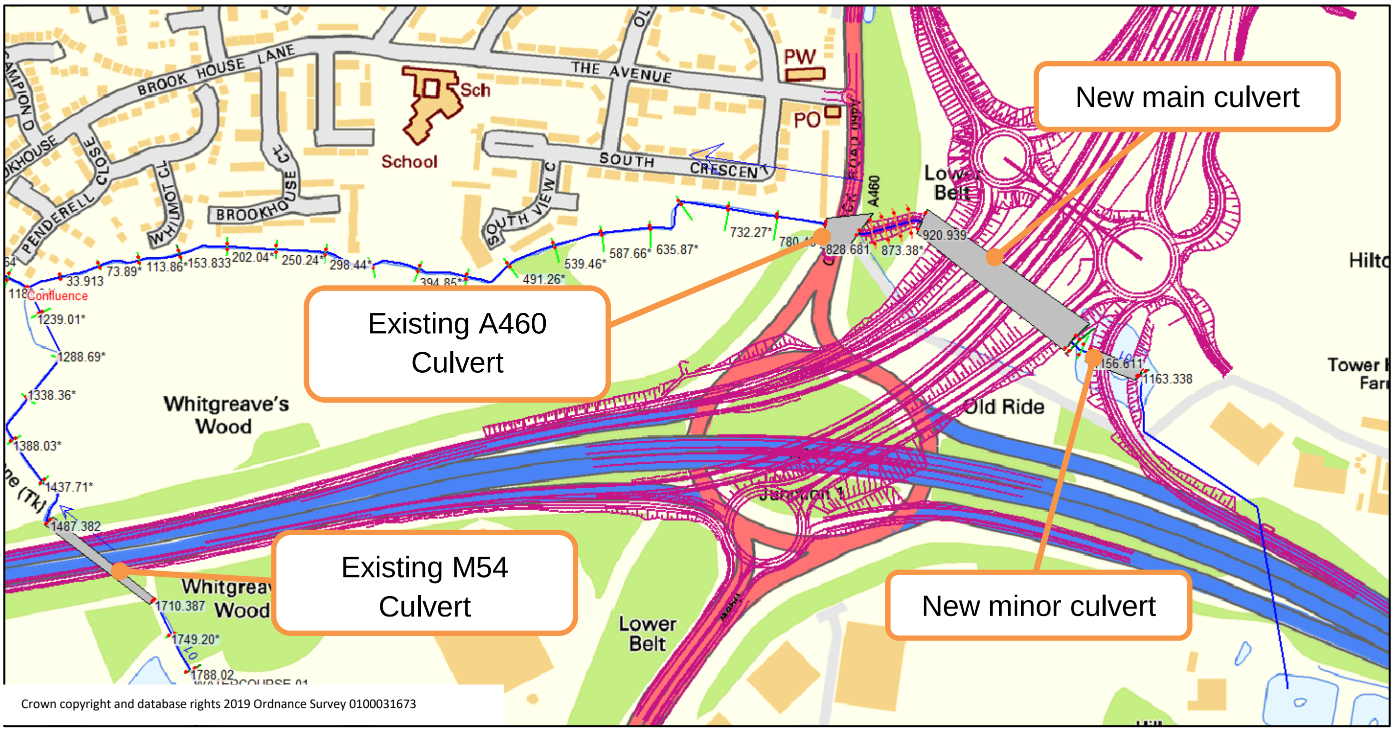


Figure 5.1: Watercourse 1 & 2 general scheme arrangement. Scheme alignment is shown in pink.

Scheme Model Results

50% AEP

5.2.2 The 1D model shows low flood risk in the 50% AEP event, as there is no out of bank flooding in close vicinity to the proposed scheme. Whilst this scenario was not requested by the Environment Agency or LLFA, this return period was tested to understand freeboard and culvert capacity during a frequently occurring event. At peak flows, the model shows that even during a low magnitude event, the existing A460 culvert which has a diameter of 580mm causes water to back up the channel. A freeboard of 610mm is achieved within the main culvert.

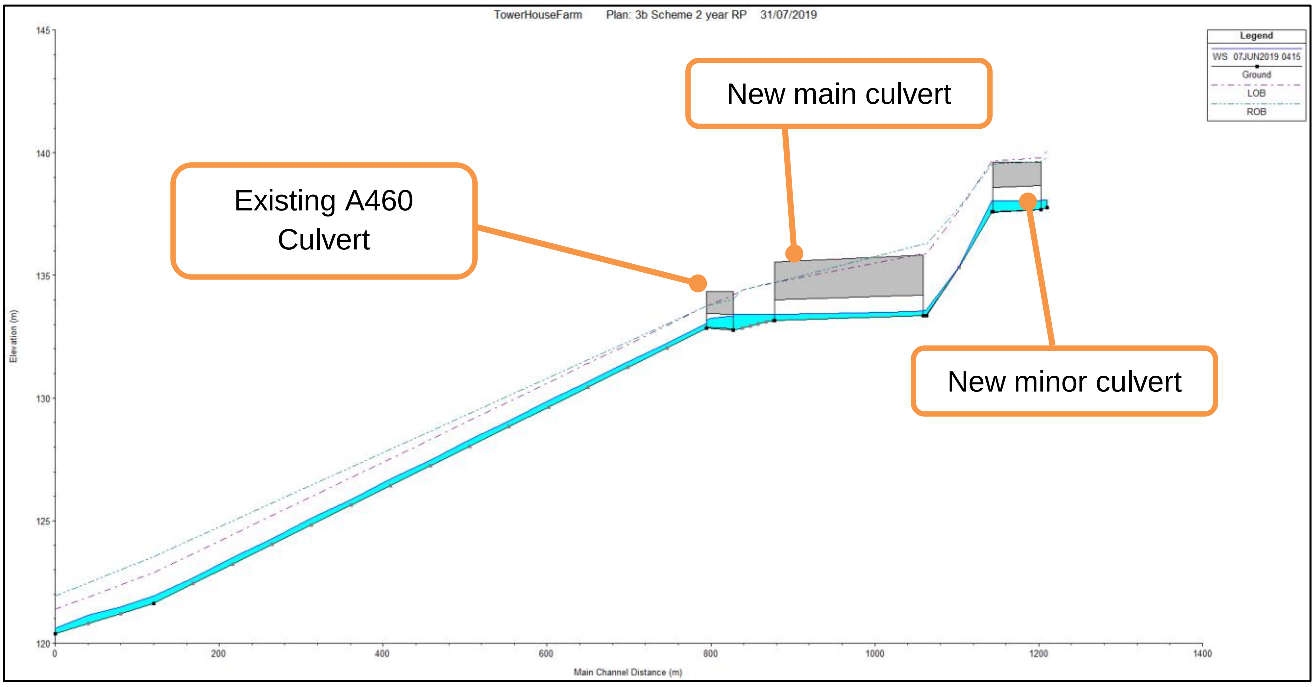


Figure 5.2: 50% AEP maximum water levels with the Scheme culverts in place

5% AEP

5.2.3 The 1D model shows low flood risk in the 5% AEP event, as there is no out of bank flooding in close vicinity to the proposed scheme. At the peak of the storm event, the existing A460 culvert causes water to back up the channel. A freeboard of 540mm is achieved within the main culvert.

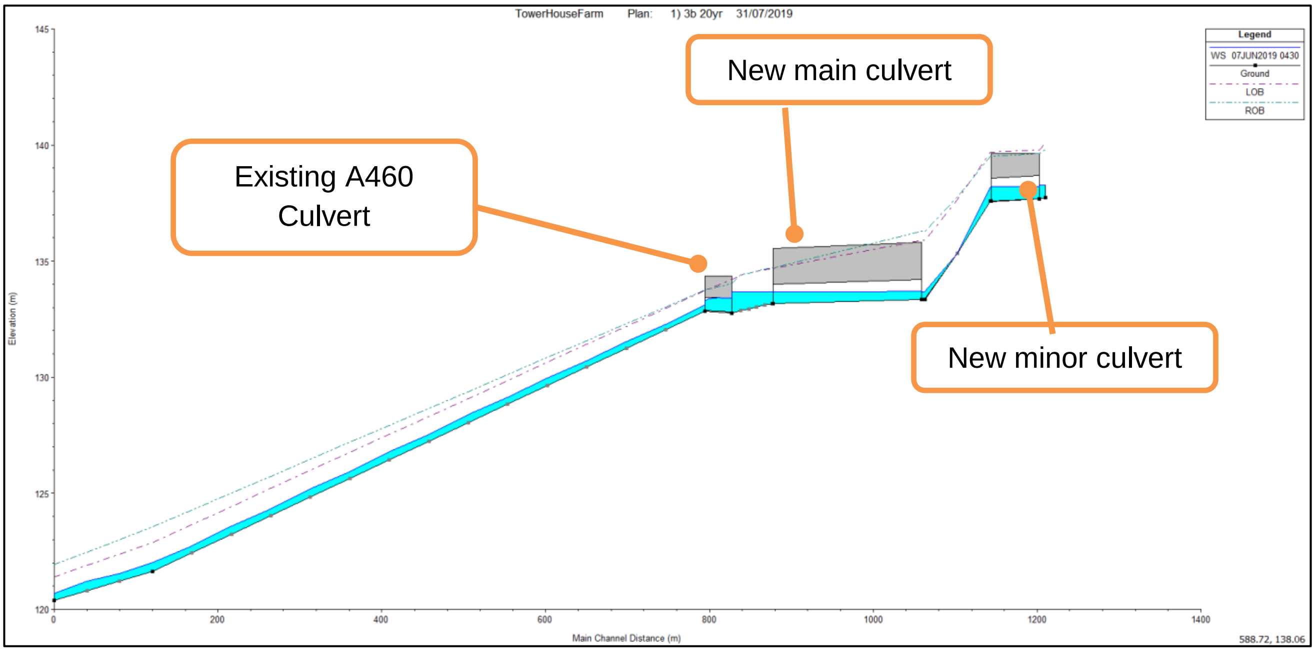


Figure 5.3: 5% AEP maximum water levels with the Scheme culverts in place

1% AEP

5.2.4 The 1D model shows low flood risk in the 1% AEP event, as there is no out of bank flooding in close vicinity to the proposed scheme. At the peak of the storm event, the existing A460 culvert causes water to back up with in the channel. A freeboard of 140mm is achieved within the main culvert, however the downstream face of the main culvert has become submerged as a result of water backing up from the existing A460 culvert.

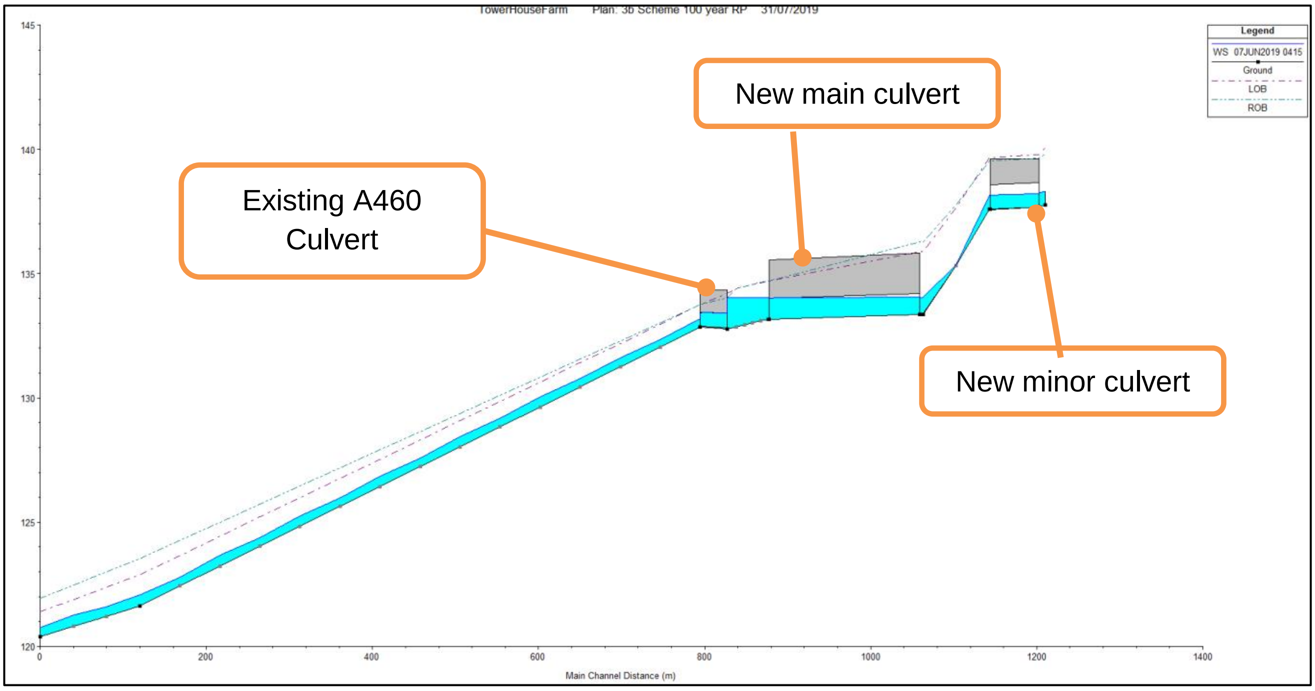


Figure 5.4: 1% AEP maximum water levels with the Scheme culverts in place

1% AEP + 50% climate change allowance

5.2.5 The 1D model shows flood risk in the 1% AEP event with 50% climate change allowance, with out of bank flooding at the existing A460 culvert. At the peak of the storm event, the existing A460 culvert causes water to back up the channel. There is no freeboard during this event as both the upstream and downstream end of the main culvert has become submerged as a result of water backing up the channel from the existing A460 culvert.

