CULLOMPTON EASTERN RELIEF ROAD AND POTENTIAL STRATEGIC MOTORWAY IMPROVEMENT

Flood Risk Assessment

JUNE 2018

Incorporating

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Flood Risk Assessment

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Report No	0005-UA005763-UU41R-07
Date	JUNE 2018

VERSION CONTROL

Version	Date	Author	Changes
02	05/12/17	EB / CG	For internal review
05	11/12/17	CG	For Issue
07	11/06/18	SD / CG	Revised following EA and MDDC Comments

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1 Introduction

1.1 Overview

Arcadis Consulting (UK) Limited has been commissioned by Devon County Council (DCC), supported by Mid Devon District Council (MDDC), to undertake a Flood Risk Assessment (FRA) to support the planning application to consider the construction of a relief road and motorway junction system, referred to henceforth as ‘the Scheme’, to the east of Cullompton town centre, Devon.

The Environment Agency (EA) Flood Map for Planning[1] indicates that the majority of the Scheme is located within Flood Zone 3 (high probability of flooding). In line with the requirements of the National Planning Policy Framework (NPPF)[2], development within Flood Zone 3 requires an FRA.

This FRA has been undertaken in accordance with the requirements of the NPPF and specific guidance provided by the EA throughout the duration of the study.

1.2 Scope of Works

The following tasks have been undertaken as part of this study:

1. Collect and review existing data (e.g. Strategic Flood Risk Assessment, Preliminary Flood Risk Assessment, EA Flood Risk Mapping)
2. Consult the Lead Local Flood Authority (LLFA), DCC, MDDC and South West Water (SWW) to gather flood risk and drainage information.
3. Undertake a qualitative assessment of flood risk from all sources.
4. Build a bespoke hydraulic model of the River Culm and tributaries in the vicinity of the Scheme to quantify fluvial flood risk to the site and to assess any third party impacts arising from the Scheme.
5. Produce an FRA report.

1.3 Terminology

Flood Risk is a product of both the likelihood and consequence of flooding. Throughout this report, flood events are defined according to their likelihood of occurrence. Floods are described according to an ‘annual chance’, meaning the chance of a particular flood occurring in any one year. This is directly linked to the probability of a flood. For example, a flood with an annual chance of 1 in 100 (a 1 in 100 chance of occurring in any one year), has an annual exceedance probability (AEP) of 1%.

1.4 Limitations

This report has been compiled from a number of sources which Arcadis believes to be trustworthy. However, Arcadis is unable to guarantee the accuracy of information provided by others. The report is based on information available at the time of writing. Additional information may become available in the future which may have a bearing on the conclusions of this report and for which Arcadis cannot be held responsible.

[1] https://flood-map-for-planning.service.gov.uk/

[2] Department for Communities and Local Government (2012) National Planning Policy Framework

2 Background Information

2.1 Scheme Location

The Scheme (Figure 2-1), is located immediately to the east of Cullompton town centre, Devon. The River Culm flows from north to south along the eastern side of the Scheme and the Spratford Mill Stream flows from north to south along the western side of the Scheme. The Spratford Stream joins the River Culm on the eastern side of the M5 at the northern edge of the Scheme. The M5 and the Bristol to Exeter mainline railway bisect the Scheme from north to south.

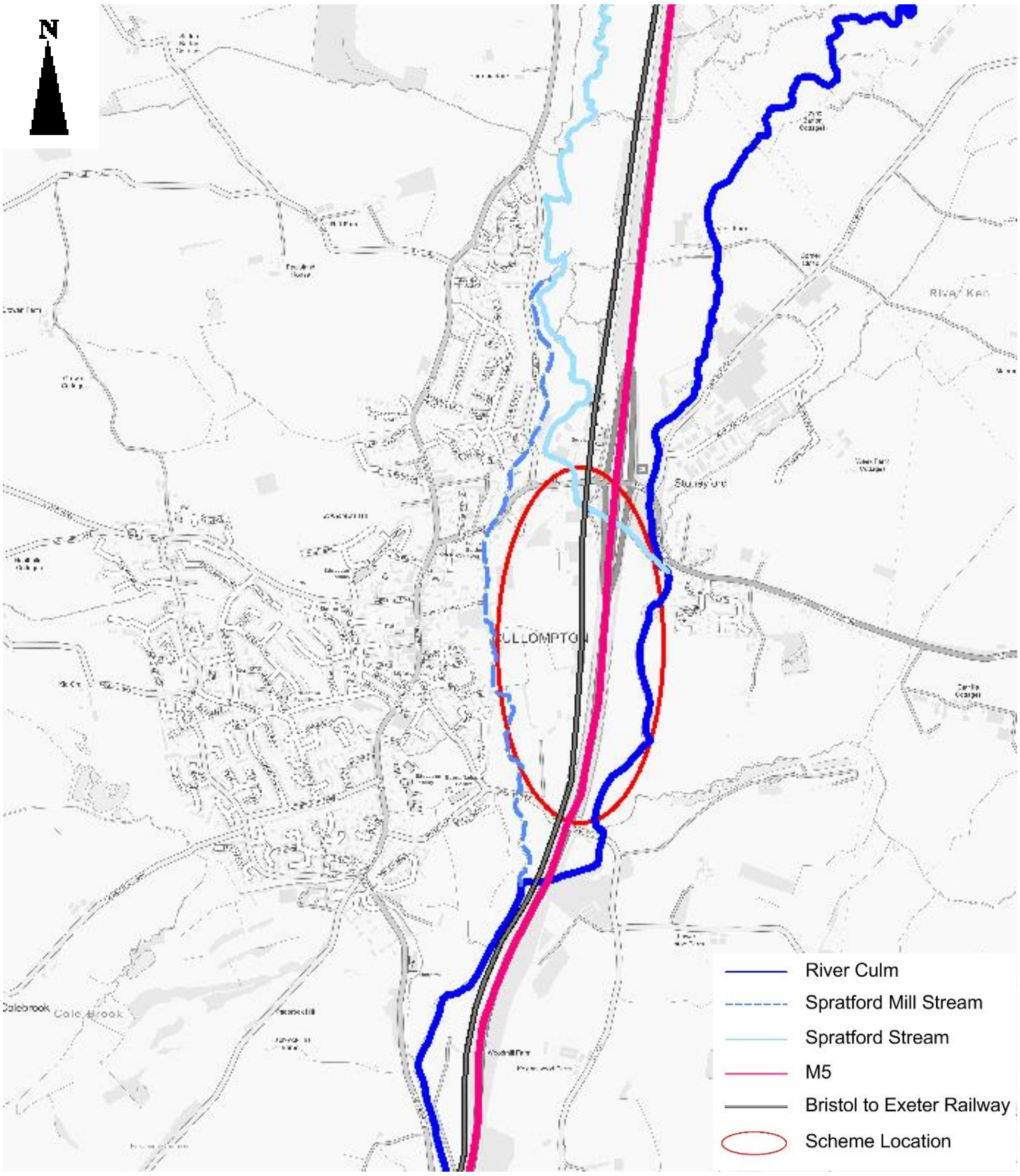

Figure 2-1: Scheme Location Plan (Contains Ordnance Survey data © Crown copyright and database right 2017)

2.2 Topography and Land Use

The area in which the Scheme is proposed is, at present, predominantly occupied by a series of fields bounded by mature hedges. The Scheme will connect with existing roads within the urban area of Cullompton.

Existing ground levels range from approximately 51mAOD at the northern extent of the Scheme to 48mAOD at the southern extent of the Scheme. The roads which comprise the Scheme will tie into existing levels where they connect with the existing road network. The new M5 Junction 28a (south of the current M5 Junction 28 – see Section 2.4) will be elevated above surrounding ground levels with a maximum elevation of approximately 59mAOD as it crosses the M5 carriageway.

2.3 Catchment Description

The Scheme is located on the floodplain of the River Culm and Spratford Stream. The River Culm flows through the Devon Redlands and is the longest tributary of the River Exe. It rises in the Blackdown Hills near RAF Culmhead in Somerset, and flows west through Hemyock, then Culmstock to Uffculme. The river turns south through Cullompton and flows alongside the M5 motorway, skirting the northern boundary of Killerton Park to join the River Exe on the north-western outskirts of Exeter. The catchment is predominantly agricultural with small areas of woodland in the eastern catchment and receives an average annual rainfall of approximately 970mm. The largest area of urban development in the catchment is Cullompton.

Nine tributary streams interact with the River Culm within the study area (Figure 2-2). Further details on these tributaries and their catchments can be found in Section 5.

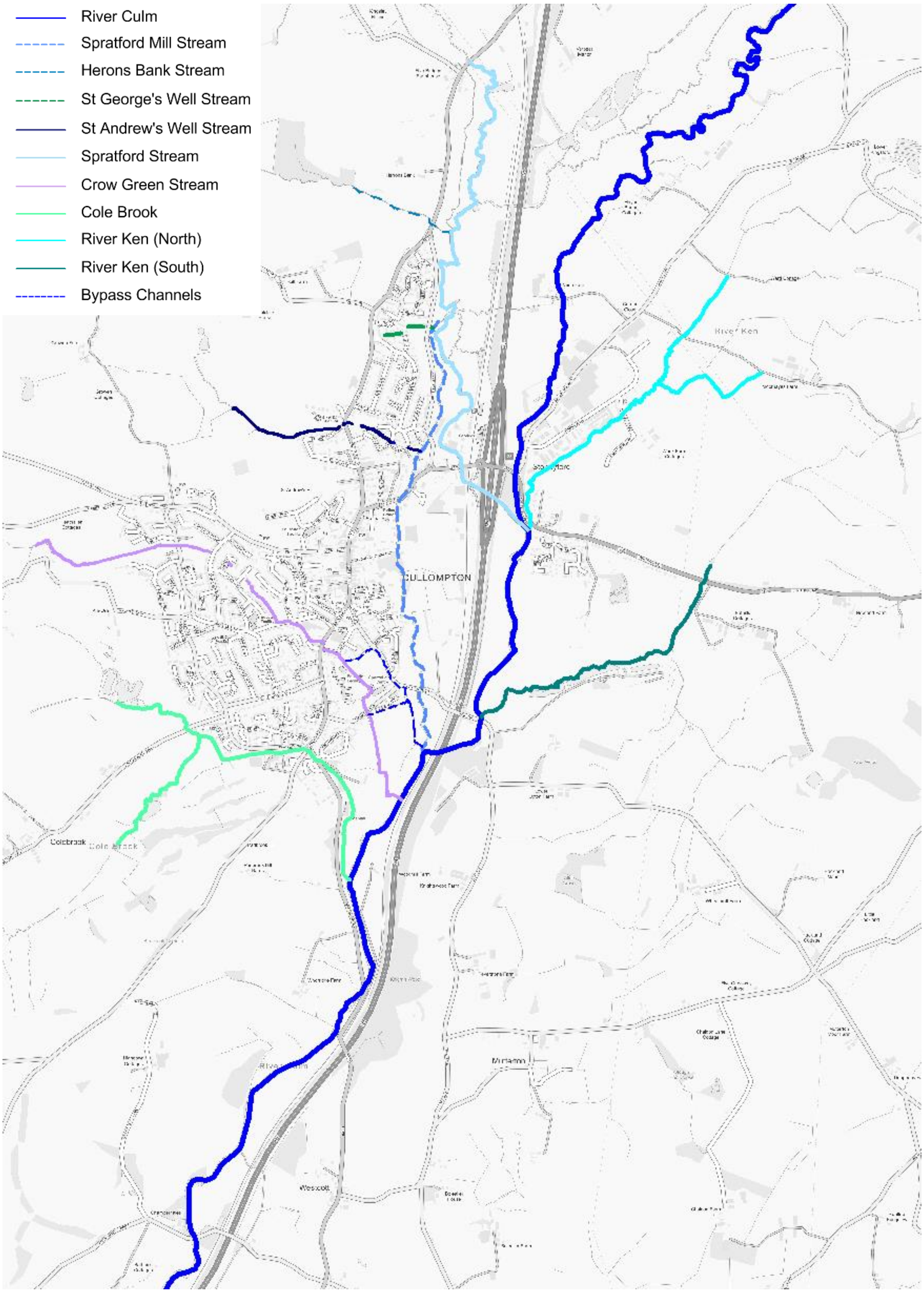

Figure 2-2: River Culm System within the Study Area (Contains Ordnance Survey data © Crown copyright and database right 2017)

2.3.1 Geology and Soils

With reference to public data provided by the British Geological Survey (BGS) via the Geology of Britain viewer[3], the local bedrock consists of Cadbury Breccia Formation (Sandstone), Aylesbeare Mudstone Group (Mudstone) and Clyst St Lawrence Formation (Siltstone and mudstone interbedded). The superficial geology underlying the majority of the Scheme consists of Alluvium (clay, silt and sand) and there are small areas of River Terrace Deposits 1 (sand and gravel) and Colluvium (diamicton) to the east of the Scheme.

The 1:250,000 scale Soil Map of England and Wales[4] characterises the soils for the river corridor through which the Scheme passes as Hollington, a reddish river alluvium comprised of deep, stoneless reddish fine silty and clayey soils, which are affected by groundwater, often on flat land and at risk of flooding.

Soilscapes[5] describes the soil as Loamy and clayey floodplain soils with naturally high groundwater.

An intrusive ground investigation[6] was carried out by Hyder Consulting (now Arcadis) on the 22nd and 23rd July 2013. The investigation concluded that the geology encountered included veneer of made ground or topsoil overlying superficial deposits of alluvium and possible terrace deposits with Sandstone lying at depths of 1.3m and 1.4m below ground level (bgl). The topsoil was identified as silty sand or sandy silt with rootlets, the made ground was described as dark brown fine very gravelly cobbly sand with abundant roots, gravel and cobbles, comprising fine to medium sub-angular to angular cubic weak sandstone and debris bricks. The Alluvium deposits were on the whole classified as sand with minor constituents of silt and gravel with occasional cobbles.