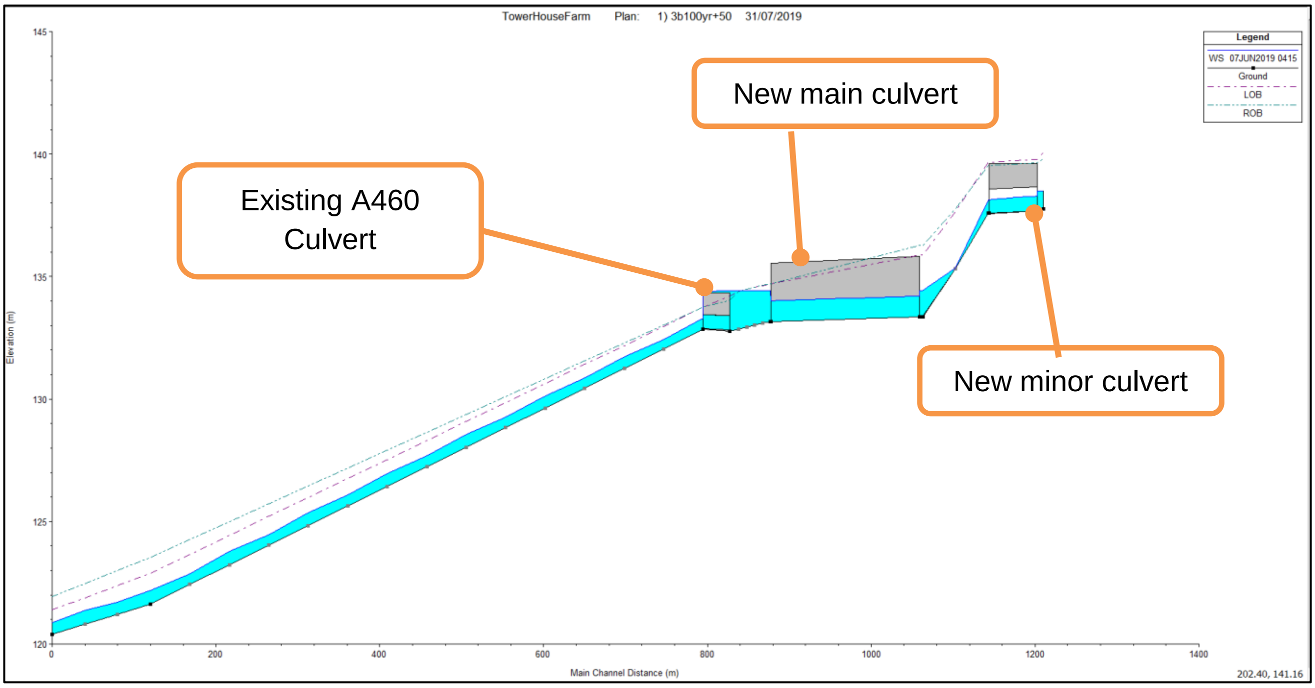


Figure 5.5: 1% AEP + 50% climate change allowance maximum water levels

5.2.6 The flood risk to the A460 has been summarised in Table 5.1.

Table 5.1: Comparison between Baseline and Scheme scenarios for a 1% AEP + 50% climate change allowance event at the A460 culvert

	Baseline	**With Scheme**
Peak Stage	134.41mAOD	134.41mAOD
Peak Flow	1.03m^3/s	1.05m^3/s
Potential flood depth on A460 Road	4 cm	4 cm

5.2.7 Analysis of stage and flows at the A460 culvert (Figure 5.6 and Table 5.1) shows no difference in the peak stage at the culvert between the baseline and the with scheme models. With the Scheme culverts in place, model results suggest peak flows occur approximately 30 minutes earlier than the baseline model.

5.2.8 Figure 5.6 shows a very minor increase in peak flow (0.03m^3/s) with the Scheme culverts in place, however the profile of recession is smoother compared to the baseline model.

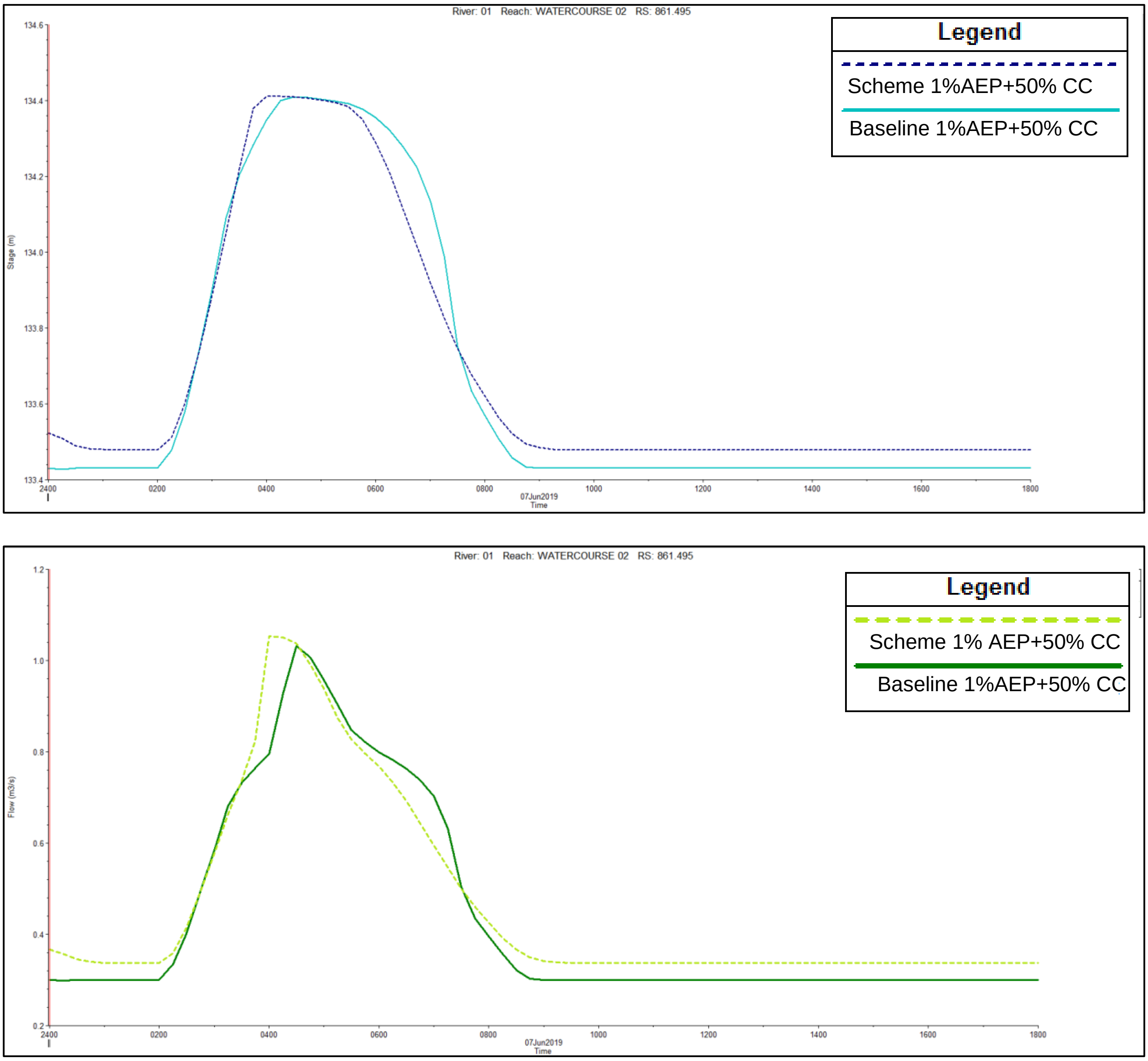


Figure 5.6: Comparison of peak stage and flow during a 1% AEP + 50% climate change event between baseline and scheme models

0.1% AEP

5.2.9 The 1D model shows flood risk in the 0.1% AEP event, as there is out of bank flooding at the existing A460 culvert. At the peak of the storm event, the existing A460 culvert causes water to back up the channel, as shown in Figure 5.7. There is no freeboard during this event as both the upstream and downstream end of the main culvert has become submerged as a result of water backing up the channel from the existing A460 culvert.

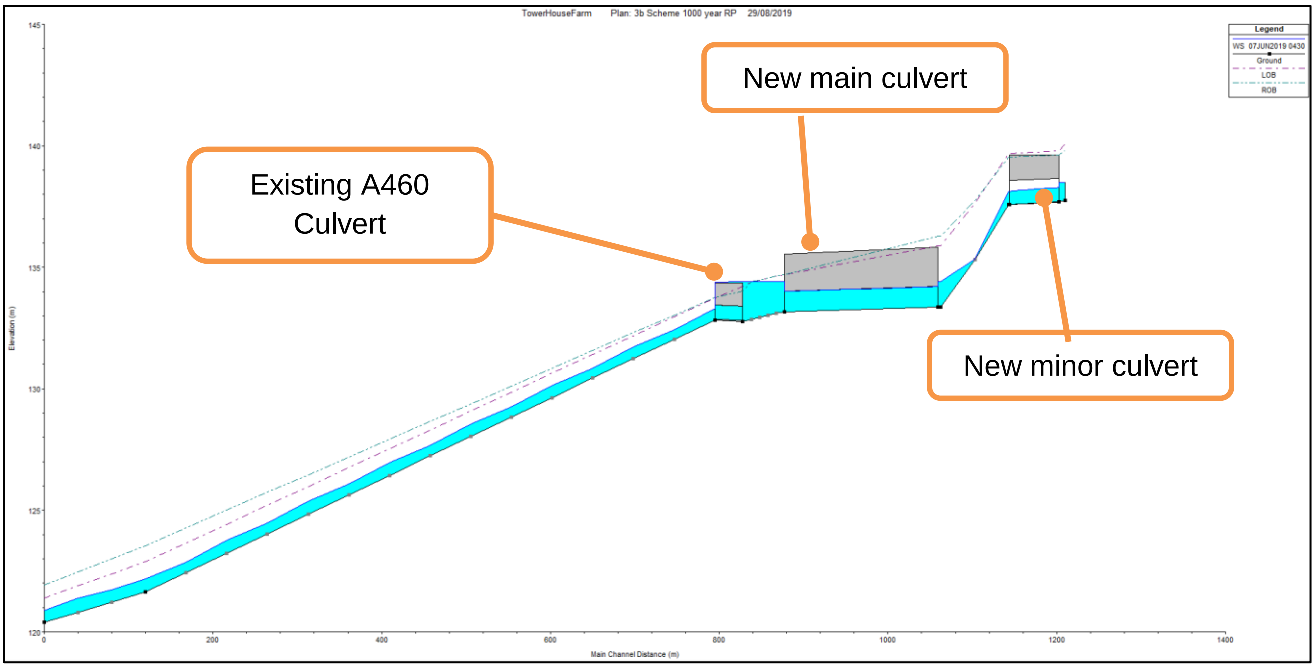


Figure 5.7: 0.1% AEP maximum water levels

5.2.10 The 0.1% AEP event results for the Scheme and baseline scenarios show there is no increase in flood risk as a result of the Scheme. The peak stage at the A460 culvert is 134.43mAOD and the peak flow is 1.27m3/s.

Options testing

5.2.11 Different Scheme alignments of the watercourse were tested as part of the development of the design. Iterations of this have included the testing of a pond storage area between the new main and minor culvert. Whilst this did have a minor impact on water levels at the existing A460 culvert, it was not deemed significant enough to include in the design given the increase in Scheme costs.

Summary of Scheme results

5.2.12 The scheme significantly changes the morphology and gradient of the river channel, which creates a minor impact stage and flow downstream of the new culverts.

5.2.13 The Scheme has been designed to ensure that flood depths to the existing A460 and return period are kept the same as the baseline scenario, and therefore not worsening flood risk.