2.4 Development Proposals

The proposed route of the scheme is shown in Figure 2-3 and comprises four main elements:

- North south link road on the western side of the M5 connecting the Station Road / Millennium Way roundabout to Duke Street / Meadow Lane;
- New junction on the M5; Junction 28a located 530m south of the existing Junction 28;
- North south link road on the eastern side of the M5 connecting the east west link to Old Hill; and
- East west link road connecting new Junction 28a with the new north south link roads either side of the M5.

The Scheme will cross the River Culm and the Spratford Mill Stream (Main Rivers), the River Ken (South) (Ordinary Watercourse) as well as several of the existing floodplain drainage ditches. In addition, flood relief culverts will be incorporated into the road embankments to maintain floodplain connectivity. Further details on these are provided in Section 7.2.

[3] British Geological Survey (BGS) Geology of Britain viewer, http://mapapps.bgs.ac.uk/geologyofbritain/home.html
[4] Soil Survey of England and Wales (1983), 1:2500,000 soil map of England and Wales
[5] Cranfield University, 2017. Soilscapes Interactive Map, http://www.landis.org.uk/soilscapes/
[6] Hyder Consulting (UK) Limited (now Arcadis) (2013) UA005763-Memo-Geo-02

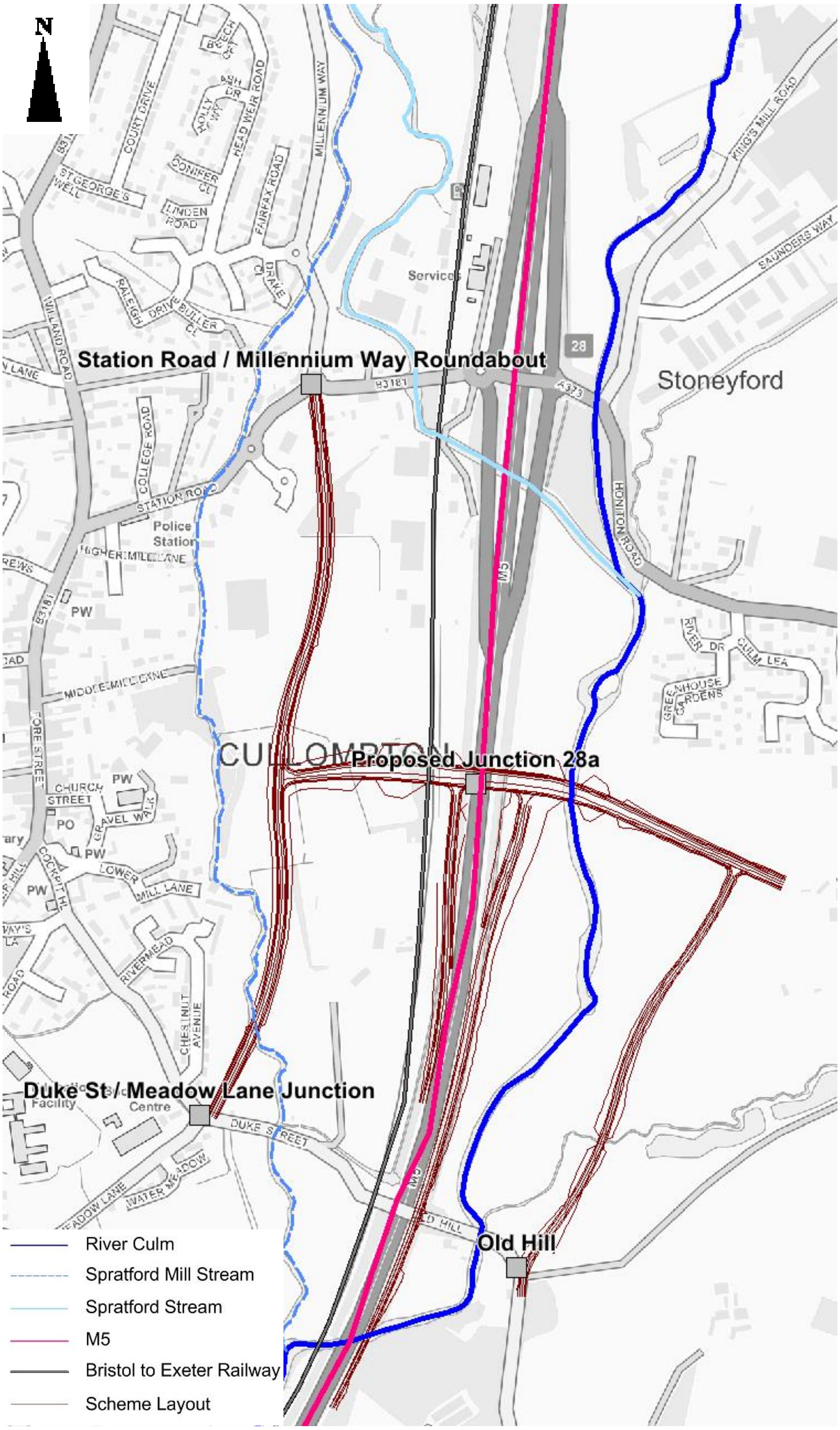

Figure 2-3 Proposed Scheme (Contains Ordnance Survey data © Crown copyright and database right 2017)

2.5 Historic Flooding

Flooding has occurred historically in Cullompton and the surrounding area; a number of sources of historic flood information, including the MDDC Strategic Flood Risk Assessments (SFRA)[7,8], have been reviewed and a summary of the key findings included below.

2.5.1 British Hydrological Society Chronology of British Hydrological Events

The British Hydrological Society (BHS) Chronology of British Hydrological Events website[9] is a public repository for hydrological facts with the aim of enabling an assessment of the spatial extent of flood events, and their relative severity. Table 2-1 summarises the events local to the scheme.

Date	Source	Commentary
23/06/1946	British Rainfall for 1946, p.29.	From Cullompton [Devon] where 2.35 in. of rain fell in 45 minutes, Mr M.T.Foster wrote:'…In the lower parts of the town flooding was 3 ft. deep in houses. In one garden and house alone £1,000 worth of damage was done. The area of the storm was about 3 square miles…'
27/10/1960	Devon Flood Story (1960) Fifth Edition with Exeter and Taunton. David and Charles, Dawlish.	"Rivers continued to rise until many were at a higher level than recorded this century. There was widespread flooding in the valleys of the Taw, Torridge, Exe, Culm, …"
	British Rainfall for 1959-60, page.102	Rivers in the south-west continued to rise until many were at the highest level recorded this century. There was widespread flooding of the Taw, Torridge, Tone, Exe and Culm during the early hours of the 27th, and many towns and villages on these rivers suffered…"
05/07/1963	Richard Mabey (1983) Cold Comforts: an almanac of the best and worst of British weather Hutchinson.	A downpour at Hemyock in Devon produced 1 inches of rain in 15 minutes and 3.1 inches in 1.25 hours." [R. Culm]

Table 2-1: Flooding in Cullompton as listed in the BHS Chronology

2.5.2 October 2008 Flood Event

The EA provided images of flooding which occurred in October 2008 (Figures 2-4 and 2-5).

[7] Hyder Consulting (2009) Mid Devon SFRA Levels 1 and 2

[8] JBA Consulting (October 2014) Mid Devon Strategic Flood Risk Assessment – Final Report

[9] http://cbhe.hydrology.org.uk/

Figure 2-4: October 2008 Flooding in Cullompton: Looking north from Exeter Road (Source Environment Agency)

Figure 2-5: October 2008 Flooding in Cullompton: Looking west towards Cullompton; River Culm in the foreground. (Source Environment Agency)

2.5.3 November 2012 Flood Event

In November 2012 significant flooding occurred across the Exe catchment. Heavy rain falling onto already saturated ground resulted in the highest recorded river levels on the Culm since 1962. Flood levels came close to overtopping the earth embankment at Millennium Way (Figure 2-6) Localised overtopping of defences protecting the Alexandria Industrial Estate occurred resulting in inundation of the estate (Figure 2-7). The Bristol Exeter Railway upstream of Old Hill flooded to an approximate depth of 100mm.

Water also backed up through drains and the capacity of a number of watercourse culverts was exceeded. The main areas affected were the Alexandria Industrial Estate, Rivermead, Pound Square, Duke Street and Meadow Lane. Forty-seven properties were impacted[10] (Figures 2-6 to 2-9).

Figure 2-6: November 2012 Flooding in Cullompton: Earth Embankment at Millennium Way (Source Environment Agency)

Figure 2-7: November 2012 Flooding in Cullompton: Entrance to the Alexandria Industrial Estate (Source Environment Agency)

[10] Devon County Council (2012) Flood Investigation Report: Devon Floods 21st – 25th November 2012

Figure 2-8: November 2012 Flooding in Cullompton: Duke Street – looking towards Rivermead (Source Environment Agency)

Figure 2-9: November 2012 Flooding in Cullompton: Long Bridge (Station Road) (Source Environment Agency)

2.5.4 Additional Notable Flood Events

Additional flood events of note identified during the review are summarised in Table 2-2.

Date	Commentary
24/05/1989	Approximately 10 properties flooded
7/8/1997	Intense thunderstorm over Cullompton caused the Crow Green Stream to flood a number of properties on Brook Road and Duke Street, as well as the Culm Valley Sports Centre car park. The overland flow reached a depth of approximately 300mm. Flooding of Cole Brook - Knightswood Estimated 30 properties affected by flooding
01/01/1999	Several houses flooded on the Kingswood Estate

Date	Commentary
07/12/2000	At least one property flooded
15/10/2002	At least one property flooded

Table 2-2: Historic Flood Events in Cullompton

2.6 Flood Defences

The EA provided a GIS layer showing the key flood defences in Cullompton (Figure 2-11). The Rivermead defences were re-surveyed for this study in December 2016. Defence data is included in the bespoke hydraulic model (Sections 6 and 7).

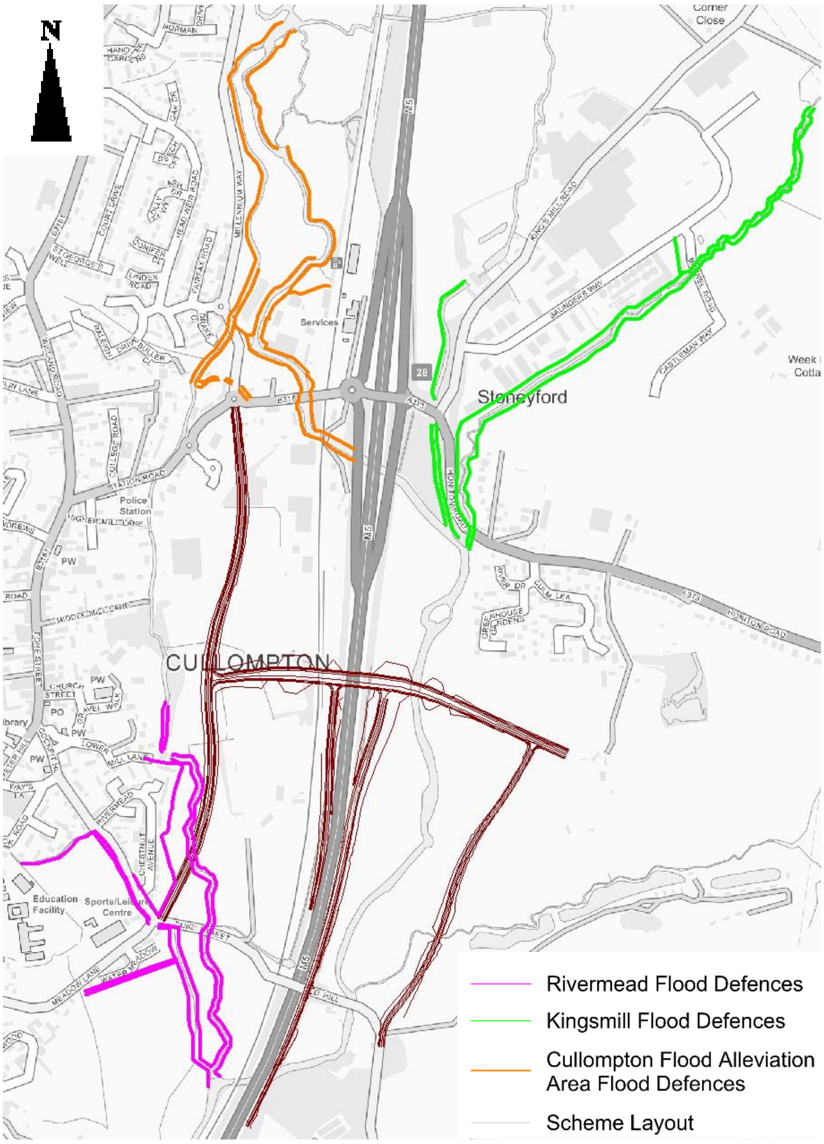

Figure 2-11 Flood Defences (Contains Ordnance Survey data © Crown copyright and database right 2017)

3 National Planning Policy Framework

3.1 Overview

The National Planning Policy Framework (NPPF) 2012[2] and its accompanying Planning Practice Guidance (PPG) 2014[11] set out Government planning policy for England. The principal aim of the NPPF is to achieve sustainable development. This includes ensuring that flood risk is taken into account at all stages of the planning process, avoiding inappropriate development in areas at risk of flooding and directing development away from those areas where risks are highest. Where development is necessary in areas at risk of flooding, the NPPF aims to ensure that it is safe, without increasing flood risk elsewhere.

A site-specific FRA is required for proposals of 1 ha or greater in Flood Zone 1, all proposals for new development (including minor development and change of use) in Flood Zones 2 and 3, or in an area within Flood Zone 1 which has critical drainage problems (as notified to the local planning authority by the EA), and where proposed development or a change of use to a more vulnerable class may be subject to other sources of flooding. The FRA should identify and assess the risks of all forms of flooding to and from the development and demonstrate how these flood risks will be managed so that the development remains safe throughout its lifetime, taking climate change into account.

Early adoption of, and adherence to, the principles set out in the NPPF and the PPG, with respect to flood risk, can ensure that detailed designs and plans for developments take due account of the importance of flood risk and the need for appropriate mitigation, if required.

3.2 The Sequential and Exception Tests

The NPPF identifies four Flood Zone classifications, detailed in Table 3-1.

Flood Zone	Annual Probability of Flooding (%)
1 Low Probability	Fluvial and Tidal <0.1%
2 Medium Probability	Fluvial 0.1 – 1.0 % Tidal 0.1 – 0.5 %
3a High Probability	Fluvial >1.0 % Tidal >0.5 %
3b The Functional Floodplain	Fluvial and Tidal >5.0 % *Starting point for consideration. LPAs should identify Functional Floodplain, which should not be defined solely by rigid probability parameters.

Table 3-1: Flood Zones (Source: NPPF PPG (2014), Table 1)

The NPPF specifies that the suitability of all new development in relation to flood risk should be assessed by applying the Sequential Test to demonstrate that there are no reasonably available sites in areas with a lower probability of flooding that would be appropriate to the type of development proposed. The NPPF provides guidance on the compatibility of each land use classification in relation to each of the Flood Zones as summarised in Table 3-2.

[11] Department for Communities and Local Government, 2014. Planning Practice Guidance: Flood Risk and Coastal Change

Flood Zone	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	✓	Exception Test required	✓	✓
Zone 3a	Exception Test required	✓	×	Exception Test required	✓
Zone 3b	Exception Test required	✓	×	×	×

Key:

✓ Development is appropriate

× Development should not be permitted

Table 3-2: Flood Risk Vulnerability Classification (Source NPPF PPG (2014, Table 3)

3.3 EA Flood Zone Classification

The EA Flood Map for Planning (Rivers and Sea)[1] shows that the majority of the Scheme is located within Flood Zone 3, defined as land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) in any year. The Flood Map for Planning does not take into account any defences that are present in the area.

With regards to flood risk vulnerability, the Scheme is classified as Essential Infrastructure. The location of this type of development is deemed appropriate in Flood Zones 1, 2 and 3, subject to satisfaction of the NPPF Exception Test in Zone 3.

Arcadis Consulting was commissioned by DCC (in conjunction with MDDC) to carry out a hydrological and hydraulic assessment of the River Culm and tributaries through Cullompton. The modelling confirms that the Scheme is located partially within Flood Zone 3. Further details regarding the bespoke Arcadis hydraulic model are presented in Section 6.

3.4 Application of the Sequential and Exception Tests

For the Sequential Test to be passed, it needs to be demonstrated that there are no alternative sites with a lower risk of flooding that could be used for the Scheme. Given the requirement for the Scheme to alleviate traffic within Cullompton town centre, to serve the employment and housing land allocations to the east of the M5 and to increase capacity onto / off the M5, the Scheme location is virtually fixed by these constraints.

Therefore, it is concluded that the Sequential Test has been passed.

The Scheme is classified as 'Essential Infrastructure' in accordance with the NPPF. The majority of the Scheme is located in Flood Zone 3. Therefore, with reference to Table 3-2, the type of development proposed must pass the Exception Test to achieve compliance with the NPPF.

For the Exception Test to be passed the following criteria are to be satisfied:

- It must be demonstrated that the development provides wider sustainability benefits to the community that will outweigh flood risk.
- A site-specific FRA must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere and, where possible, will reduce flood risk overall.

A Sequential and Exception Test document has been prepared by MDDC (with support from the EA) which is included as Appendix A. The key conclusions from this are summarised in Section 3.4.1.

3.4.1 Wider Sustainability Benefits

- Provision of increased volume of floodplain; an increase of 52,080m³ over the existing situation.
- Creating capacity for the growth and development of Cullompton, which is currently constrained by the severely limited capacity of Junction 28 of the M5 and air quality issues in the Town Centre.
- Provision of a new additional southbound M5 motorway junction (28A) which will remove congestion from the existing, at capacity, Junction 28.
- Provision of an additional road and pedestrian/cycle overbridge across the M5 motorway linking Cullompton town centre with areas to the east, removing congestion from the only existing (main route) overbridge.
- Provision of a Town Centre Relief Road removing substantial through traffic from the town centre and improving air quality in the town.

Therefore, it is concluded that the first part of the Exception Test has been passed.

3.4.2 Development Safety and Impacts on Flood Risk

The remainder of this FRA will:

- Demonstrate how the Scheme will be safe for its lifetime.
- Demonstrate that the Scheme will not lead to a net loss of floodplain storage
- Demonstrate how the Scheme will be designed to avoid impeding water flows
- Demonstrate how the Scheme will be designed to minimise increases in flood risk elsewhere
- Consider the requirement for flood warnings and evacuation plans
- Assess the impact of the Scheme on third parties

In doing so, this will show how the Scheme passes the second part of the Exception Test.

4 Potential Sources of Flooding

4.1 Overview

In line with best practice, this section of the FRA considers flood risk from the range of possible sources listed in Table 4-1.

Source of Flooding	Description
1. Flooding from Rivers (Fluvial)	Floodwater originating from a nearby watercourse when the amount of water exceeds the channel capacity of that watercourse
2. Flooding from the Sea (Coastal)	High tides, storm surges and wave action, often acting in combination, flooding low-lying coastal land
3. Flooding from Groundwater	Flooding caused when groundwater levels rise above ground level following prolonged rainfall
4. Flooding from Land (Surface Water)	Flooding caused by intense rainfall exceeding the available infiltration and/or drainage capacity of the ground
6. Flooding from Sewers	Flooding originating from surface water, foul or combined drainage systems, typically caused by limited capacity or blockages
6. Flooding from Reservoirs, Canals and other Artificial Sources	Failure of infrastructure that retains or transmits water or controls its flow

Table 4-1: Sources of Flooding

4.2 Fluvial

The EA 'Flood Map for Planning'[1], which does not take existing defences into account, shows that the majority of the Scheme is located within Flood Zone 3; this floodplain is associated with the River Culm and the Spratford Stream / Spratford Mill Stream.

The EA 'Flood Map for Flood Risk from Rivers or the Sea', which takes into account the effect of any flood defences, shows that the majority of the Scheme is in a location considered to be at high risk (greater than 3.3% chance of flooding in any given year) of flooding. The area through which the Scheme passes between Station Road and the northern edge of the Cullompton Community Association Fields is at medium (between 1% and 3.3% chance of flooding in any given year) risk of flooding.

The Scheme is not within the floodplain of any other watercourses in the study area although these tributary watercourses do contribute flood flows to the Culm and the Spratford Stream.

The Scheme is considered to be at risk of fluvial flooding; this is discussed further in Sections 5, 6 and 7.

4.3 Coastal

The Scheme is approximately 22km from the nearest coast. Ground levels in the vicinity of the Scheme range from 51mAOD to 48mAOD. The Mid Devon SFRA[7] concludes that that the Mid Devon district as a whole lies over 15m above the highest astronomical tide. Furthermore, the Scheme is approximately 27km upstream of the Exe tidal limit at Countess Wear, Exeter.

The Scheme is therefore not considered to be at risk of coastal flooding.

4.4 Groundwater

Groundwater flooding occurs when water originating in aquifers reaches the surface, typically as a result of high groundwater levels caused by prolonged rainfall, obstructions to groundwater flow or rebound of previously depressed groundwater levels. Information on the risk of groundwater flooding can be found from a number of sources which have been assessed at a range of scales. A summary of these sources is presented below.

4.4.1 Site Specific Intrusive Testing

The site specific testing carried out in July 2013[6] encountered groundwater as damp seepages at approximately 1 – 1.5m below ground level (bgl) in four out of six trial pits dug in the vicinity of the Scheme (Figure 4-1). In trial pit TP4, groundwater was encountered between 0.5 and 1m bgl. No water strike was recorded for TP5.

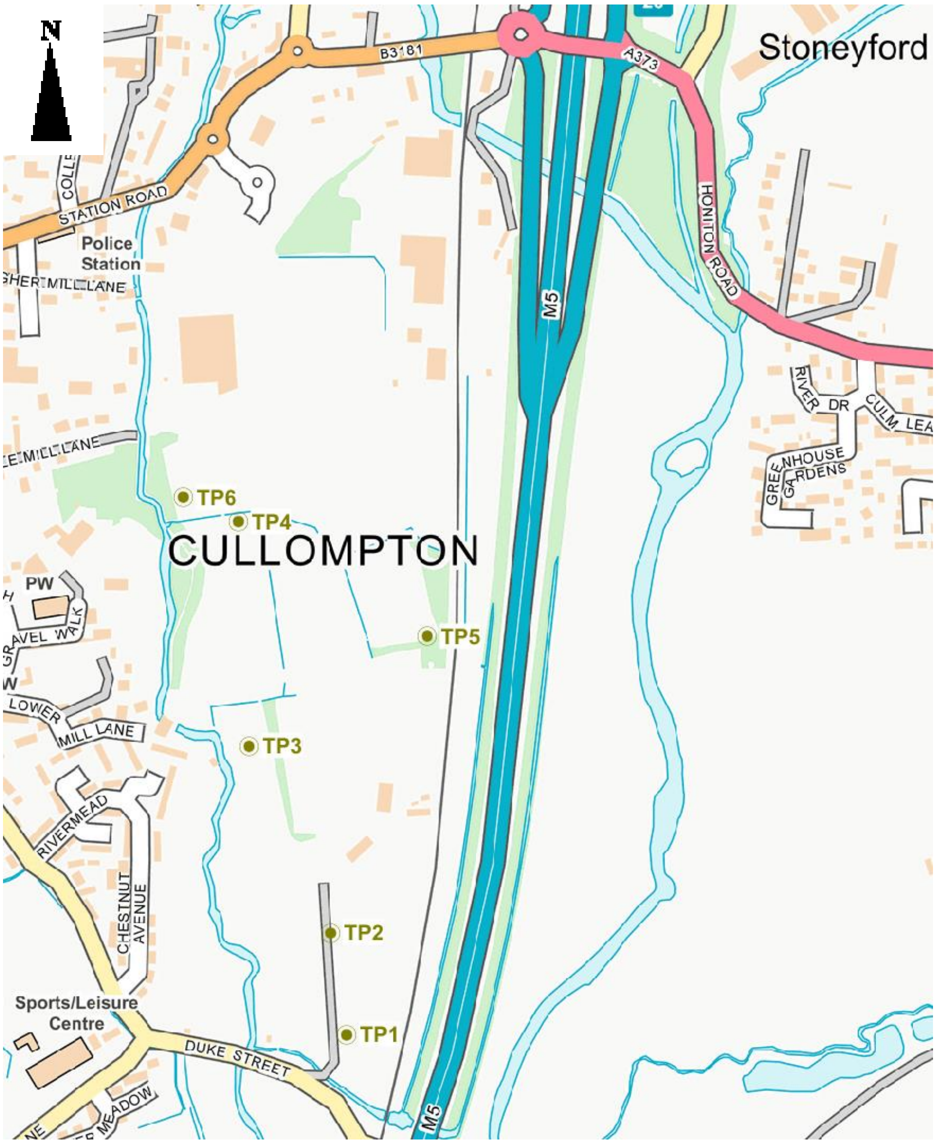

Figure 4-1: Trial Pits Excavated in July 2013 (Contains Ordnance Survey data © Crown copyright and database right 2017)

4.4.2 Environment Agency Groundwater Map

The EA groundwater map shows that the Bedrock designation for the area within which the Scheme is located is almost entirely ‘Secondary B’. These are predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers. A small area in the southeast extremity of the scheme is classed as Secondary A. These are permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

In terms of superficial deposits, the map identifies that, on the western side of the M5, the Scheme is located in an area designated as having Secondary A superficial deposits.

Although the EA groundwater map shows no superficial deposits on the eastern side of the M5, the British BGS GeoIndex[12] Onshore Hydrogeology map shows a layer of superficial deposits associated with the River Culm floodplain which extends to both the east and west of the M5.

4.4.3 Areas Susceptible to Groundwater Flooding

The MDDC SFRA[8] includes the Areas Susceptible to Groundwater Flooding (AStGWF) strategic scale map which depicts groundwater flood areas on a 1km square grid. The 1km grid squares are coloured based on the proportion of the square where geological and hydrogeological conditions indicate that groundwater might emerge rather than assessing the likelihood of groundwater flooding.

The Scheme lies partially within two 1km grid squares, both of which are assessed as being 50 – 75% underlain by ground conditions associated with potential groundwater emergence.

4.4.4 British Geological Society Onshore Hydrogeology

With reference to the BGS GeoIndex[13] Onshore Hydrogeology layer, the rock unit is classified as Permian Rock (Undifferentiated), characterised as ‘rocks with essentially no groundwater’.

4.4.5 Summary of Groundwater Data

Based on the information reviewed above, and given that the Scheme is predominantly to be constructed on an embankment, **it is considered that the Scheme is at low risk of groundwater flooding**. However, the detailed design of the Scheme should consider groundwater levels and the impacts they may have on construction work.