5.3 Hilton Park

5.3.1 The Scheme design for this location includes:

- Dissection of the Lower Pool by the carriageway which is a cutting at this location. The dissection of Lower Pool will reduce it's area from 13200 m^2 to 8723 m^2 (approximate values);
- Creation of a new channel and weir configuration downstream of the dissected Lower Pool. It has been assumed that similar channel dimensions to the existing watercourse would be implemented for this new section of channel. Therefore,

the route was interpolated from the geometry of existing cross sections. The weir configuration has been estimated from the crest height of the existing weir to maintain the level of the remaining pond;

- A new 1.2m diameter, 60m long circular culvert which will pass underneath the carriage way. This has been assumed to be made of concrete, and a Manning's n of 0.011 applied.
- Reprofiling of the watercourse downstream of the new culvert, as detailed in design drawings.

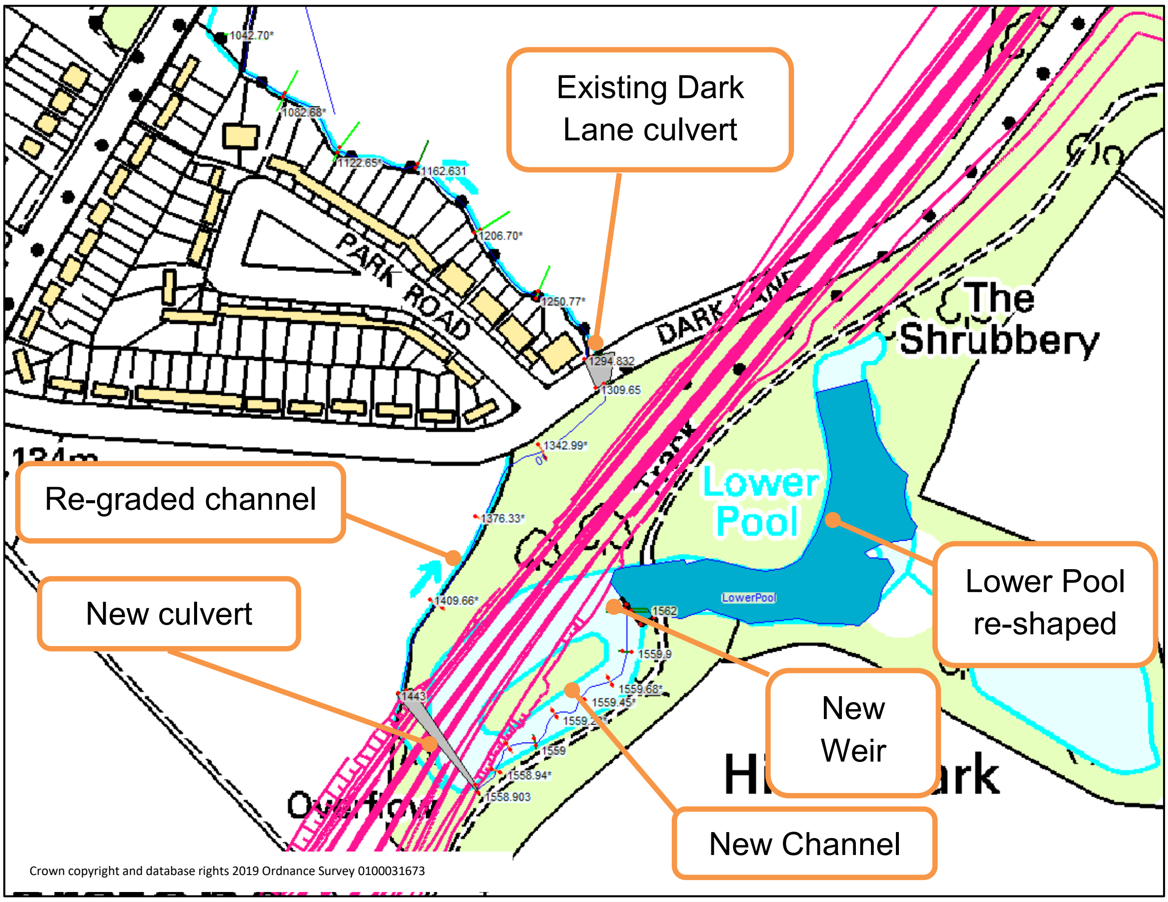


Figure 5.8: Watercourse 3 general scheme arrangement. Scheme alignment is shown in pink.

Scheme Model Results

5.3.2 The 1D model results in Figure 5.9 shows a long profile of 1D model results on the Hilton Park watercourse. The 1D model shows low flood risk in the 5%, 1%, 1% + 50% Climate Change and the 0.1% AEP events, as there is no out of bank flooding in close vicinity to the proposed scheme

5.3.3 The following model results are based upon the more conservative scenario with inflow hydrographs applied downstream of the pond, as discussed in the section on 'Sensitivity Testing'.

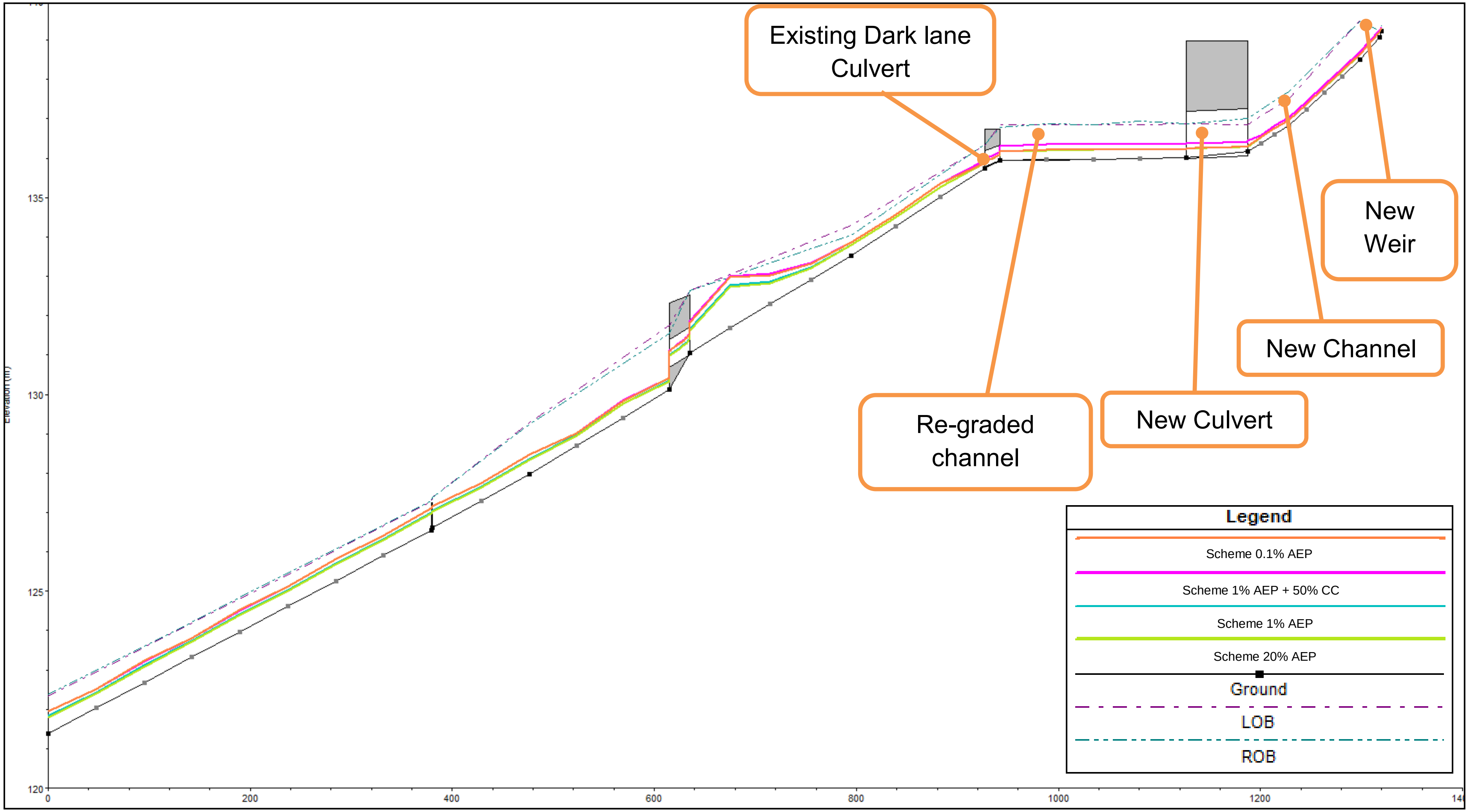


Figure 5.9: All AEP maximum Scheme water levels – Hilton Park watercourse

Sensitivity testing

5.3.4 Whilst the model does not show any out of bank flooding in the scenarios tested for the Scheme design, despite a reduction in the pond area. However it should be noted that the storage capacity in Lower Pool has a significant impact on the flood risk downstream at the Dark Lane culvert and the A460 culvert. To understand the impact of Lower Pool on flood risk in this catchment, sensitivity testing was undertaken in the model, by running a simulation with Lower Pool offline. The results are shown in the long profile in Figure 5.10 and show significantly higher risk in this scenario.

5.3.5 This risk should be taken in to account at the detailed design stage, given the significant increase of flood river stage that model results suggest would occur if the Lower Pool is no longer an online pond. To ensure there is no increase to flood risk in this sub-catchment, the Lower Pool should remain as an online pond.

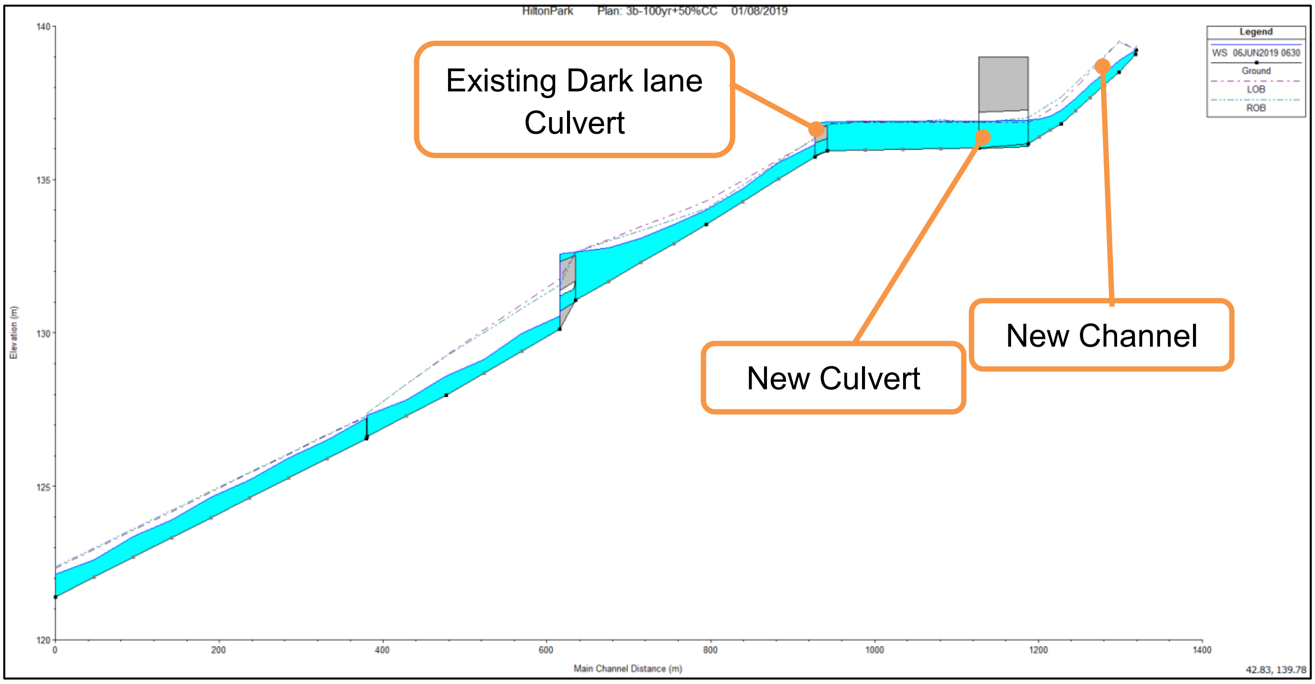


Figure 5.10: Lower Pool offline scenario 1% AEP event + 50% climate change allowance

5.3.6 A comparison of the flood risk of the baseline model and two scenarios (online or offline Lower Pool) can be seen in the table and graphs below. Whilst both scenarios increase stage and flow, the offline Lower Pool sees a significant increase in peak flow and stage, which results in an increase in flood risk to Dark Lane road.