4.5 Surface Water

Flooding from the land (often known as surface water flooding) occurs when extreme rainfall exceeds the infiltration or drainage capacity of the ground surface. This form of flooding can pose both flood risk to a site, from surface water runoff from off-site areas, and an increased flood risk to adjacent sites, where proposed development affects the existing rainfall runoff regime.

The EA online ‘Flood Risk from Surface Water’ map shows a small area considered to be at ‘high’ risk of surface water flooding (greater than a 1 in 30 annual chance) where the Scheme joins Station Road. To the west of the M5, the area crossed by the Scheme is predominantly at ‘very low’ risk of surface water flooding (less than 1 in 1000 annual chance). Areas at ‘low’ (1 in 1000 to 1 in 100 annual chance), ‘medium’ (1 in 100 to 1 in 30 annual chance) and ‘high’ risk of surface water flooding are shown coincident with the existing field boundaries and drainage ditches. Post construction, the distribution of surface water flood risk is likely to change and a suitable surface water drainage scheme should be designed as discussed in Section 0.

East of the M5, the majority of the surface water flooding (‘low’, ‘medium’ and ‘high’ risk) is constrained to the River Culm, Spratford Stream and the River Ken (North).

It is therefore concluded that, providing an appropriate surface water drainage scheme is designed and implemented, the Scheme is at low risk of surface water flooding.

4.6 Sewers

South West Water was contacted for details of sewer flooding in the vicinity. As the Scheme crosses predominantly undeveloped areas, records of sewer flooding were limited to a couple of reports pertaining to

12 http://www.bgs.ac.uk/GeoIndex/

13 http://www.bgs.ac.uk/GeoIndex/

properties on Duke Street, approximately 150m from the Scheme. No critical issues were raised by South West Water.

It is therefore concluded that the Scheme is at low risk of flooding from sewers.

4.7 Reservoirs, Canals and other Artificial Sources

The EA provides a map showing the maximum potential flood extent, in the event that all reservoirs with a capacity of over 25,000 cubic metres were to fail and release the water they hold. The Scheme is not within this mapped extent.

The Grand Western Canal lies approximately 8km to the north west of the Scheme, following the 90m contour from Tiverton towards Sampford Peverell. The stretch of canal between Whipcott and Halberton passes through the upper catchment of the Spratford Stream. Within this length, there are some embanked sections which may be susceptible to a breach. Therefore, there is a possibility that any breach flows entering the downstream watercourse network would be conveyed onwards to Cullompton. However, it is noted that a breach in the Halberton Embankment in November 2012 resulted in a £1.5 million reconstruction scheme and investment in new sluices and warning systems to mitigate for this risk.

It is therefore concluded that the Scheme is at low risk of flooding from artificial sources.

5 Hydrological Analysis

5.1 Background

Full documentation of the detailed hydrological analysis carried out as part of this study is described in report number 0007-UA005763-NER-01, included as Appendix B. The key findings from this report are summarised below.

5.2 Flood Estimation Points

Inflows were derived for 11 flow estimation points and four intervening catchment areas (Figure 5-1) and applied to the hydraulic model (Section 6). Note, that to generate design event hydrographs for the Crow Green Stream, the catchment was divided and the modified ReFH method applied in the lower catchment, due to its highly urbanised nature, and the FEH Statistical method applied in the upper catchment.

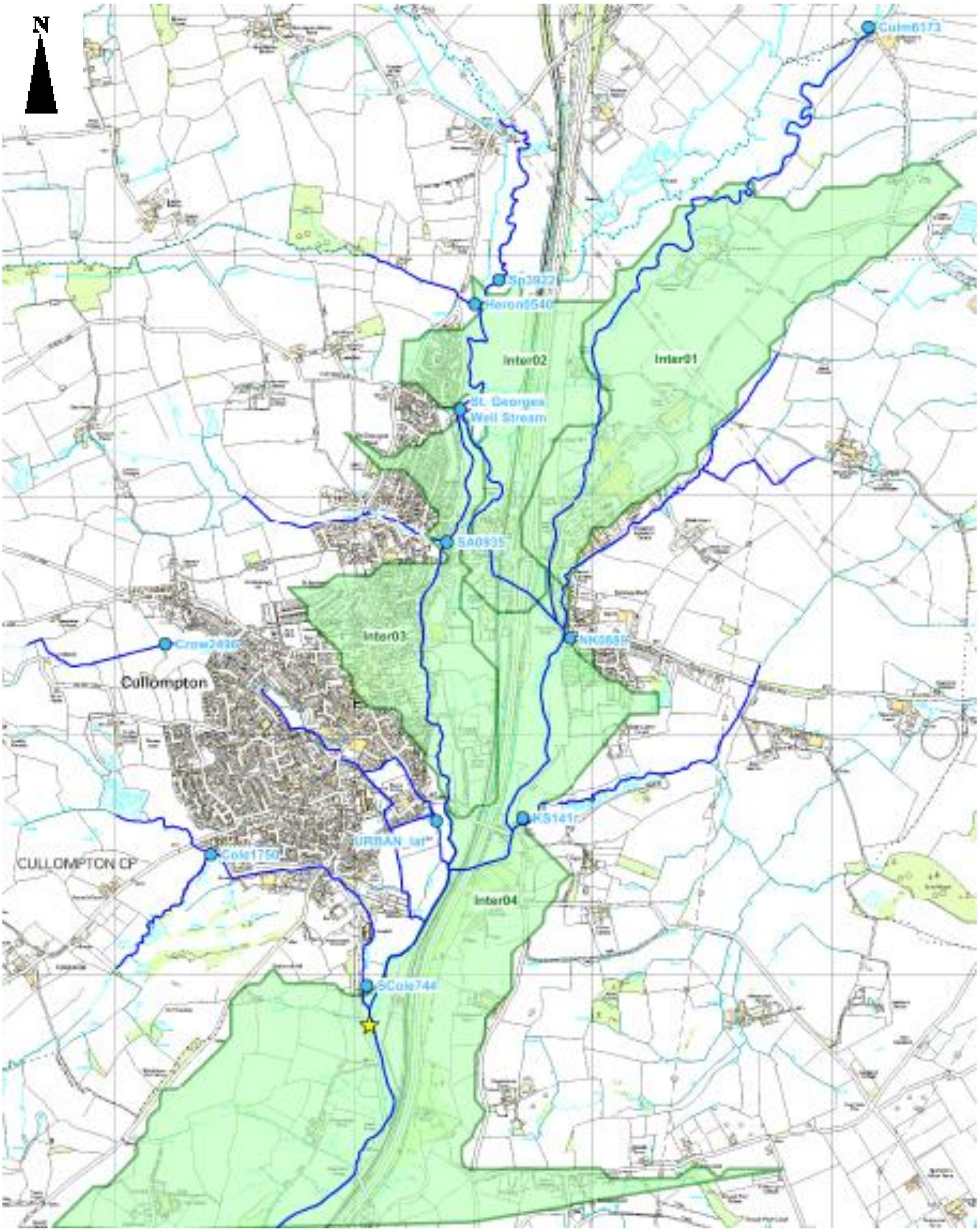

Figure 5-1 Flood Estimation Points. (This map is reproduced from Ordnance Survey material with the permission of Ordnance Survey on behalf of Her Majesty's Stationery Office © Crown Copyright. Devon County Council. 100019783. [2017])

5.3 Calibration Hydrology

A key requirement in developing the design inflows for the River Culm and tributaries was that they were consistent with observed flows at the Woodmill Gauge at the downstream model extent. In addition, the EA required that modelled flooding for the 2% AEP (1 in 50 annual chance) design event was consistent with the observed flooding which occurred in November 2012. In order to meet these criteria, all available hydrological data were reviewed and all standard flood estimation methodologies implemented. Key findings from this work are set out below, with full details included in Appendix B.

5.4 Review of Flood Estimation Methodologies

5.4.1 Flood Estimation Handbook (FEH) Statistical Method

Review of the available gauged data record at the re-rated Woodmill gauge and the results of a model calibration exercise centred on the November 2012 flood event indicated that the best practice Flood Estimation Handbook (FEH) Statistical method underestimates design flow estimates in the study catchment.

5.4.2 Revitalised Flood Hydrograph (ReFH) Method

ReFH models, informed by catchment descriptors, were applied using ReFH boundary units in the Flood Modeller Pro software package. This method was applied in only those catchments that are not deemed as permeable (i.e. BFIHOST < 0.65) or urbanised. Flows produced using this method were, in general, lower than those produced using the FEH Statistical methodology.

5.4.3 Revitalised Flood Hydrograph (ReFH) Optimisation

Flood event analysis was undertaken on the lumped catchment of the River Culm to the Woodmill gauge, using gauged rainfall and river flow data recorded during a series of historical events to optimise catchment descriptor based estimates of Cmax in an attempt to improve the ReFH models. Design flow estimates from the optimised ReFH models are higher than flow estimates produced by the catchment descriptor based models and compare more closely with (although are still generally lower than) the FEH Statistical peaks.

5.4.4 Devon Hydrology Strategy (DHS)

The DHS, developed by Haskoning in 2007[14], is a method of flow estimation that takes into account regional equations for different parts of Devon. Where available, for each FEP, peak flows from the most appropriate DHS model node were supplied by the Environment Agency. It is noted that these represent flow estimates for lumped catchments draining to each DHS model node and that the flow estimates generated are applicable to catchment critical storm durations for that lumped catchment.

5.5 Selection of Final Estimation Methodology

Despite efforts to optimise one of the key parameters in the ReFH model, and use of local hydrometric data records to inform the FEH Statistical method, routed flows from the FEH Statistical method (the methodology generally producing the higher flows of the two FEH methods) do not result in sufficient flow at the Woodmill gauge to tally with the gauged flow record. For example, routed 50% AEP FEH Statistical flow estimates do not generate enough flow (60.6m^3/s) to match with the QMED flow calculated from the AMAX data series (71.25m^3/s). Also, these flows indicate that the magnitude of the November 2012 flood was in excess of the 1% AEP, when available evidence provided by the EA indicates a more likely AEP of around 2%.

Woodmill is the only suitable donor for use in informing FEH flow estimates. Whilst situated on the study reach of the River Culm it is at the downstream limit of the study catchment and the effect of using the gauged data is moderated by the distance weighting factor in the QMED equation. The model also represents several small tributaries of the Culm that are quite different hydrologically to the overall Culm catchment. These tributaries are not gauged for flow, so no data records are available to improve FEH flow estimates for these FEPs.

As the Culm6173 FEP makes the largest contribution of flow to the model, followed by the FEP representing the Spratford Stream (SP3922), a test was undertaken whereby the higher DHS flows were routed through the model for these two FEPs, with FEH Statistical flows retained for the other tributaries. Three design events were run through the hydraulic model (5%, 2% and 1% AEP); adopting a catchment wide uniform storm duration of 14 hours, representative of the recommended duration of the lumped catchment of the Culm to the downstream boundary of the model. The routed flows were then compared to the results of

[14] Haskoning, 2007. *Devon Flood Hydrology Strategy*. Report on additional analyses. Report to Environment Agency South West Region.

lumped catchment analysis at the Woodmill gauge and the DHS peak flows for the lumped catchment at the gauge.

This comparison indicates that adopting DHS lumped catchment inflows for the two largest contributing catchments results in too much flow in the model. Routed flow at Woodmill exceeds the DHS lumped catchment estimates at Woodmill. Also, when comparing the routed flows at Woodmill to the November 2012 flood event peak (192m^3/s), this event would be assigned an AEP of around 5% AEP, which is more frequent than evidence suggests.

A further suite of model runs was therefore undertaken with DHS peak inflows at FEPs Culm6173 and SP3922 (which contribute by far the most flow to Woodmill) reduced by 20%. The reduction factor was selected based on the differential between the DHS lumped catchment flow and the routed DHS inflows, to account for the fact that the DHS inflows represent individual catchment critical storm flows, so are more conservative than flows that would be generated during a catchment wide storm. At Woodmill, routed flows for the 1%, 2% and 5% AEP events equal to 220 m^3/s, 192 m^3/s and 156 m^3/s respectively were extracted from the model. These flows compare very closely to the DHS lumped catchment flows and the simulated peak of the 2% AEP design event matches that of the observed November 2012 flood event peak.

To test the sensitivity of the model predictions to storm duration, inflows were generated for catchment wide storms of a longer and shorter duration. The durations selected were 9 hours (5 hours shorter than the lumped catchment 14 hour duration), representing the recommended duration storm for the largest of the Culm tributaries, the Spratford Stream, and 19 hours representing a corresponding increase in 5 hours over the 14 hour storm duration. These durations were agreed with the Environment Agency and inflow hydrographs were generated for the two storms, fitted to the adopted flow peaks described above

Further discussion on model calibration is included in Section 6.3.

6 Baseline Hydraulic Model

6.1 Model History

Modelling of the River Culm and its tributaries through Cullompton began in 2002. The sections below provide a brief overview of the modelling carried out since 2002 and describe the development of the final model used to inform this FRA.

6.1.1 Haskoning Model (2002)

A 1D only ISIS model of the River Culm was built by PDMM Posford Haskoning (now Royal HaskoningDHV) in 2002, under the EA's former Section 105 Flood Risk Mapping Framework Agreement. The model included nine watercourses in the vicinity of Cullompton: the River Culm, Spratford Stream, River Ken (North), River Ken (South), Heron's Bank, St Andrew's Well Stream, Crow Green Stream, Cole Brook and Spratford Millstream.

A review of this model was carried out by Arcadis (formerly Hyder Consulting) in July 2013 which recommended a number of improvements including the conversion of the 1D only model to a linked 1D 2D model. This review is included in Appendix C.

6.1.2 Hyder Model (2014)

A linked 1D 2D ISIS TUFLOW model of the River Culm and its tributaries was built by Hyder (now Arcadis) and submitted to the EA in February 2014. This was based on the 2002 Haskoning model and addressed the recommendations from the 2013 review. The Model Operation Manual written to accompany this model is included in Appendix C.

A review of the 2014 model was undertaken by the EA in May 2014; this highlighted some concerns over model calibration and identified some areas where the hydraulic schematisation could be improved.

6.1.3 Arcadis Model (2016)

A revised model was submitted to the EA in July 2016 which sought to address the comments noted by the EA in their May 2014 review. This model was then reviewed by a third party consultant on behalf of the EA which recommended that additional survey data be collected in order to improve the schematisation of a number of structures.

6.2 Arcadis Model (2017)

New survey data was collected by AP Land Surveys in December 2016. This was used to update the baseline hydraulic model. Alongside these geometry updates, the revised, scaled DHS flows (Section 5.5) were applied to the model to improve the calibration (Section 6.3). A model update memo describing these improvements is included in Appendix C.

6.3 Model Calibration

Discussion with the EA indicated that the November 2012 event had an annual exceedance probability of around 2%. It was therefore requested that a comparison of the 2% AEP design results with recorded data from the November 2012 event be made.

A drawing showing the difference between the levels of the wrack marks surveyed after the November 2012 event and the modelled 2% AEP flows is included in Appendix D. The Environment Agency Fluvial Design Guide[15] gives an indicative model water level accuracy for a flood defence model as +/- 250mm; at 52 (out of 107) of the locations surveyed, observed water levels are within 250mm of the modelled levels. At a further 23 locations, modelled floodwater depths are overestimated by between 250mm and 500mm. In 7 locations the model underestimates flood levels. Five locations are overestimated by between 0.5m to 0.8m. There are 20 locations where flooding was recorded in November 2012 but are not predicted to be flooded by the model, however these locations are only just outside the modelled flood extent. Given that 70% of modelled

[15]Environment Agency Fluvial Design Guide http://evidence.environment-agency.gov.uk/FCERM/en/FluvialDesignGuide/Chapter7.aspx?pagenum=5

water levels are either within expected tolerances, or overestimate surveyed levels (by up to 500mm), this is considered to be satisfactory, taking a conservative approach.

As part of the calibration review, flood levels have also been estimated from photographs taken during the November 2012 flood event. A summary of the findings is provided below.

Photo and Description	Estimated Water Level	2% AEP Modelled Flood Event Information
Control Structure (Sluice) at 302435, 107892 	Estimate that water level is 300mm below crest which gives an estimated stage of **52.79mAOD** at approximately 2 hours before event peak.	The modelled stage at Node ST17us is 52.83mAOD around 2 hours before the peak. This is 40mm above the estimated observed water level which is within the +/- 250mm tolerance referred to in the Fluvial Design Guide.
Embankment at 302475, 107811 	The assumed crest level of the embankment is **52.52mAOD** and based on the photo, the EA reported in their Flood Reconnaissance Report[16] that the observed water level is within 0-50mm of this (photo labelled as the peak of the event). This gives a level of between 52.47mAOD and 52.52mAOD.	The 2% AEP modelled results show a peak water level of **52.48mAOD** adjacent to the bund. This level is just short of overtopping the bund and hence modelled extents for the 2% AEP in this location are similar to those observed during the November 2012 event. Given that the modelled 2% AEP peak stage is within the estimated observed level range, this meets requirements in the EA Guidance.

[16] Environment Agency (2012) Cullompton recce Industrial Estates DRAFT

Photo and Description	Estimated Water Level	2% AEP Modelled Flood Event Information
Cattle fence at 302792, 107745 (fence is causing the weir effect shown on the photo below) 	The cattle fence was modelled assuming a 1.5m high structure. Water levels have been estimated to be overtopping the structure by approximately 100mm, giving an estimated water level of **52.2mAOD.**	The 2% AEP modelled results show the water level at the structure to be **52.1mAOD.** The afflux is also represented as a drop of around 110mm, in line with that observed.

6.4 Baseline Model Results

6.4.1 Depth

The following events were modelled: 50% AEP, 5% AEP, 2% AEP, 1% AEP, 0.1% AEP and 2016 Climate Change allowances for the Higher Central estimate (1% AEP plus 40%). The baseline hydraulic model was signed off by the Environment Agency in June 2017. The baseline modelled flood depths are shown in Figures 6-1 to 6-6.

Baseline model results show that, in the vicinity of the Scheme, out of bank flooding from the 50% AEP is limited to small areas to the east of the M5. Results from modelled events with an AEP less than or equal to 5% (i.e. events of larger magnitude) indicate that out of bank flooding in the vicinity of the Scheme would occur on both sides of the M5.

On the eastern side of the M5, the relatively constrained flooding observed in the 50% AEP spreads rapidly via the network of field drains and ditches for the larger modelled events resulting in significant floodplain coverage for all modelled events with an AEP less than or equal to 5%.

On the western side of the M5, this flooding propagates northwards from the Duke Street area. This flood water is met by water flowing south from Station Road for events with an AEP less than or equal to 1%.

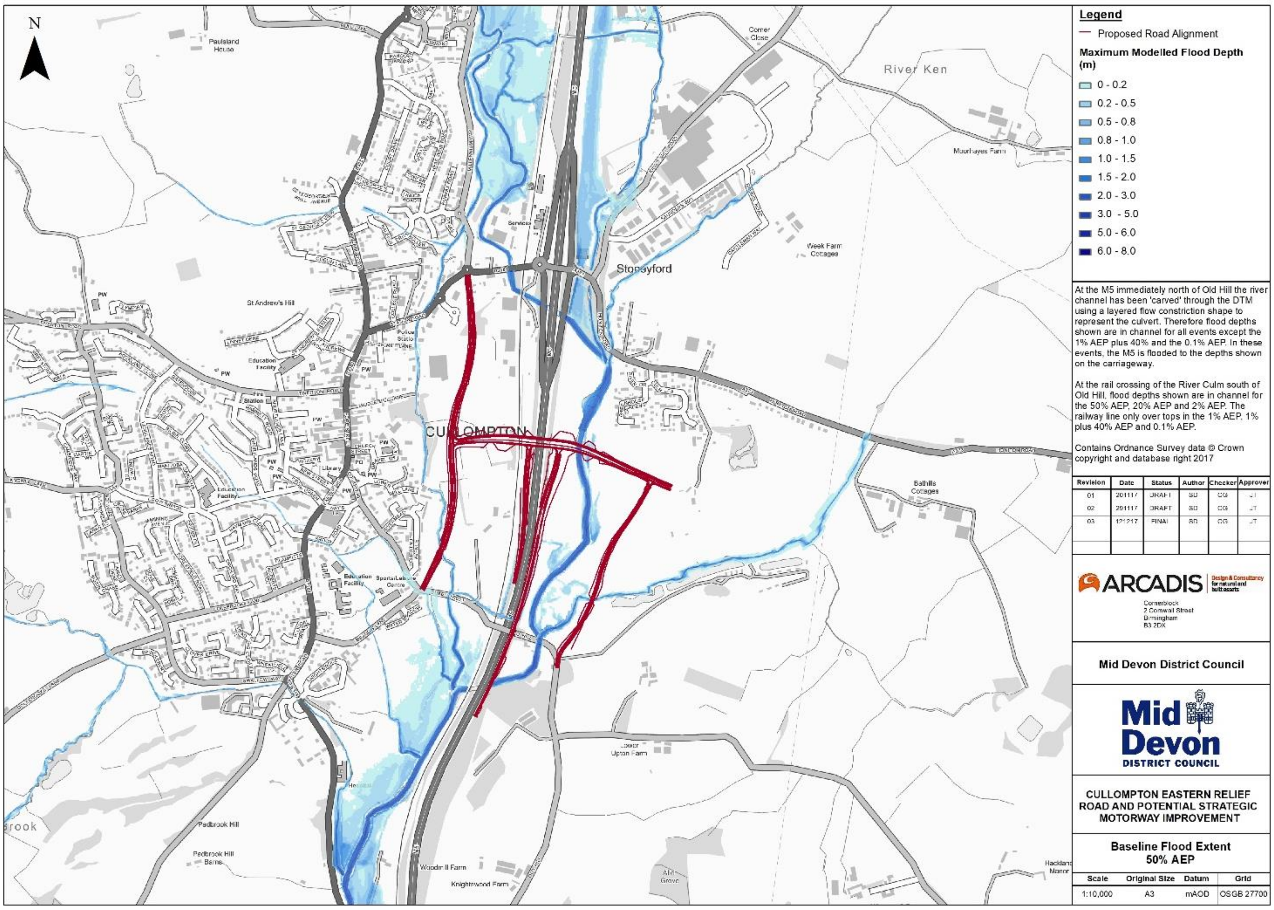

Figure 6-1 Baseline 50% AEP Flood Extents (Contains Ordnance Survey data © Crown copyright and database right 2017)

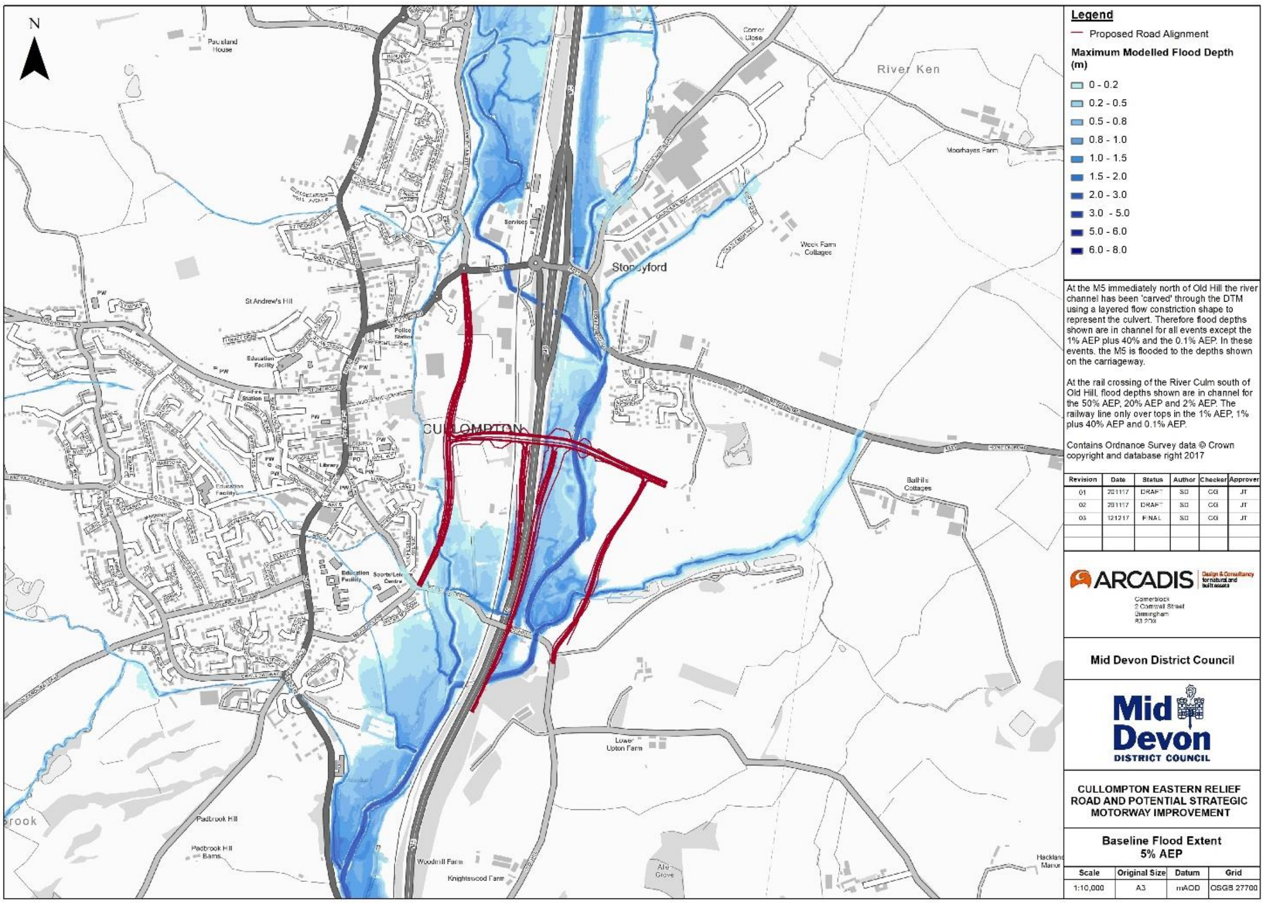

Figure 6-2 Baseline 5% AEP Flood Extents (Contains Ordnance Survey data © Crown copyright and database right 2017)