Table 5.2: comparison of Baseline against possible scheme scenarios during a 1% AEP event with a 50% climate change allowance at Dark Lane culvert

	Baseline	**With scheme – assumes Lower Pool offline**	**With scheme – assumes Lower Pool online**
Peak Stage	136.01mAOD	136.93mAOD	136.32mAOD
Peak Flow	0.11m3/s	1.31m3/s	0.21m3/s
Potential flood depth on Dark Lane	0cm	17cm	0cm

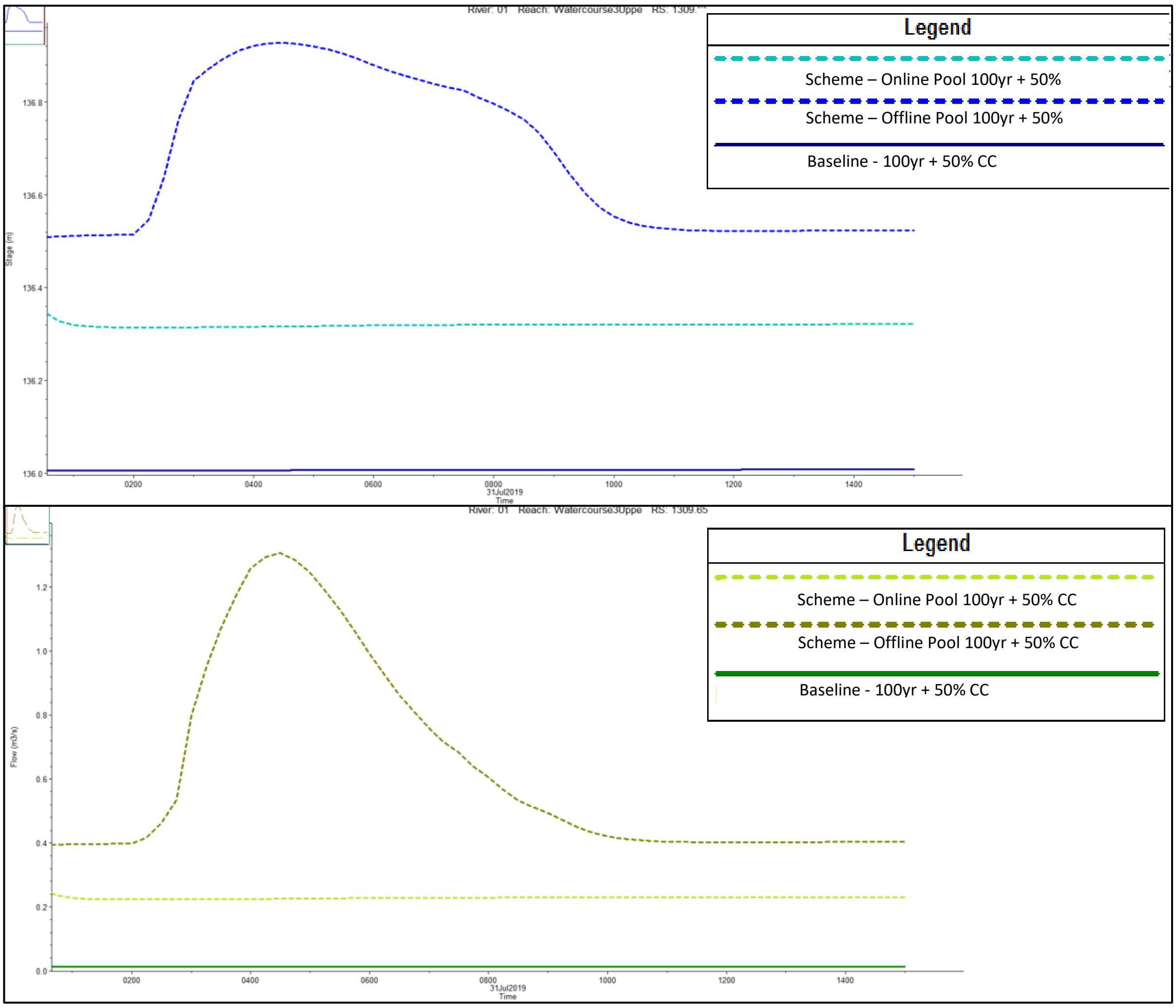


Figure 5.11: Stage and Flow comparison of Baseline and scheme scenarios in a 1% AEP with 50% Climate Change allowance

Summary of Scheme results

5.3.7 Flooding does not occur in the model during any of the storm events tested.

5.3.8 However, sensitivity testing shows by applying upstream flows to the upstream cross-section rather than to Lower Pool, flood risk is increased, causing out of bank flooding. This could put properties at risk in the vicinity of the Dark Land Culvert. Therefore, it is important that the Lower Pool is retained as an online feature, as it provides flood protection downstream.

5.3.9 Despite the Scheme reducing the area of the Lower Pool pond from 13200 m^2 to 8723 m^2 (approximate values), this does not increase flood risk to properties downstream. However, further sensitivity testing concerning the pond size and weir design should be considered at the detailed design stage.

5.4 Latherford Brook

5.4.1 The Scheme design for Watercourse 4 includes:

- Demolition of Pond 6 at Brookfield Farm - the 2D storage area has been removed the application of the Scheme terrain to the model, including the BC line. The lateral structures have been edited to ensure that Pond 7 will be able to discharge upstream of the new culvert;
- A 1.2 m diameter circular culvert approximately 55m in length has been modelled, passing underneath the carriageway as per scheme drawings. This has been assumed to be made of concrete, and a manning's of 0.011 applied.

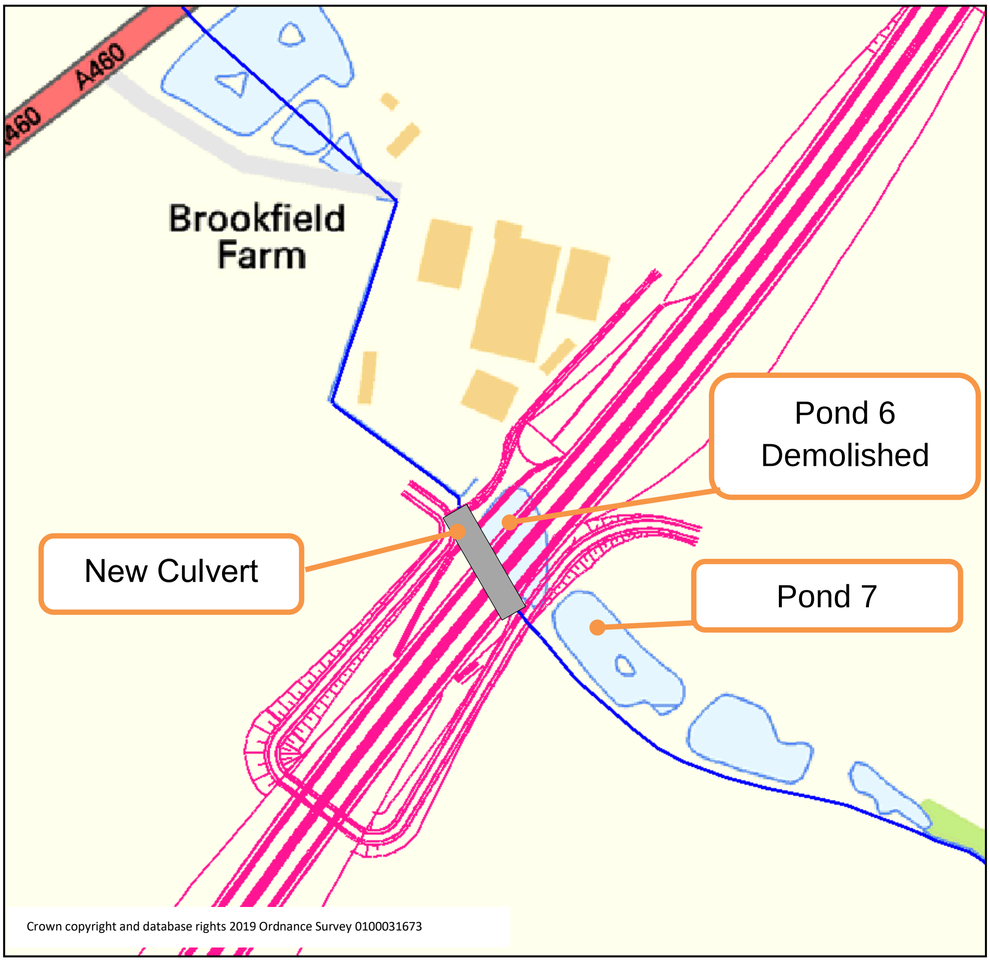


Figure 5.12: Watercourse 4 general scheme arrangement. Scheme alignment is shown in pink.

5.4.2 The Scheme design for Watercourse 5 includes:

- A 10 m wide structure underneath the carriageway to cross the watercourse, approximately 77 m long – this has been modelled as a free span bridge. The opening is wide enough to allow a channel to be reinstated after construction, with banks either side of the channel. Given that this channel will have a natural bed, manning's values for the crossing have been kept the same as the baseline scenario for this section.
- Raised earth embankments with in the flood plain, as per the Scheme terrain.

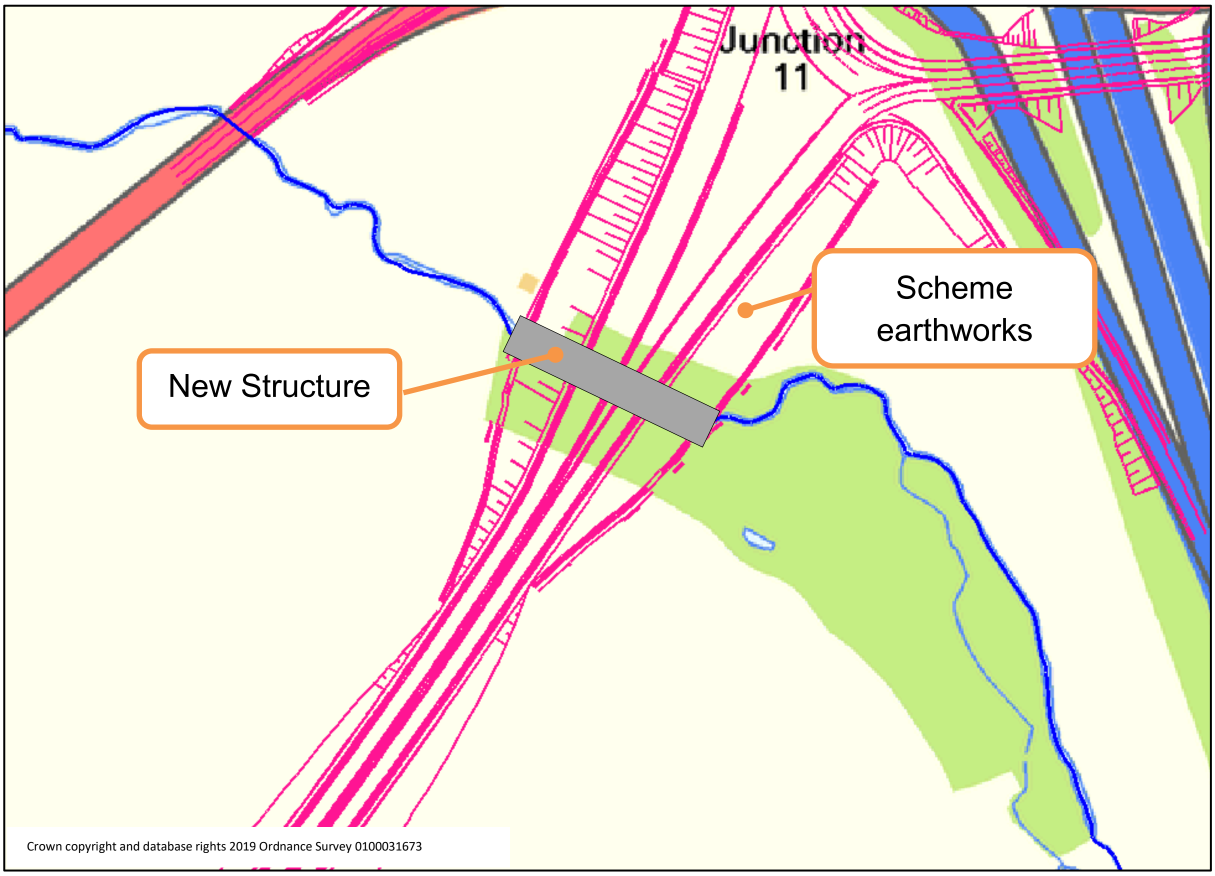


Figure 5.13: Watercourse 5 general scheme arrangement. Scheme alignment is shown in pink.

5% AEP

5.4.3 As shown in the depth maps in Figure 5.14, there is some out of bank flooding during the 5% AEP event. Most of this flooding occurs on the downstream reach of Watercourse 5.

5.4.4 In addition, a secondary channel is activated on Watercourse 5 through woodland close to Junction 11. It is in this area where the Scheme will cross the watercourse.

5.4.5 Aside from the secondary channel being activated, there is very little out of bank flooding within close proximity to the proposed scheme for Watercourse 5. The flooding that does occur is similar to the baseline scenario, both in extents and depth.

5.4.6 Peak in-channel depths at the upstream end of the Watercourse 5 crossing proposed crossing are increased by 11cm compared to the baseline scenario water level. Peak flows in the channel at the upstream end of the proposed crossing are 2.44m3/s, which is the same as in the baseline scenario.

5.4.7 There is very little out of bank flooding for Watercourse 4 where the Scheme will cross the watercourse. The model is showing ponding downstream of the Watercourse 4 crossing which may result in some minor ponding of water at the entrance/exit of the foot bridge which is proposed as part of the Scheme.

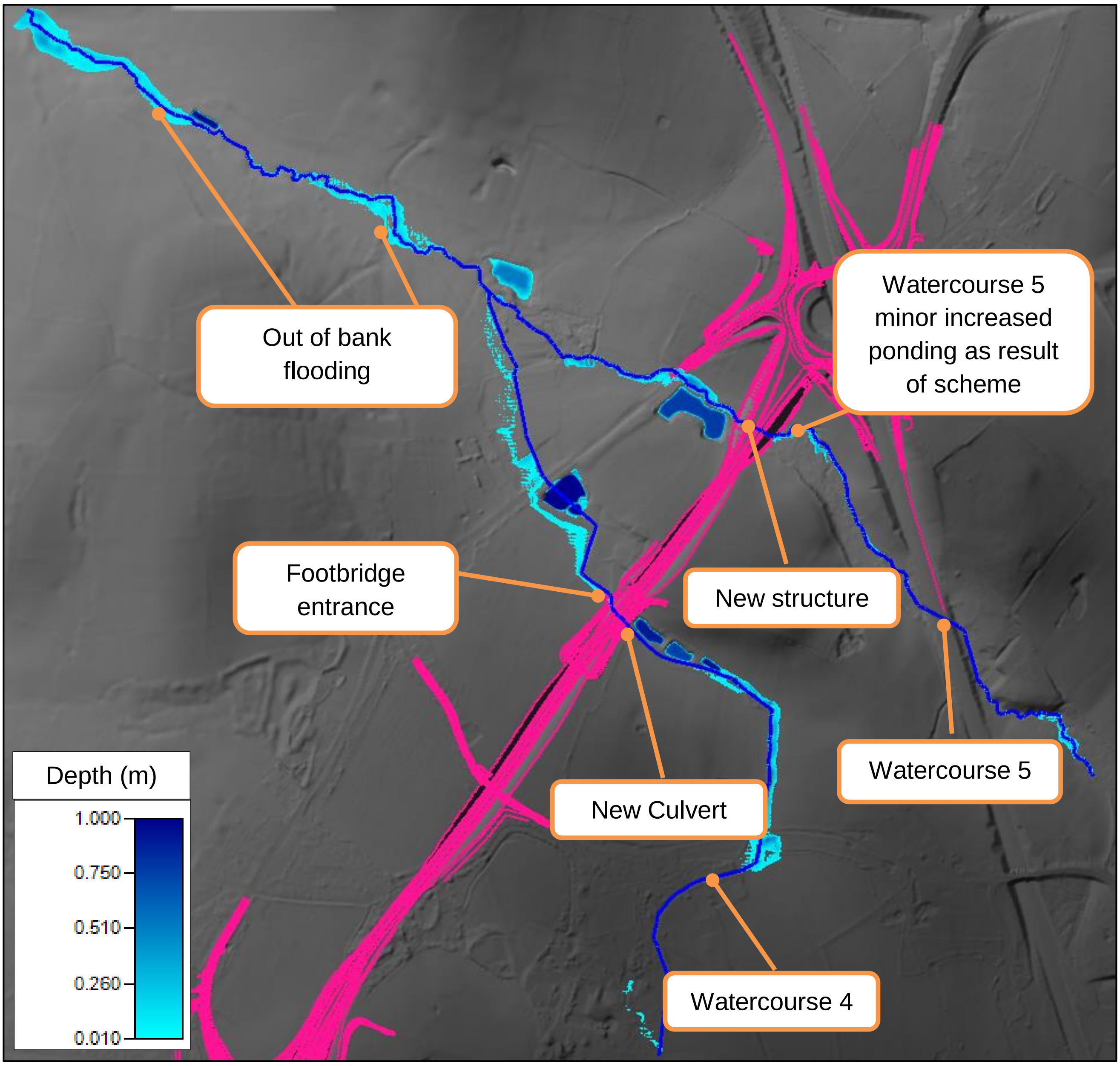


Figure 5.14: 5% AEP maximum flood depths with scheme in place

1% AEP

5.4.8 The flood depth map in Figure 5.15 shows there is out of bank flooding during the 1% AEP event. Most of this flooding occurs on the downstream reach of Watercourse 5.

5.4.9 The out of bank ponding occurring at the upstream end of the new structure for watercourse 5, is more extensive compared to the baseline scenario. This is due to the earthworks of the Scheme dissecting natural flow paths to the north of the watercourse. The depths are increased immediately upstream of the watercourse 5 crossing, with depths up to 60cm in small isolated areas. However upstream, the floodplain extents and depths are very similar to the baseline scenario with modelled flood depth up to 25cm.

5.4.10 Peak in-channel depths at the upstream end of the proposed Watercourse 5 crossing are increased by 10cm compared to the baseline scenario water level. Peak flows in the channel at the upstream end of the proposed crossing are 3.58m^3/s, the same as the baseline scenario.

5.4.11 There is very little out of bank flooding for Watercourse 4 where the Scheme will cross the watercourse. The model is showing ponding downstream of the Watercourse 4 crossing which may result in some minor ponding of water at the entrance/exit of the footbridge which is proposed as part of the Scheme. Depths here are up to 9cm.

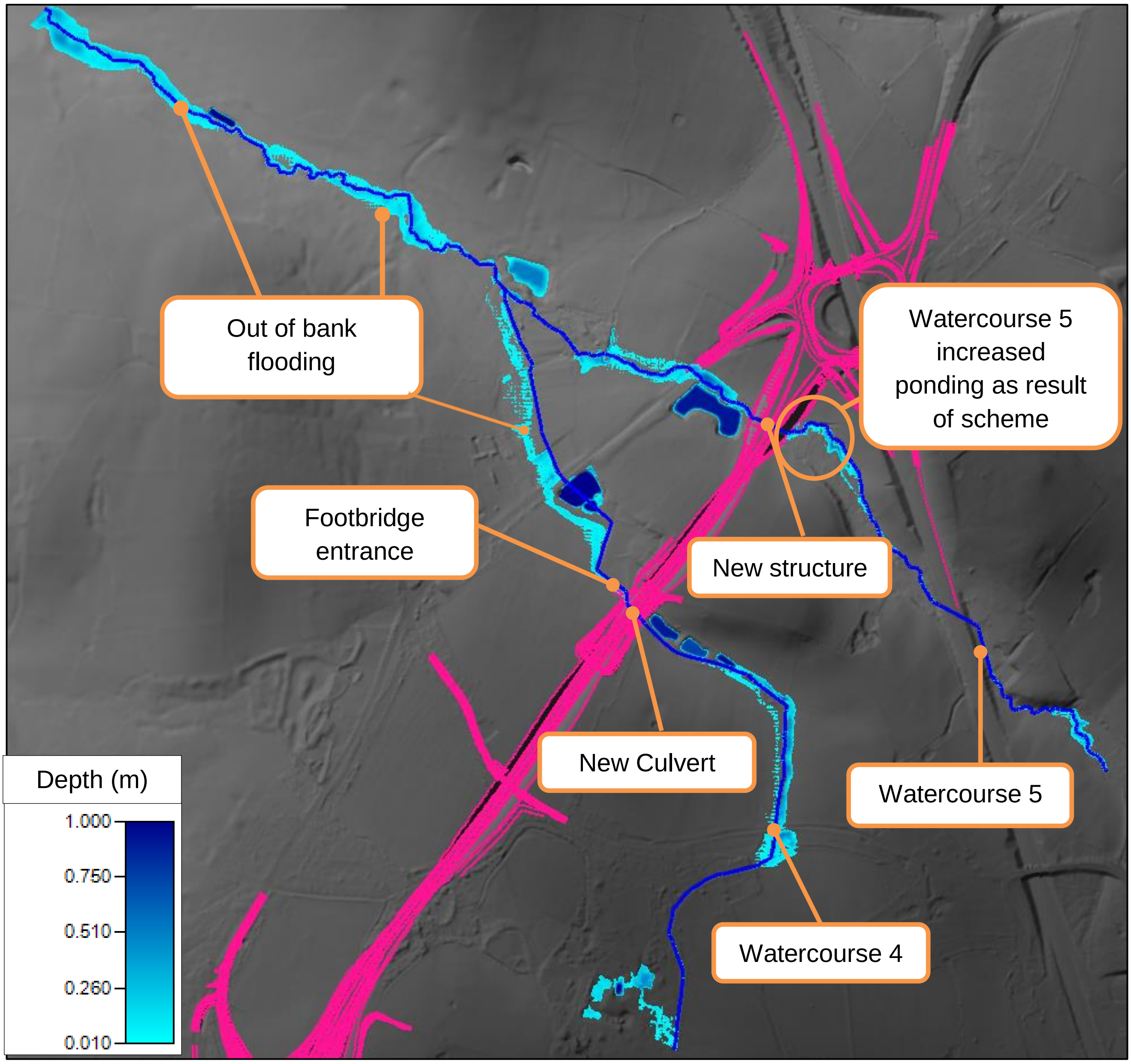


Figure 5.15: 1% AEP maximum flood depths with scheme in place

1% AEP + 50% climate change allowance

5.4.12 There is out of bank flooding during the 1% AEP + 50% climate change event. Most of this flooding occurs on the downstream reach of Watercourse 5. The extents of this flooding are noticeably wider than the 1% AEP event.

5.4.13 The out of bank ponding occurring at the upstream end of the new structure for Watercourse 5, is more extensive compared to the baseline scenario. This is due to the earthworks of the Scheme dissecting natural flow paths to the north of the watercourse. The change of depths in the flood plain can be seen in Figure 5.16.

5.4.14 Peak in-channel depths at the upstream end of the proposed crossing are increased by 12cm compared to the baseline scenario water level. Peak flows in the channel at the upstream end of the proposed crossing are $5.35m^3/s$, compared to $5.27m^3/s$ in the baseline scenario.

5.4.15 There is very little out of bank flooding for Watercourse 4 where the Scheme will cross the watercourse. The model is showing ponding downstream of the Watercourse 4 crossing which may result in some minor ponding of water at the entrance/exit of the foot bridge which is proposed as part of the Scheme. Depths here are up to 10cm.