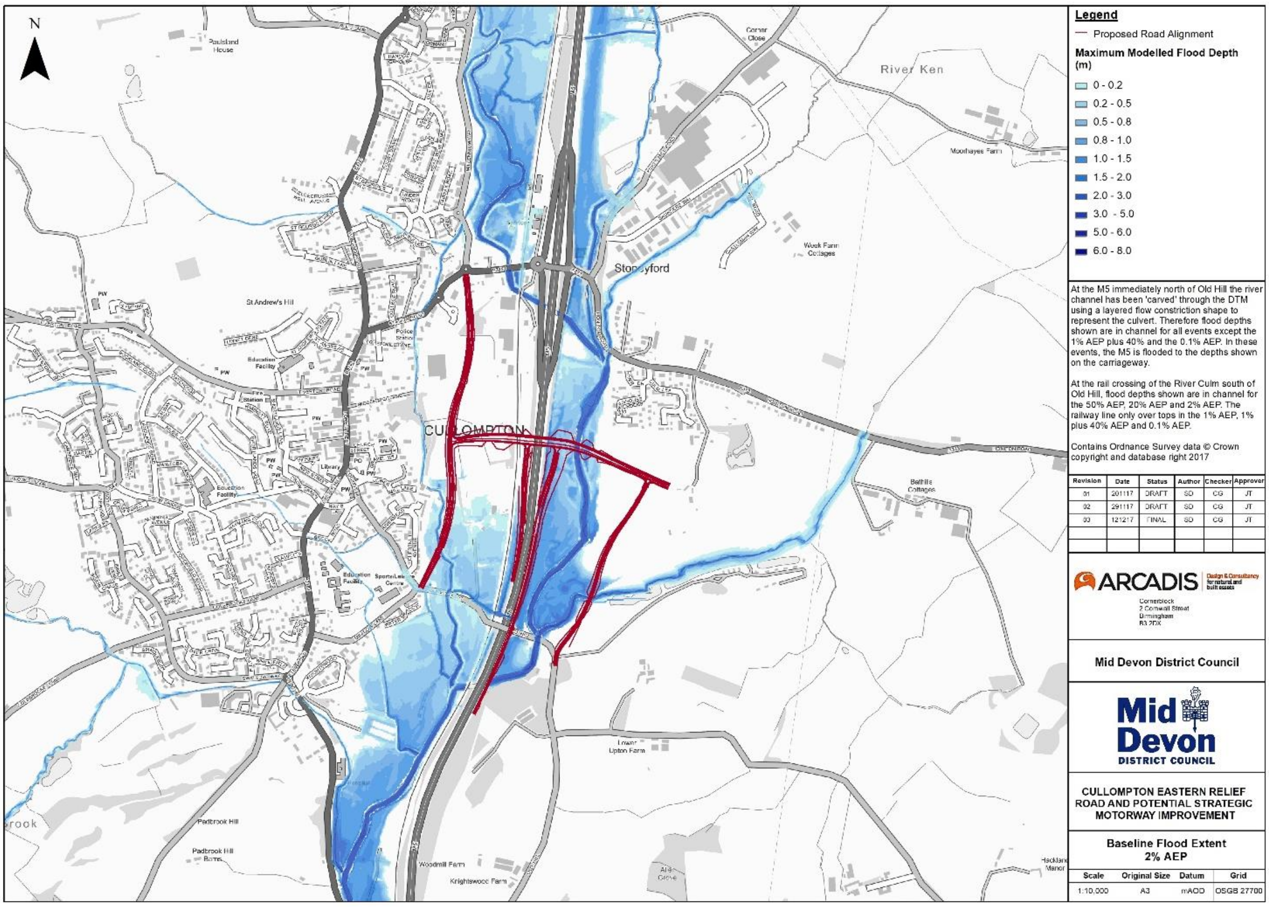

Figure 6-3 Baseline 2% AEP Flood Extents (Contains Ordnance Survey data © Crown copyright and database right 2017)

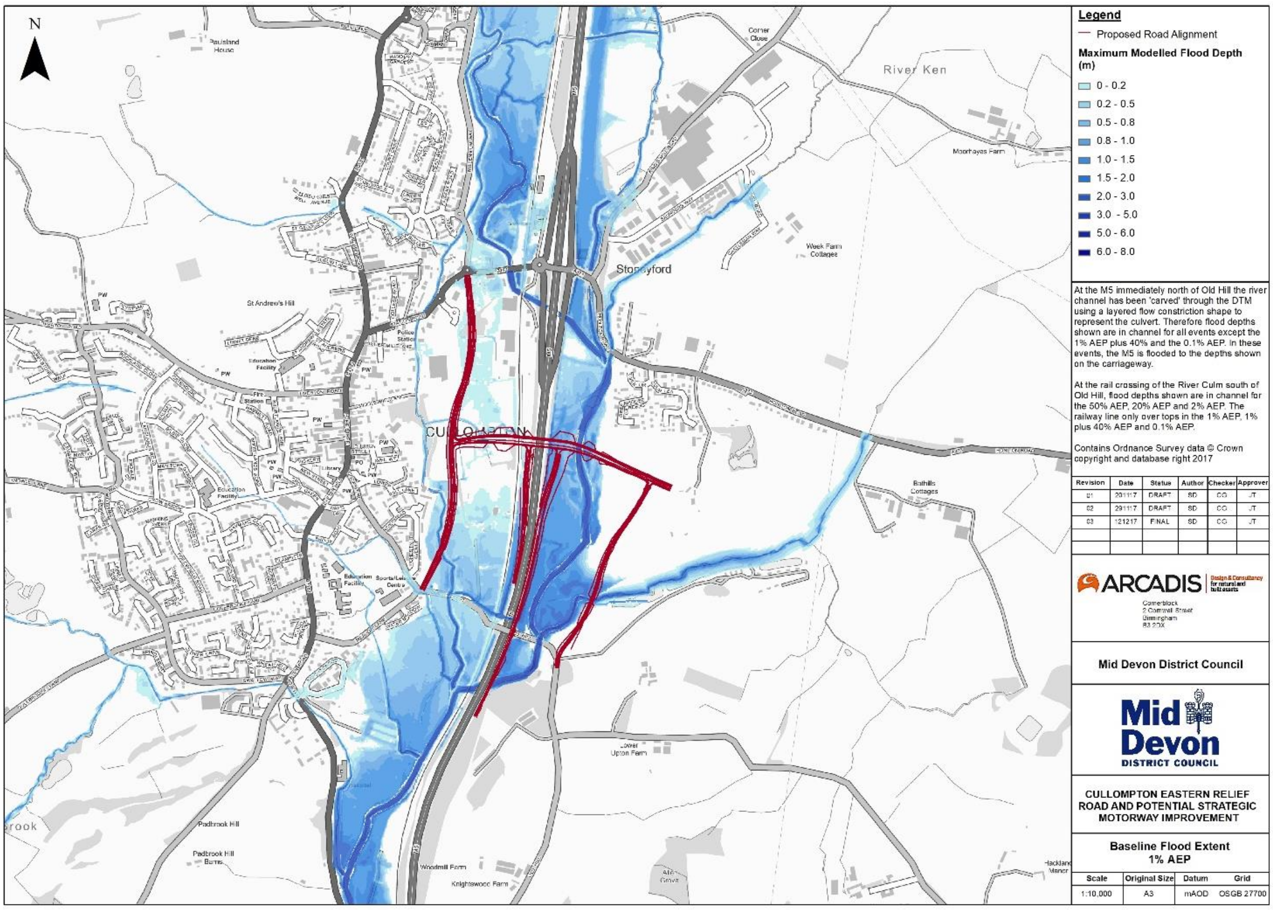

Figure 6-4 Baseline 1% AEP Flood Extents (Contains Ordnance Survey data © Crown copyright and database right 2017)

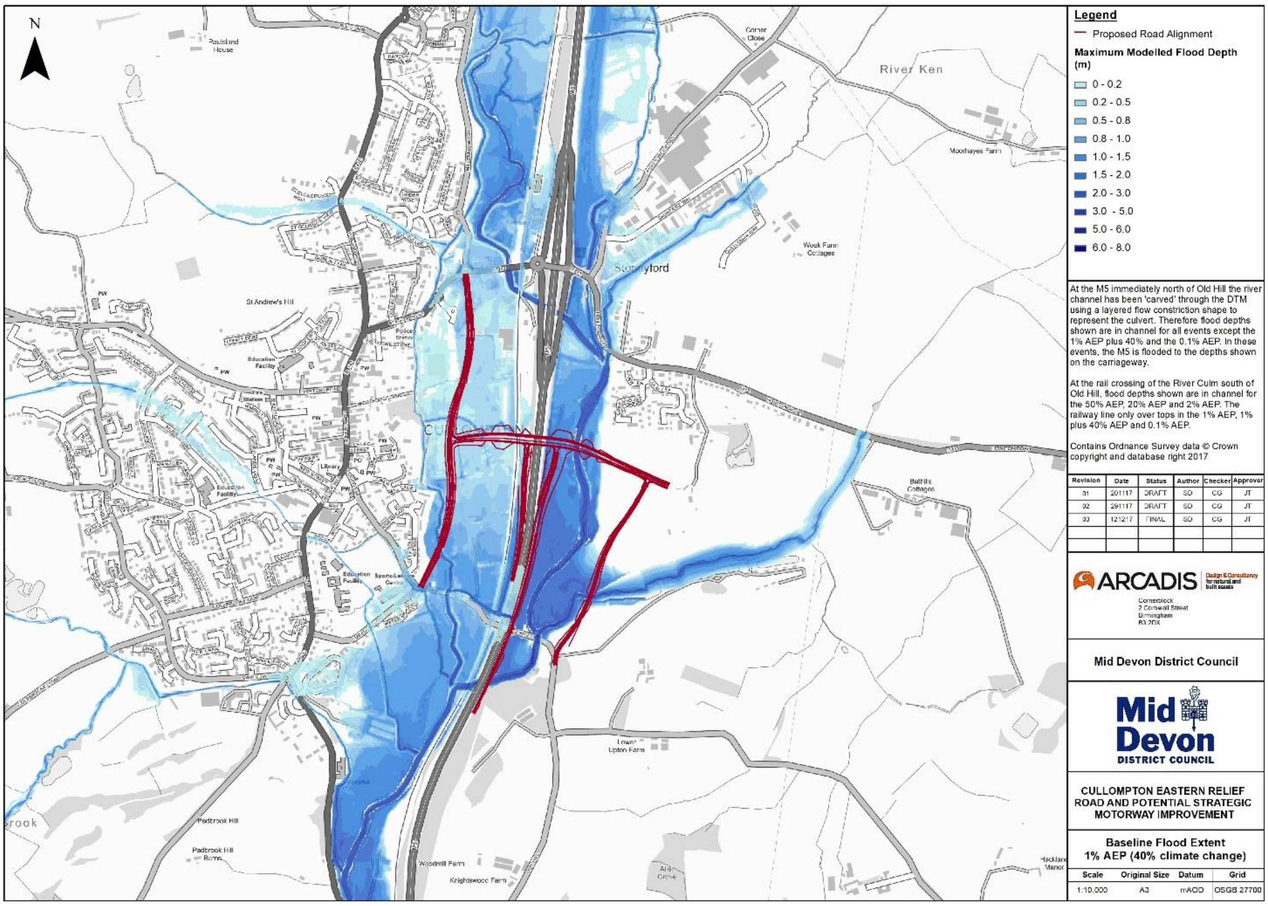

Figure 6-5 Baseline 1% AEP plus 40% Flood Extents (Contains Ordnance Survey data © Crown copyright and database right 2017)

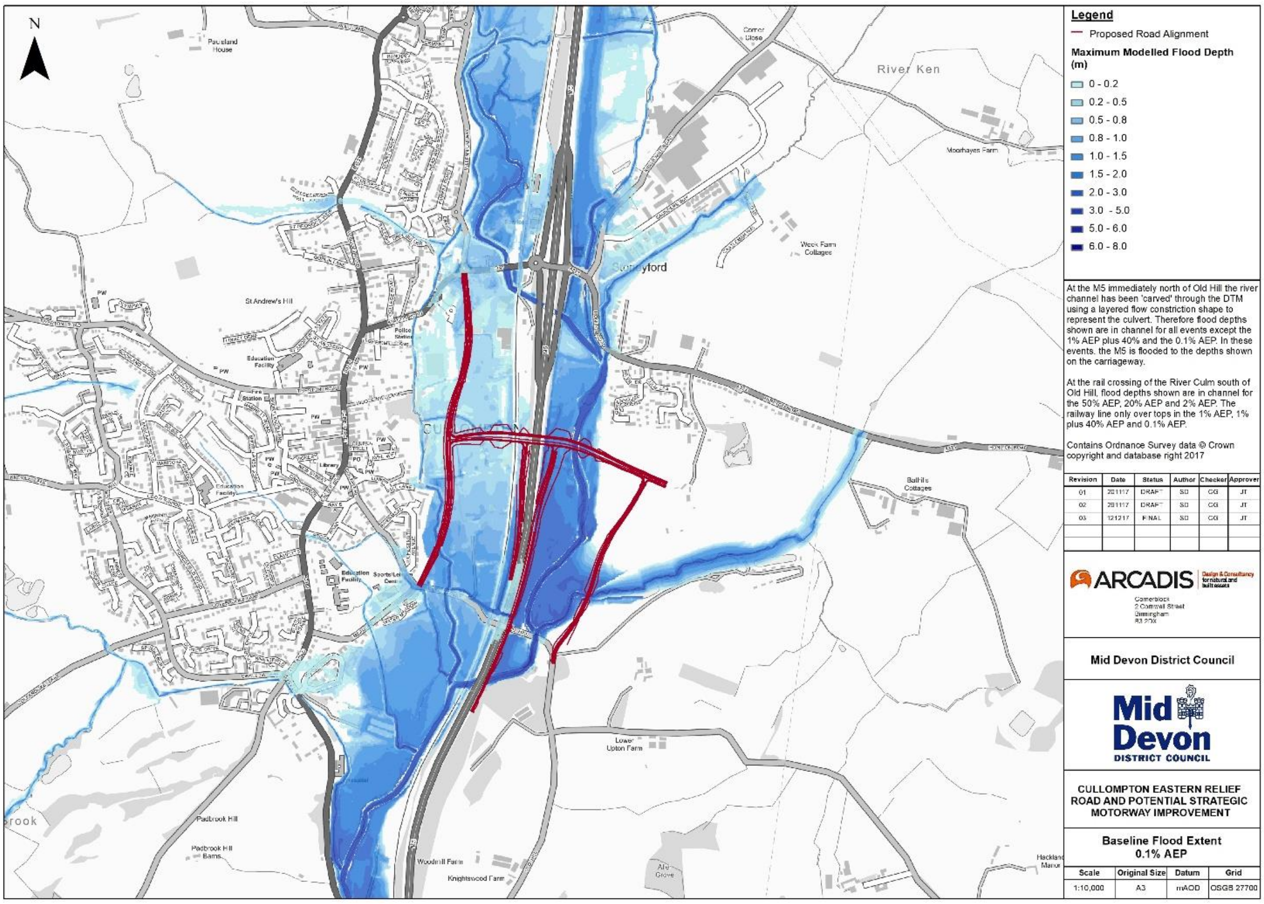

Figure 6-6 Baseline 0.1% AEP Flood Extents (Contains Ordnance Survey data © Crown copyright and database right 2017)

6.4.2 Velocity

Baseline results showing the maximum flood velocities for each event are included within Appendix E. These are discussed in further detail and compared to the ‘with Scheme’ results in Section 7.3.2

6.4.3 Stage

Baseline peak stage results in the vicinity of both the existing and proposed culverts are included within Appendix F. The results indicate that there is no significant afflux across the A373 culvert in the baseline conditions. Discussion on the proposed culverts is included in Section 7.3.2.