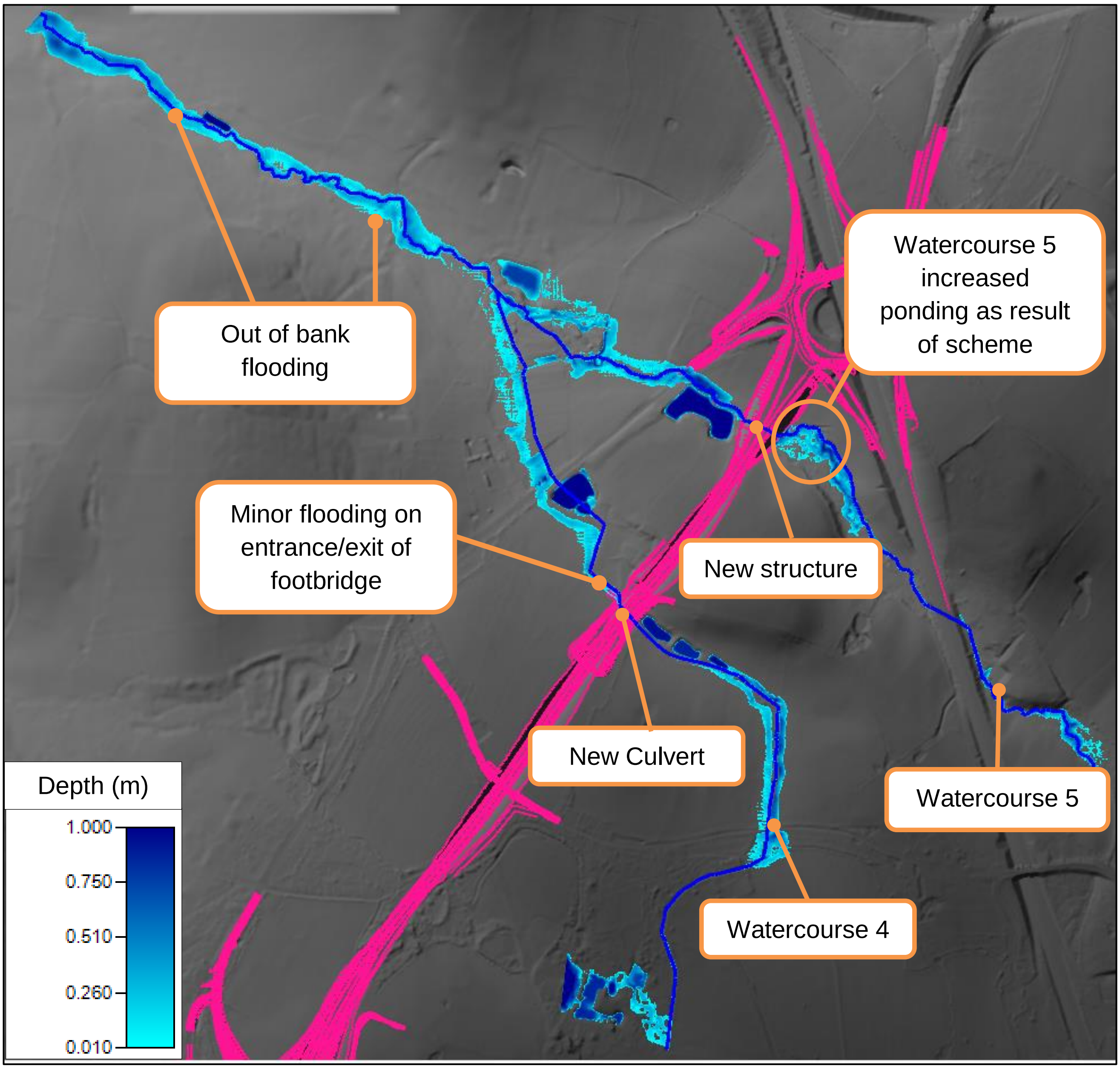


Figure 5.16: 1% AEP + 50% climate change allowance maximum flood depths with scheme in place

0.1% AEP

5.4.16 The out of bank ponding occurring at the upstream end of the new structure for Watercourse 5, is more extensive compared to the baseline scenario event. This is due to the earthworks of the Scheme dissecting natural flow paths to the north of the watercourse. The depths are increased immediately upstream of the watercourse 5 crossing.

5.4.17 Peak depths at the upstream end of the proposed crossing are increased by 11cm compared to the baseline scenario water level. Peak flows in the channel at the upstream end of the proposed crossing are 5.99m3/s, compared to 5.94m3/s in the baseline scenario

5.4.18 There is very little out of bank flooding for Watercourse 4 where the Scheme will cross the watercourse. The model is showing ponding downstream of the Watercourse 4 crossing which may result in some minor ponding of water at the entrance/exit of the foot bridge which is proposed as part of the Scheme. Depths here vary between 3cm and 9cm.

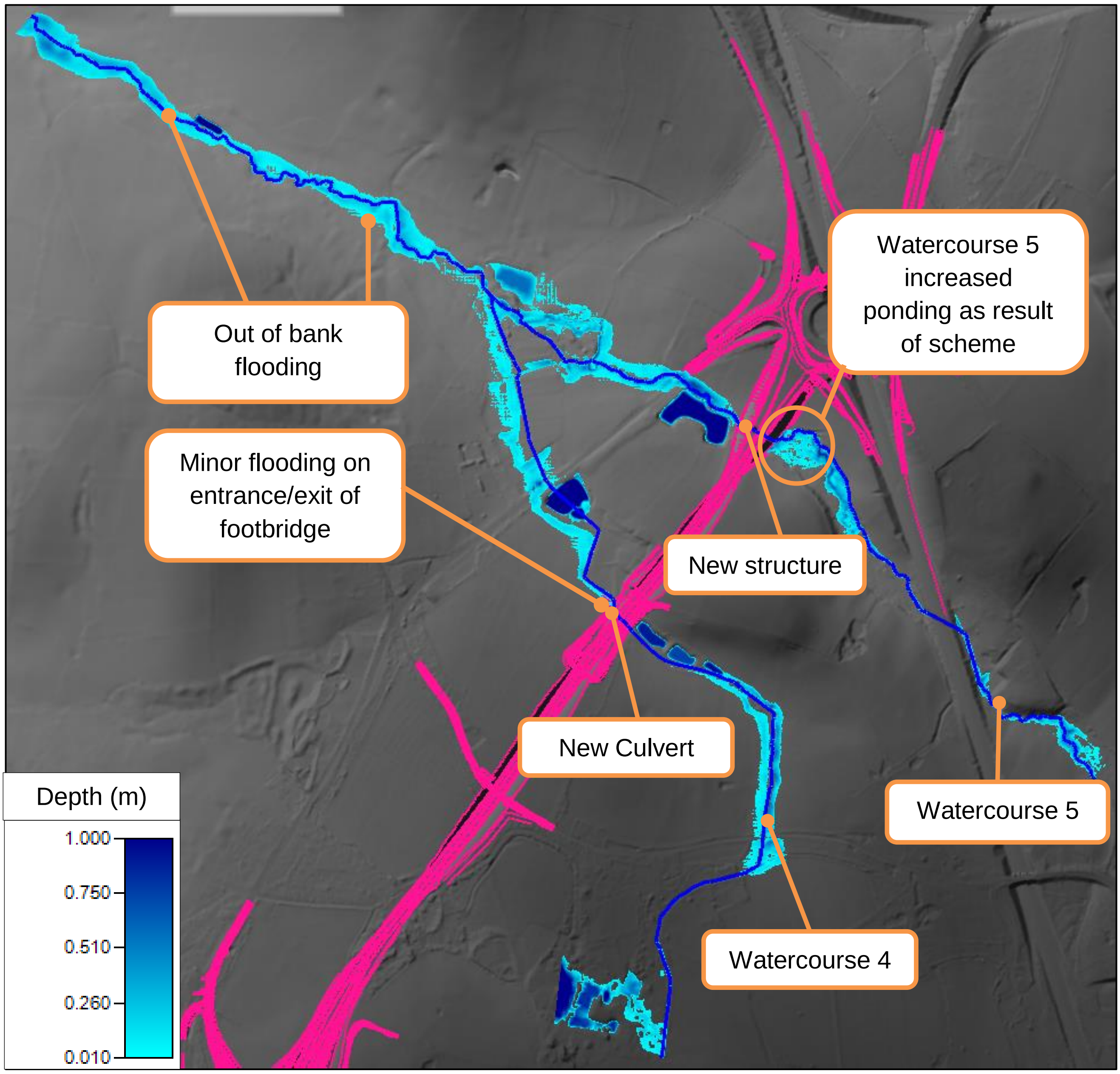


Figure 5.17: 0.1% AEP maximum flood depths with scheme in place

Watercourse 4 crossing analysis

5.4.19 Analysis of the model runs has shown that the impact of the Scheme along watercourse 4 is negligible. The works related to the Scheme do not dissect any flow paths along the floodplain, and therefore there is little difference between the baseline and Scheme flood extents or depths. Slight variations are caused by differences in the way the terrain data has been generated, rather than by any changes to the watercourse.

5.4.20 The model is showing ponding downstream of the Watercourse 4 crossing which may result in some minor ponding of water at the entrance/exit of the foot bridge which is proposed as part of the Scheme. Some ponding occurred here in the baseline scenario, however the addition of the footbridge to the terrain has displaced this water meaning that there are areas which were dry, but are now wet (shown in blue), see Figure 5.18.

5.4.21 The main receptor to any change in flood depths and extents is the Brookfield Farm buildings. The model results show that despite the demolition of the pond upstream, there is no change in flood extents are generally unchanged in the vicinity of these buildings. There is a small increase in flood extents, however this is confined to agricultural land. There is also a 2cm in flood depths on the access road to Brookfield farm, however this is not a significant change to flood risk.

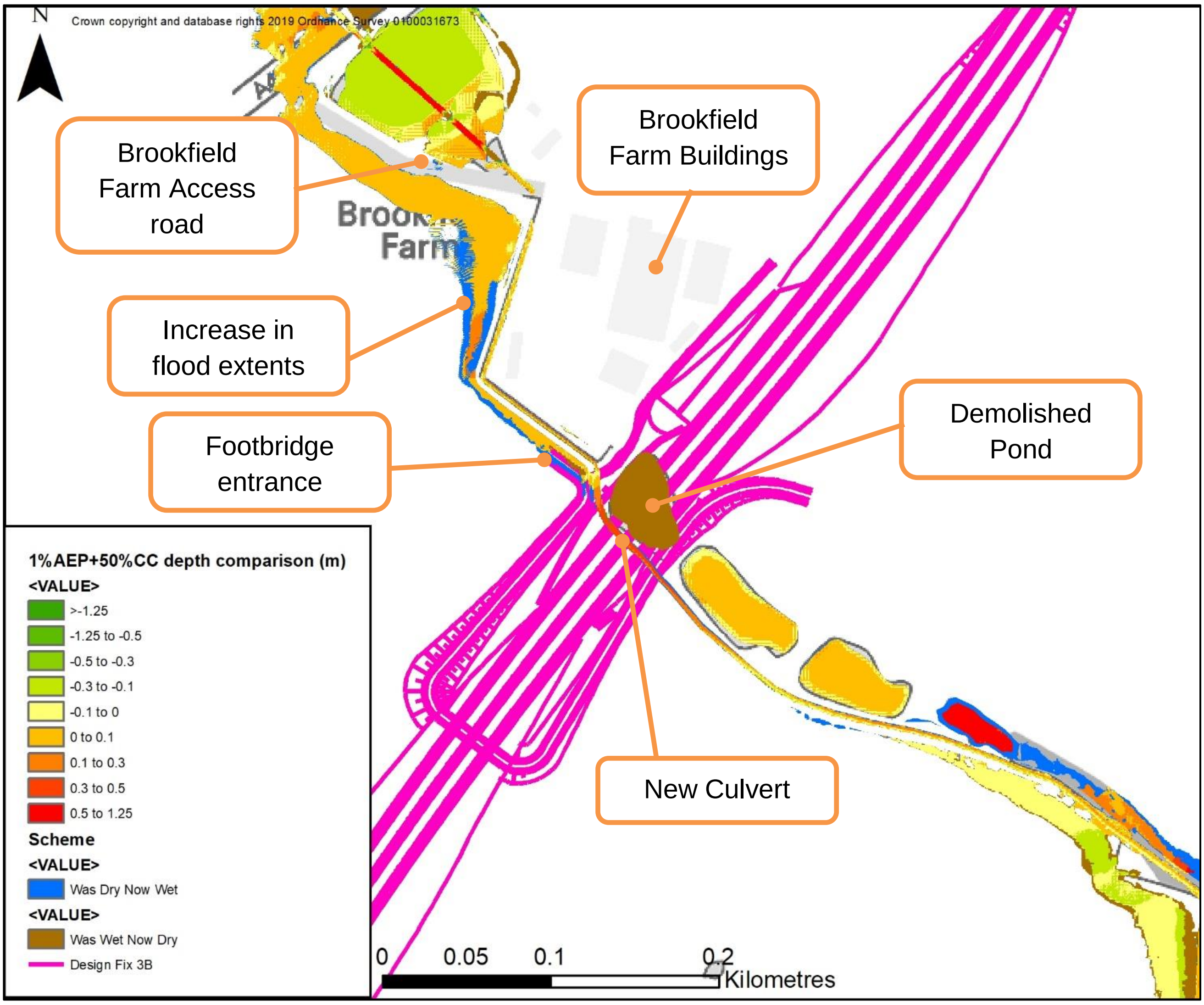


Figure 5.18: Depth comparison between Baseline and Scheme scenarios for a 1% AEP + 50% climate change allowance event

Watercourse 5 crossing analysis

5.4.22 The model results for Watercourse 5 show that there is some change in the distribution of flood depths in the vicinity of the proposed scheme, but these changes are confined within the Scheme boundary and do not affect third parties. There is no change in flood risk downstream of this area.

5.4.23 Analysis of the model runs has shown that the impact of the Scheme along watercourse 5 is isolated to the areas immediately upstream and downstream of the proposed river crossing, to the south of Junction 11 of the M6. The impact of the proposed earthworks related to the Scheme is to dissect natural flood paths. The result is an increase in depths upstream of the proposed crossing and flood depths are decreased downstream of the river crossing. Figure 5.19 shows a comparison between the 1% AEP + 50% climate change allowance event for the baseline scenario, and the Scheme scenario.

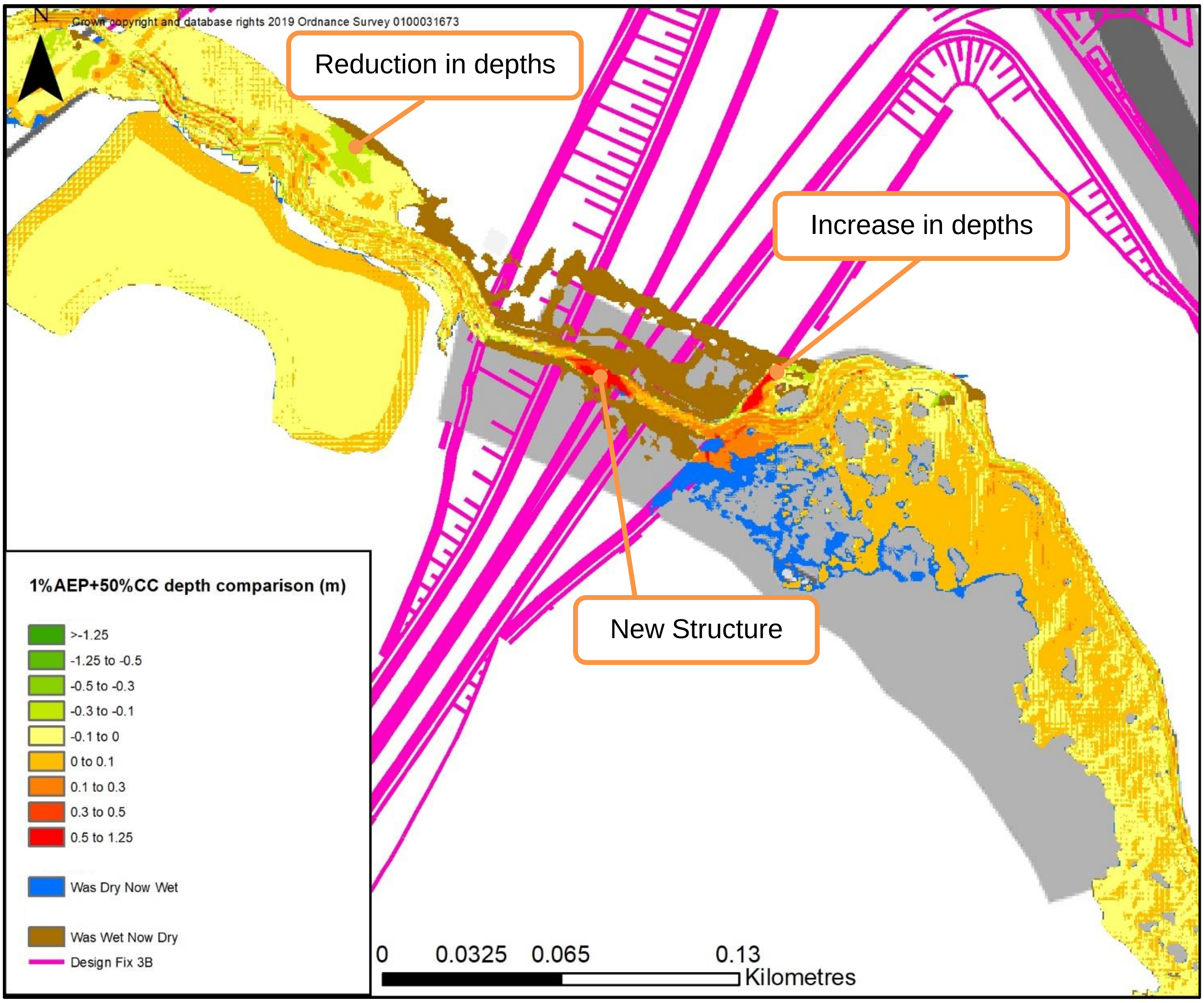


Figure 5.19: Depth comparison between Baseline and Scheme scenarios for a 1% AEP + 50% climate change allowance event

5.4.24 As shown in Figure 5.19, the difference in floodplain depth between the baseline and scheme scenarios is between -0.1m and +0.1m. Where the natural flow paths have been dissected, upstream depths have increased up to 0.5m in isolated sections of the existing floodplain. Downstream depths have decreased in small pockets by -0.3m. In addition, there are areas which were flooded in the baseline model, which are 'dry' in the Scheme scenario (shown in brown). Similarly, there are areas which were dry in the baseline model which are now flooded in the Scheme scenario (shown in blue). The effect of the earthworks associated with the Scheme is to retain flood volume at a higher elevation.

5.4.25 A comparison of the stage volume displacement can be seen in Figure 5.20, which clearly shows that the Scheme will result in 188m3 being displaced to a higher elevation. These areas can be seen on Figure 5.19 in red and orange.

5.4.26 Conversely, the dissection of flow paths also has the effect of reducing volumes by 89m^3 at lower elevations immediately downstream of the earthworks. These areas can be seen on Figure 5.19 in pale green.

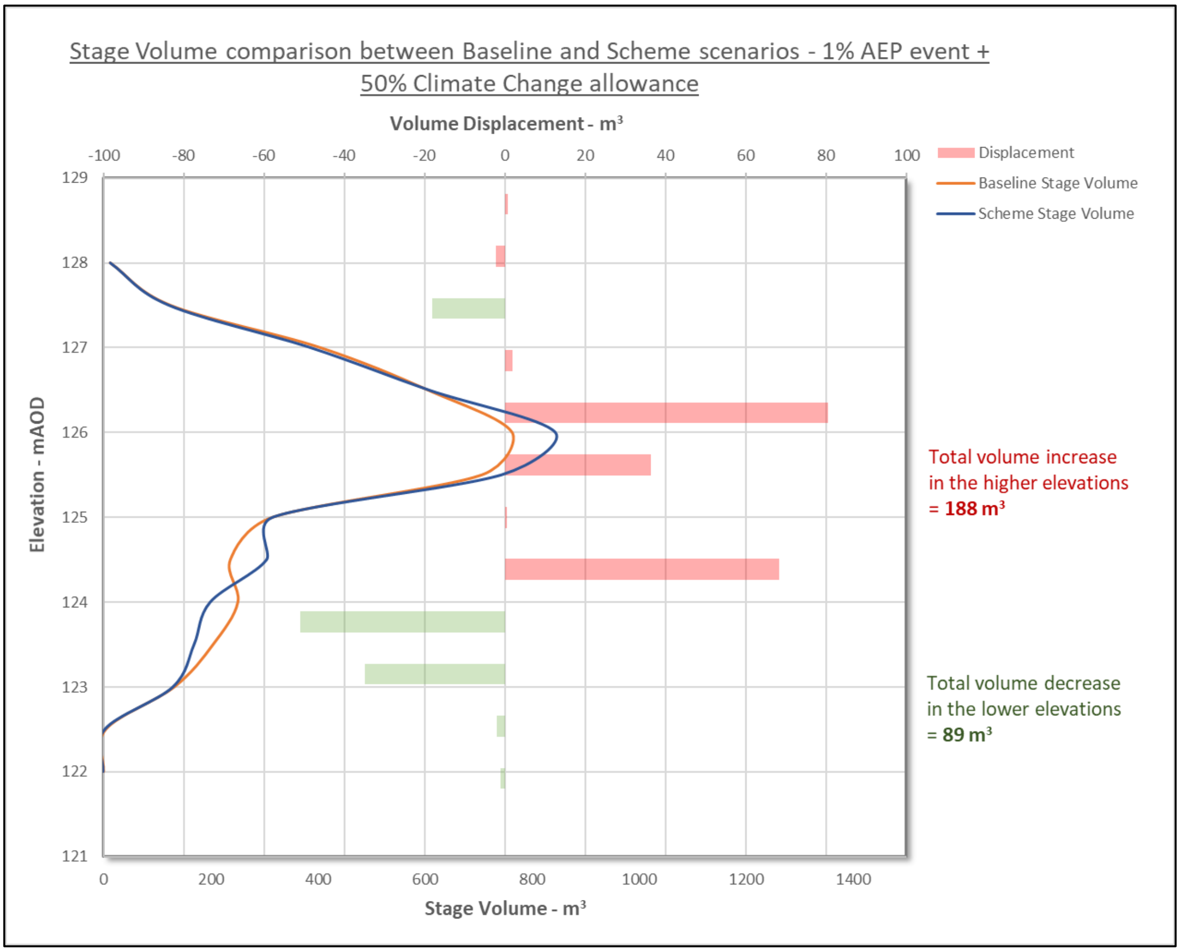


Figure 5.20: Stage/volume displacement comparison between Baseline and Scheme scenarios for a 1% AEP + 50% climate change allowance event

5.4.27 The impacts of the Scheme are localised to the immediate areas up and downstream of the new crossing, as demonstrated in Figure 5.19 and Figure 5.20. Therefore, the Scheme has a minimal impact on Watercourse 5 overall.

5.4.28 The areas where flood depth is predicted to increase include existing woodland and pockets of ancient woodland. Woodland as a habitat is generally resilient to flooding, and the impact of a 1% AEP + 50% climate change event would be unlikely to change the habitat once the area had recovered.

5.4.29 A 50% AEP event was simulated to understand how flooding from this watercourse may affect the woodland in more frequent events. Simulations show that there is very little out of bank flooding during this event, and extents and depths between the baseline and scheme events are very similar (see Figure 5.21). Therefore, the impacts on these woodlands would be minimal as the frequency of flooding will not increase for smaller storm events.

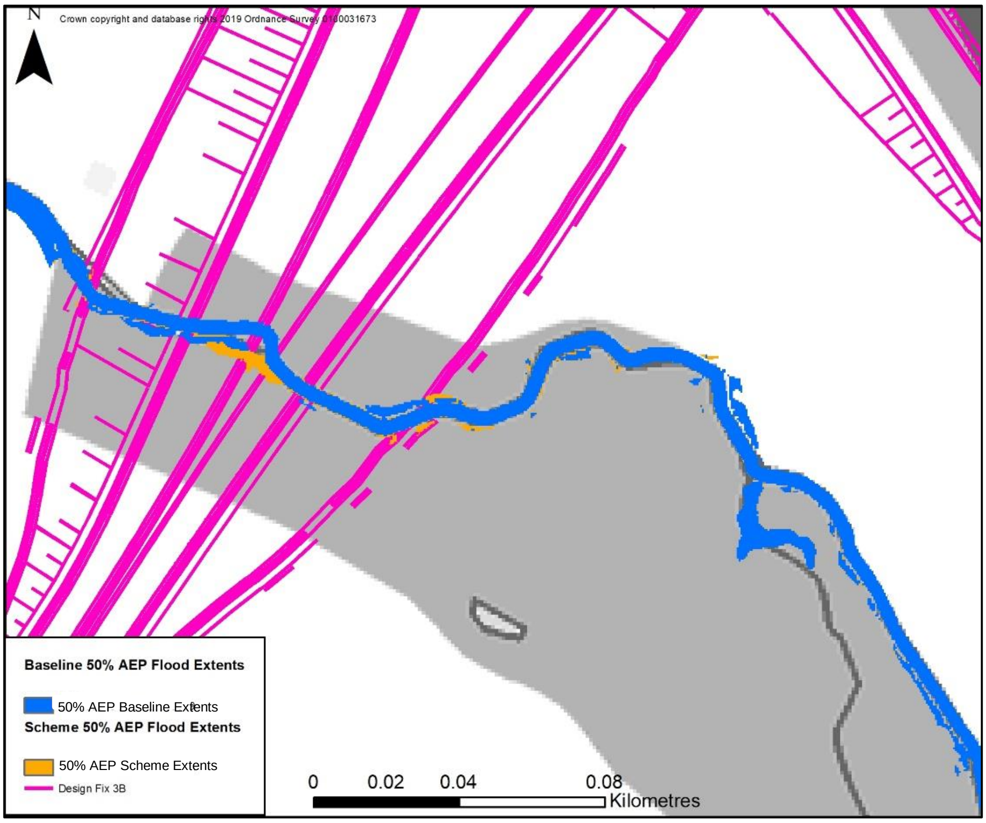


Figure 5.21: 50% AEP baseline and scheme flood extents

Summary of Scheme results

5.4.30 The model shows out of bank flooding in all the design storms tested.

5.4.31 The flood extents for the 1% AEP + 50% climate change allowance are similar to the 0.1% AEP event flood extents.

5.4.32 The impact of the Scheme on flood extents and depths for Watercourse 4 is negligible. Therefore, no additional mitigation is required at this location.

5.4.33 The scheme does have a predicted impact on flood extents and depths for Watercourse 5. However, this impact is isolated to the area upstream of the proposed river crossing. No mitigation is required at this location, as there are no receptors which will be adversely impacted by the change in the floodplain.