7 'With Scheme' Hydraulic Model

7.1 Scheme Components

The proposed Scheme is shown in Figure 7-1 and includes a new road running north south on both the east and west sides of the M5 and a new east west link between these roads which crosses the M5 and River Culm. The crossings of the River Culm and River Ken (South) will be single span; the former will have a soffit level above the 0.1% AEP maximum modelled flood level (to be finalised as part of the detailed design) and a width of 27m spanning the channel and floodplain, whilst the latter will comprise a 5.5m wide box culvert with a soffit level of 50.3mAOD, 36mm below the modelled 1% AEP peak flood level. The new road is to be, in part, constructed on an embankment and therefore has the potential to impact on both floodplain storage and conveyance.

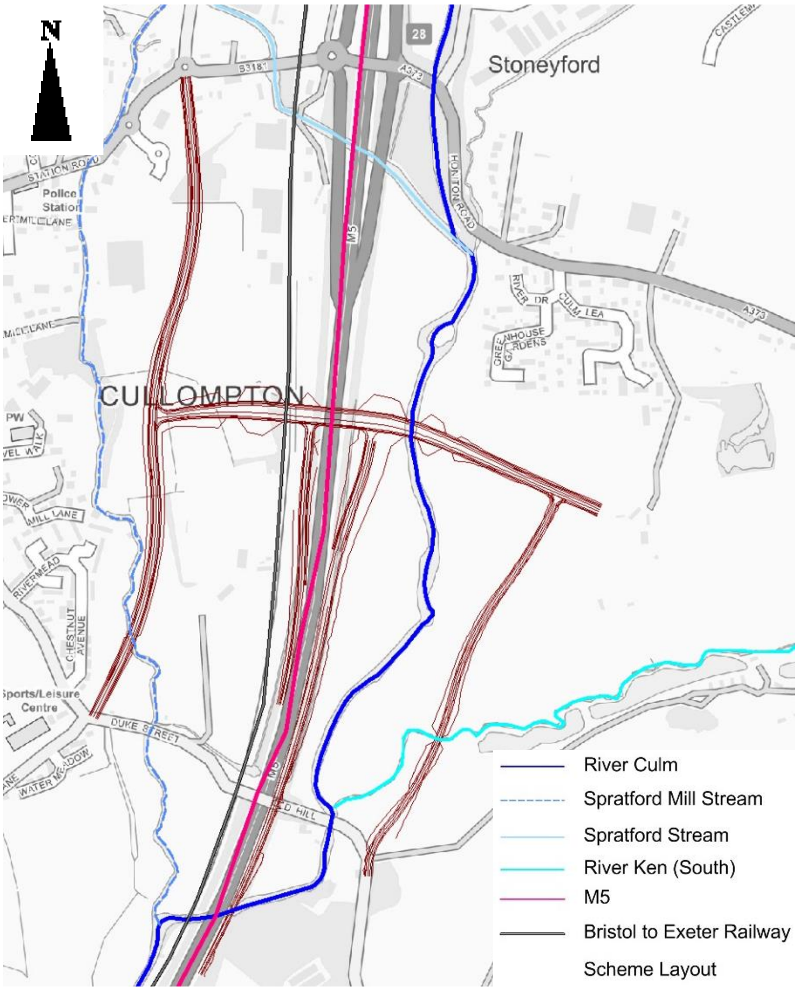

Figure 7-1 Scheme Layout. (Contains Ordnance Survey data © Crown copyright and database right 2017)

Further details on the files used to model the Scheme are included in Appendix C.

7.2 Scheme Mitigation Measures

In order to mitigate for any potential reduction in floodplain storage and conveyance, a number of culverts have been designed into the Scheme where it crosses the Culm and Spratford Stream floodplain, along with some compensatory lowering of other areas of floodplain (Figure 7-2). The Scheme has been developed with integral compensation measures as, based on local knowledge of the Culm floodplain hydraulics, the EA advised that compensation works would be essential in order to minimise third party increases in flood risk.

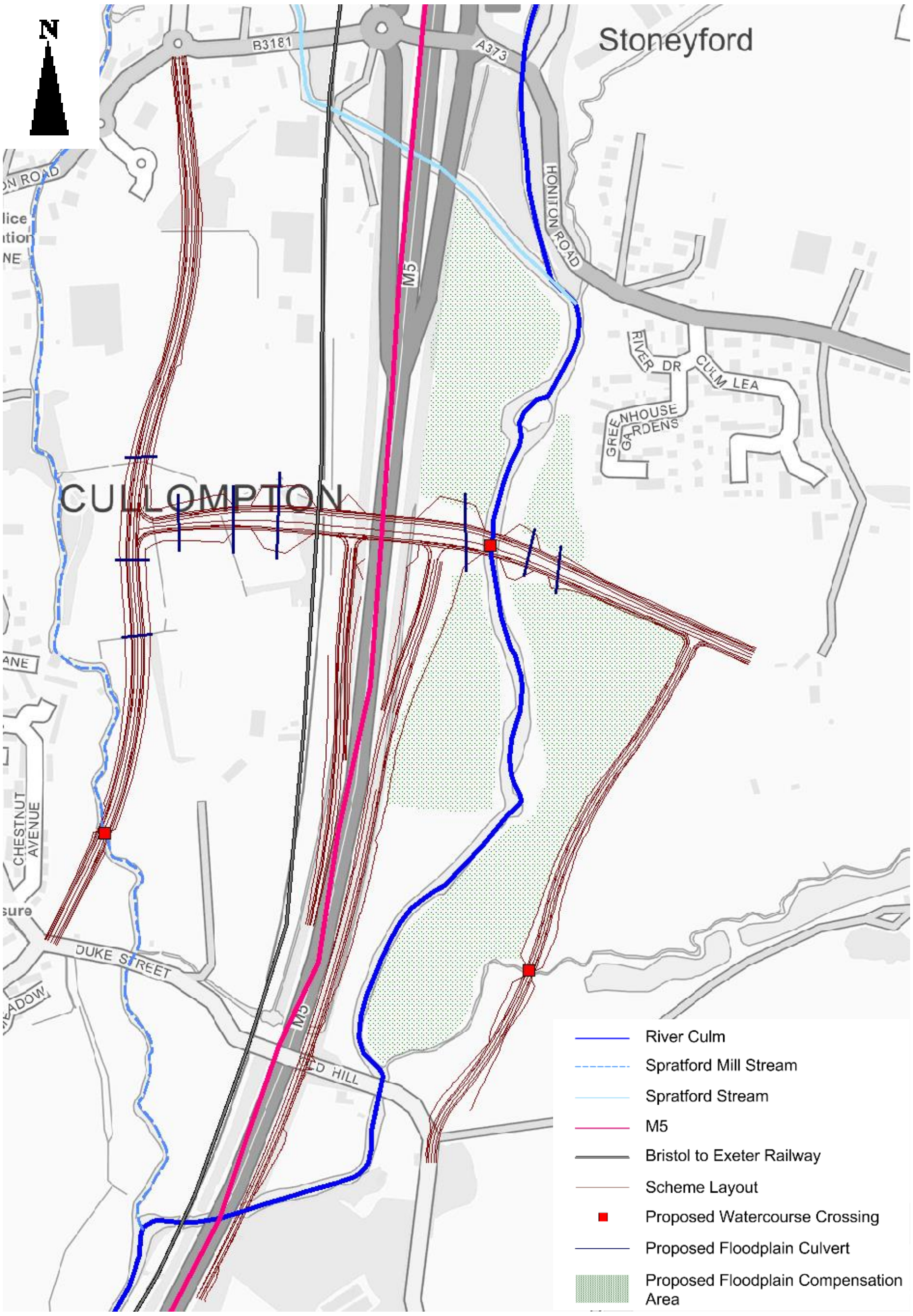

Figure 7-2 Scheme and Mitigation Layout. (Contains Ordnance Survey data © Crown copyright and database right 2017)

Further details on the files used to model mitigation for the Scheme are included in Appendix C.

7.2.1 Floodplain Conveyance

In addition to the watercourse bridges and culverts, nine further culverts have been incorporated into the design in order to maintain conveyance on the floodplain with the Scheme in place (Figure 7-2). These culverts allow floodwaters to move around the floodplain and help to prevent water becoming trapped by the Scheme embankments. The locations and sizes of the culverts have been developed through several iterations of modelling to maximise their effectiveness in conveying floodplain flows. Full details of the culvert sizes together with the approach taken to model them are included in Appendix C.

7.2.2 Floodplain Storage

The Environment Agency requested that a sufficient volume of compensation storage is provided as part of the Scheme to mitigate any loss of floodplain storage volume occurring as a result of the road proposals. The EA provided outline suggestions early in the project regarding potential locations for the compensation storage areas. The extents and dimensions of these compensation areas have subsequently been further developed through detailed consultation with the WSP Highway Design Team, supported by the EA. In designing the compensation storage, the Highway Design Team at WSP took into account constraints associated with the highway design itself such as engineering feasibility, ground conditions, visibility splays and land availability. Figure 7-3 shows the locations of the compensation areas referred to in Table 7-1. Note that where the new road ties into existing roads, the new road is at grade and does not take up any additional volume within the floodplain and hence is not included within Area 1.

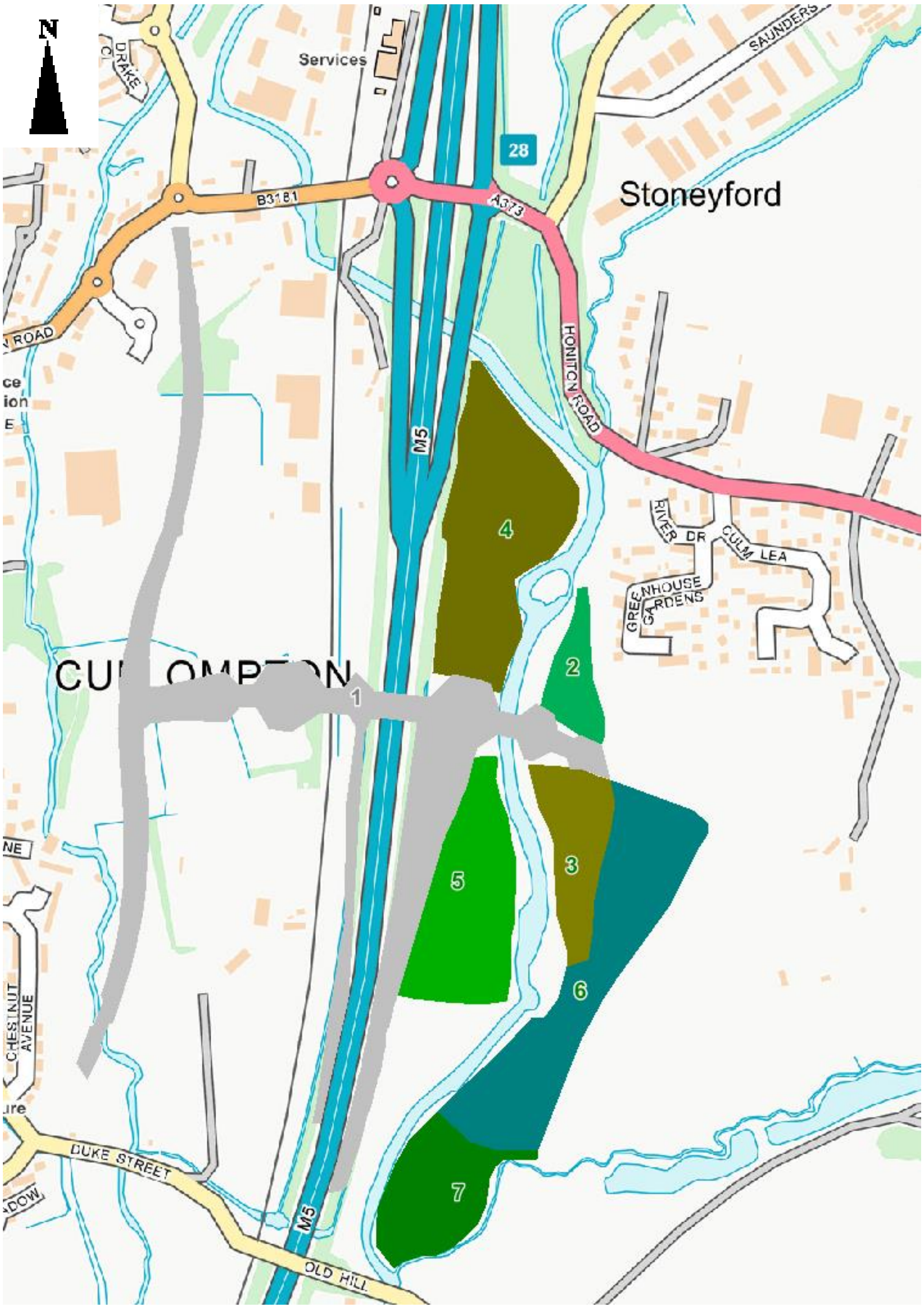

Figure 7-3 Floodplain Storage: Removed (Grey) and Provided (Blue/Green). (Contains Ordnance Survey data © Crown copyright and database right 2017)

Area ID	Plan Area (m^2)	Average Elevation Pre Scheme (mAOD)	Average Elevation Post Scheme (mAOD)	Volume Change (m^3)
1	59,400	51.7	53.8	-59,000
2	4,800	52.0	49.3	+6,500

Area ID	Plan Area (m^2)	Average Elevation Pre Scheme (mAOD)	Average Elevation Post Scheme (mAOD)	Volume Change (m^3)
3	10,300	51.7	48.6	+18,500
4	27,000	50.8	49.8	+17,500
5	20,200	49.2	48.7	+11,200
6	28,400	52.2	48.5	+55,400
7	13,490	48.7	48.4	+1,980
TOTAL VOLUME CHANGE				+52,080

Table 7-1 Approximate Volume of Floodplain Storage Removed and Provided

Figure 7-4 shows the locations of cross sections through the proposed compensation areas which are presented in Figures 7-5 to 7-11. All cross sections have been taken from west to east.