5.5 Wheatsheaf Farm

5.5.1 There are no works related to the Scheme which will impact Watercourse 6. Flows remain in-channel in the 0.1% AEP event. Therefore, there were no requirements to incorporate the proposed Scheme alignment into the Wheatsheaf Farm model.

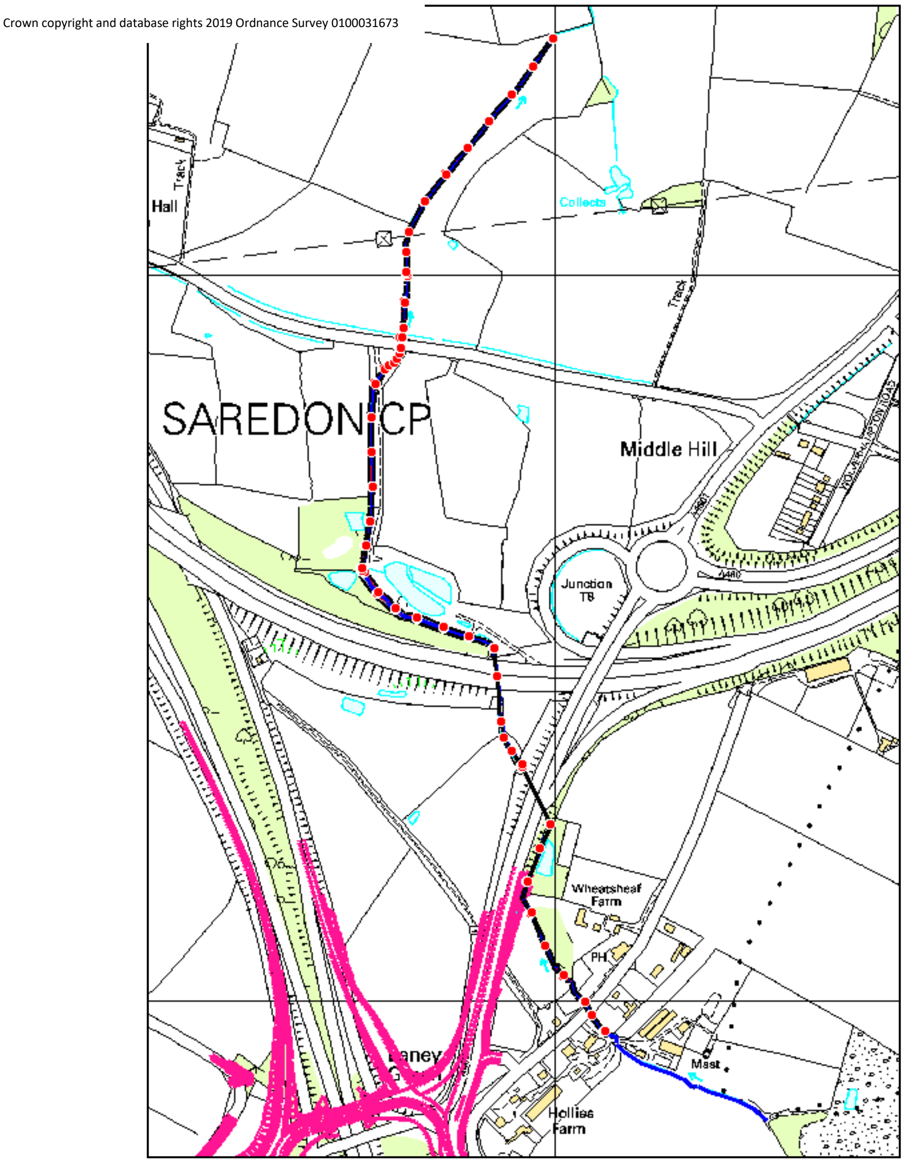


Figure 5.22: Watercourse 6 general scheme arrangement. Scheme alignment is shown in pink

6 Conclusions

6.1.1 Three 1D Models and one 1D-2D HEC-RAS models have been built to understand baseline flood risk and scheme flood risk. These models have been based upon survey data, best available LiDAR and mapping data, hydrological analysis and interpolation where necessary.

6.1.2 There is some existing flood risk shown in the baseline model results. It is not within the remit of the Scheme to solve all existing flood risk in the area, but to ensure it is not worsened.

6.1.3 A summary of the main impacts of the Scheme are included in Figure 6.1. The main impacts on flood extents and depths as a result of the Scheme are:

- Watercourse 2 will be significantly diverted, however flood risk is not impacted as a result.
- Lower Pool must remain as an online pond to minimise flood risk along Watercourse 3, protecting properties around Dark Lane.
- The loss of Pond 6 on Watercourse 4 will have a negligible impact on flood risk to Brookfield Farm.
- Increased flood depths and extents upstream of the Watercourse 5 crossing. There is change in the distribution of flood depths in the vicinity of the proposed scheme, but these changes are confined within the Scheme boundary and do not affect third parties.
- Decreased flood depths and extents downstream of the Watercourse 5 crossing.
- A wider area of woodland around Watercourse 5 will experience flooding during higher magnitude events. However, frequent events which could cause environmental change will impact the same area as the baseline scenario.

6.1.4 The design of the Scheme has taken flood risk in to account, and therefore impacts to flood risk are negligible and no additional mitigation is required.

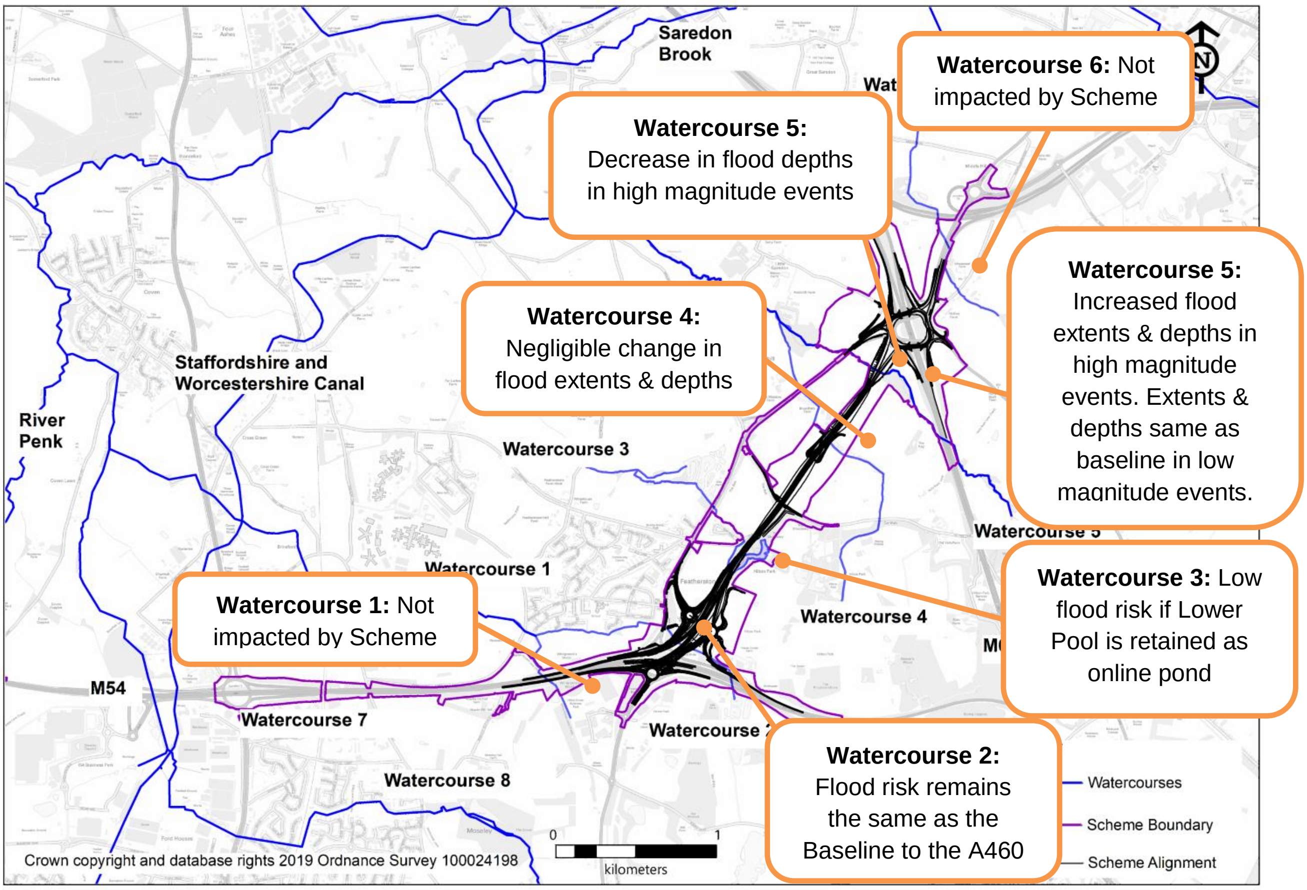


Figure 6.1: Summary of scheme impacts on flooding

Annex 1 - Catchment descriptors

The catchment descriptors used to generate flow estimates.

Descriptor	Subject Site						
	WF_DS	LB_DS	LB_US	LB_Trib	HP_DS	THF_DS	THF_US
Catchment X	396000	393900	395400	395100	393800	392350	394250
Catchment Y	308300	307400	306550	306350	305850	305000	304850
Centroid X	395859	395750	396334	395474	394758	393951	394845
Centroid Y	307598	305753	305115	305577	305246	304501	304190
AREA	1.83	6.44	3.49	0.98	1.99	3.57	1.01
ALTBAR	130.00	145.00	156.00	146.00	146.00	142.00	166.00
ASPBAR	11.00	336.0	349.0	346.00	320.00	295.00	299.00
ASPVAR	0.28	0.36	0.39	0.66	0.58	0.66	0.48
BFIHOST	0.47	0.44	0.39	0.41	0.43	0.48	0.58
DPLBAR	1.11	3.11	2.29	1.08	1.46	2.04	1.17
DPSBAR	33.60	36.60	38.30	35.60	33.50	40.50	66.90
FARL	1.00	0.993	0.993	1.00	0.95	0.98	0.92
FPEXT	0.04	0.06	0.05	0.04	0.07	0.11	0.02
FPDBAR	0.31	0.46	0.35	0.30	0.53	0.68	0.19
FPLOC	0.64	0.80	0.82	0.89	0.61	0.58	0.71
LDP	2.22	5.91	4.04	2.31	3.22	4.33	2.21
PROPWET	0.31	0.31	0.31	0.31	0.31	0.31	0.31
RMED-1H	10.80	10.90	11.10	10.90	10.90	10.90	11.10
RMED-1D	31.60	31.90	32.00	32.00	31.80	31.70	31.80
RMED-2D	38.60	38.60	38.60	38.70	38.70	38.70	38.60
SAAR	693.00	698	703	698.00	697.00	696.00	702.00
SAAR4170	719.00	715	716	715.00	710.00	707.00	709.00
SPRHOST	36.32	37.06	38.66	38.27	36.88	34.81	29.89
URBCONC1990	-999999.00	0.68	0.71	0.25	0.68	0.76	-999999.00
URBEXT1990	0.00	0.02	0.03	0.01	0.10	0.09	0.01
URBLOC1990	-999999.00	1.33	1.64	0.50	0.56	0.69	-999999.00

Descriptor	Subject Site						
	WF_DS	LB_DS	LB_US	LB_Trib	HP_DS	THF_DS	THF_US
URBCONC2000	-999999.00	0.95	0.93	-999999.00	0.84	0.85	0.50
URBEXT2000	0.00	0.02	0.02	0.00	0.11	0.19	0.02
URBLOC2000	-999999.00	1.28	1.67	-999999.00	0.37	0.61	0.20
C	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
D1	0.36	0.37	0.37	0.37	0.36	0.36	0.36
D2	0.29	0.30	0.30	0.30	0.31	0.32	0.31
D3	0.29	0.30	0.30	0.30	0.30	0.30	0.30
E	0.32	0.32	0.32	0.32	0.32	0.32	0.32
F	2.42	2.41	2.40	2.41	2.40	2.40	2.40
C (1 km)	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
D1 (1 km)	0.36	0.36	0.36	0.37	0.36	0.35	0.36
D2 (1 km)	0.30	0.30	0.30	0.30	0.31	0.33	0.31
D3 (1 km)	0.295	0.297	0.295	0.295	0.296	0.298	0.301
E (1 km)	0.318	0.318	0.317	0.318	0.318	0.318	0.32
F (1 km)	2.416	2.416	2.419	2.414	2.409	2.403	2.402
Urban Expansion Factor (UEF) for URBEXT							
Design Year	2015	URBEXT1990		1.076	URBEXT2000		1.032878