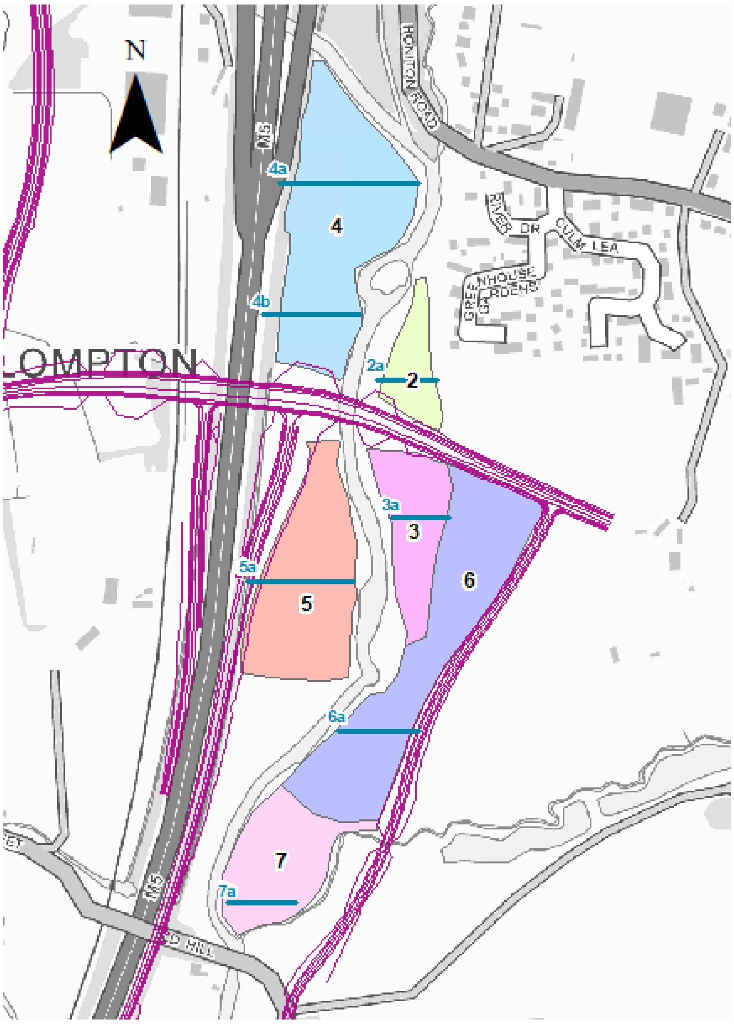

Figure 7-4 Floodplain Storage Provided and Cross Section Locations through these. (Contains Ordnance Survey data © Crown copyright and database right 2017)

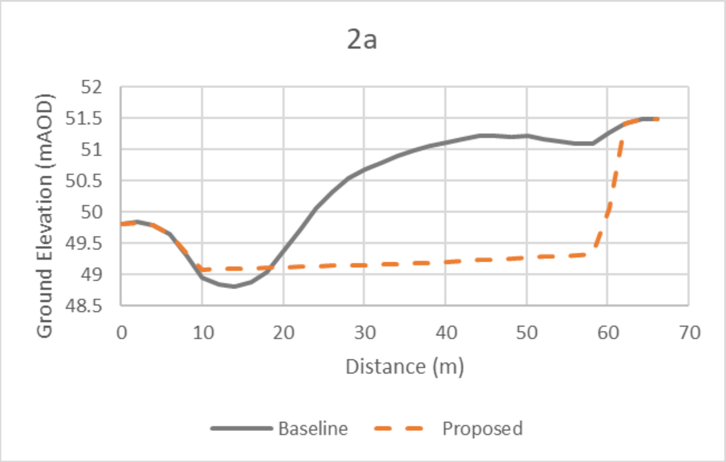

Figure 7-5 Cross section through compensation area 2 showing the change to the ground profile between the baseline and proposed.

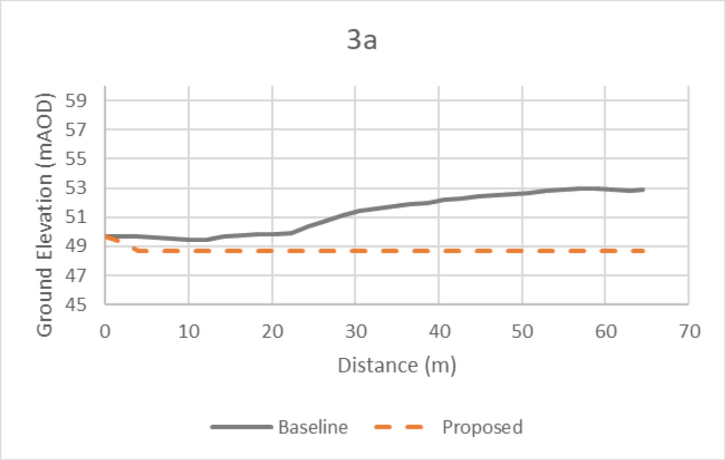

Figure 7-6 Cross section through compensation area 3 showing the change to the ground profile between the baseline and proposed.

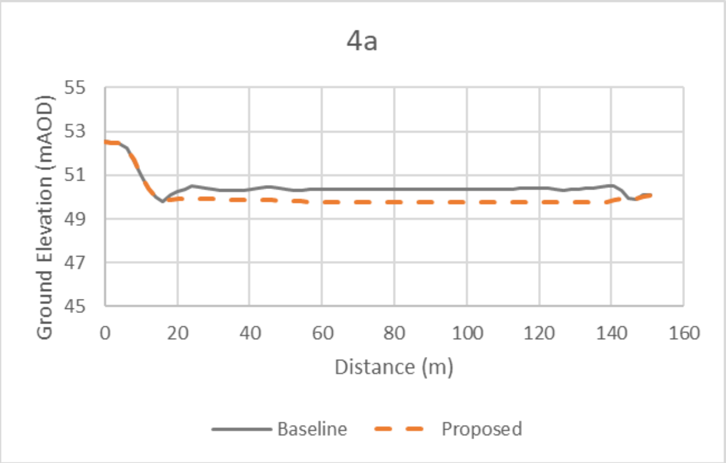

Figure 7-7 Cross section through compensation area 4 showing the change to the ground profile between the baseline and proposed.

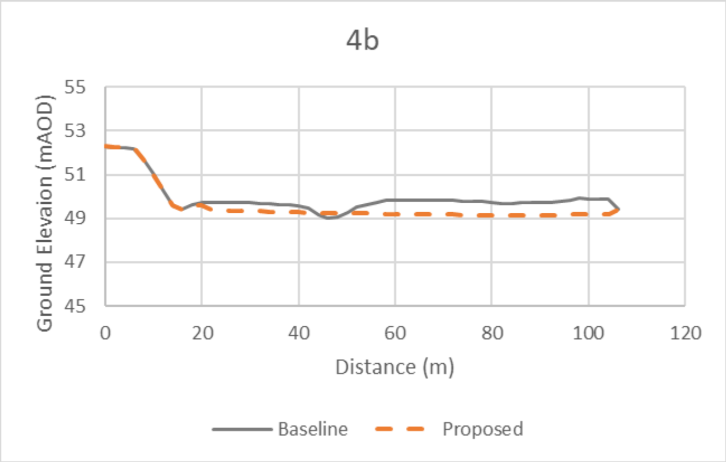

Figure 7-8 Cross section through compensation area 4 showing the change to the ground profile between the baseline and proposed.

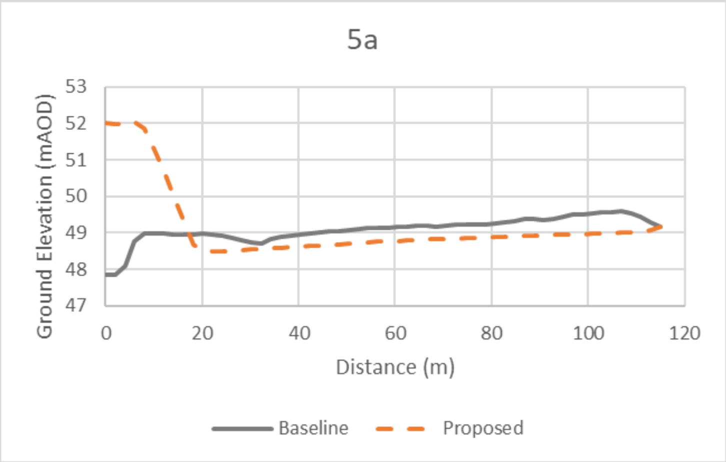

Figure 7-9 Cross section through compensation area 5 showing the change to the ground profile between the baseline and proposed.

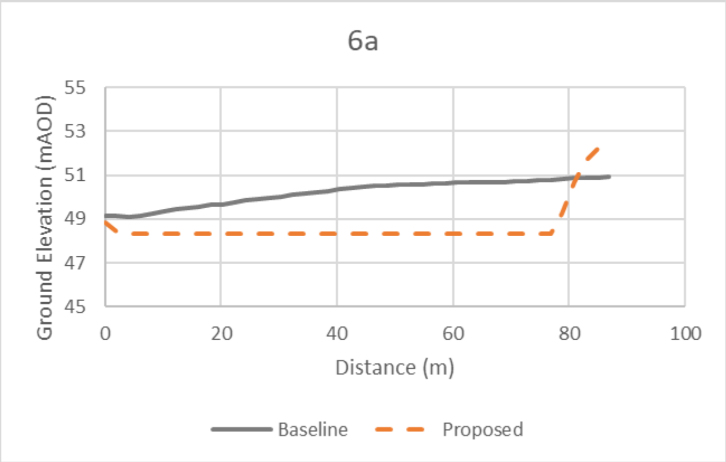

Figure 7-10 Cross section through compensation area 6 showing the change to the ground profile between the baseline and proposed.

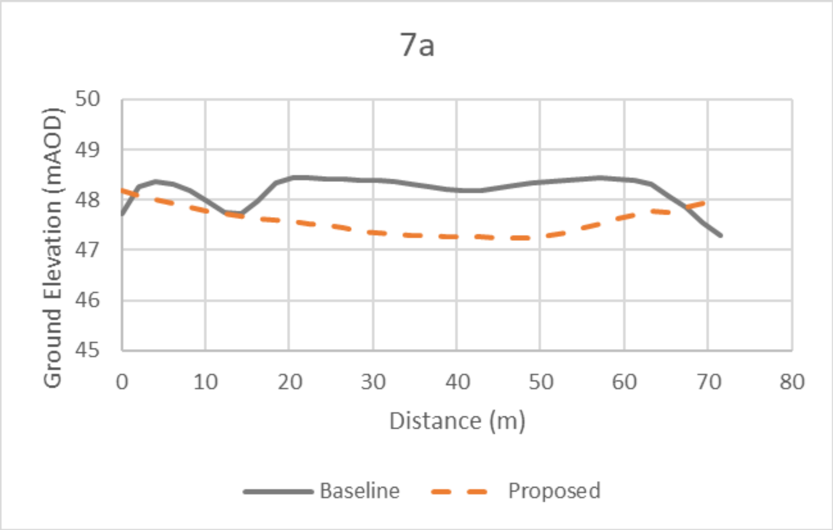

Figure 7-11 Cross section through compensation area 7 showing the change to the ground profile between the baseline and proposed.

7.3 'With Scheme' Model Results

7.3.1 Flood Risk to the Scheme

Model results indicate that the Scheme is predicted to be at risk of flooding, in part, from all events assessed. The scale of the flood risk increases in line with increasing event magnitude. Further details, including maximum modelled flood depths, are given in Section 7.4.

7.3.2 Impact on Third Party Flood Risk

Difference grids showing the change in flood depth as a result of implementing the Scheme are shown in Figures 7-12 to 7-17. The associated Table 7-2 for the River Ken (South) is also included below as the depth difference is not shown as the model is 1D only in this location. Flood map outputs have only been included for the linked 1D 2D elements of the model.

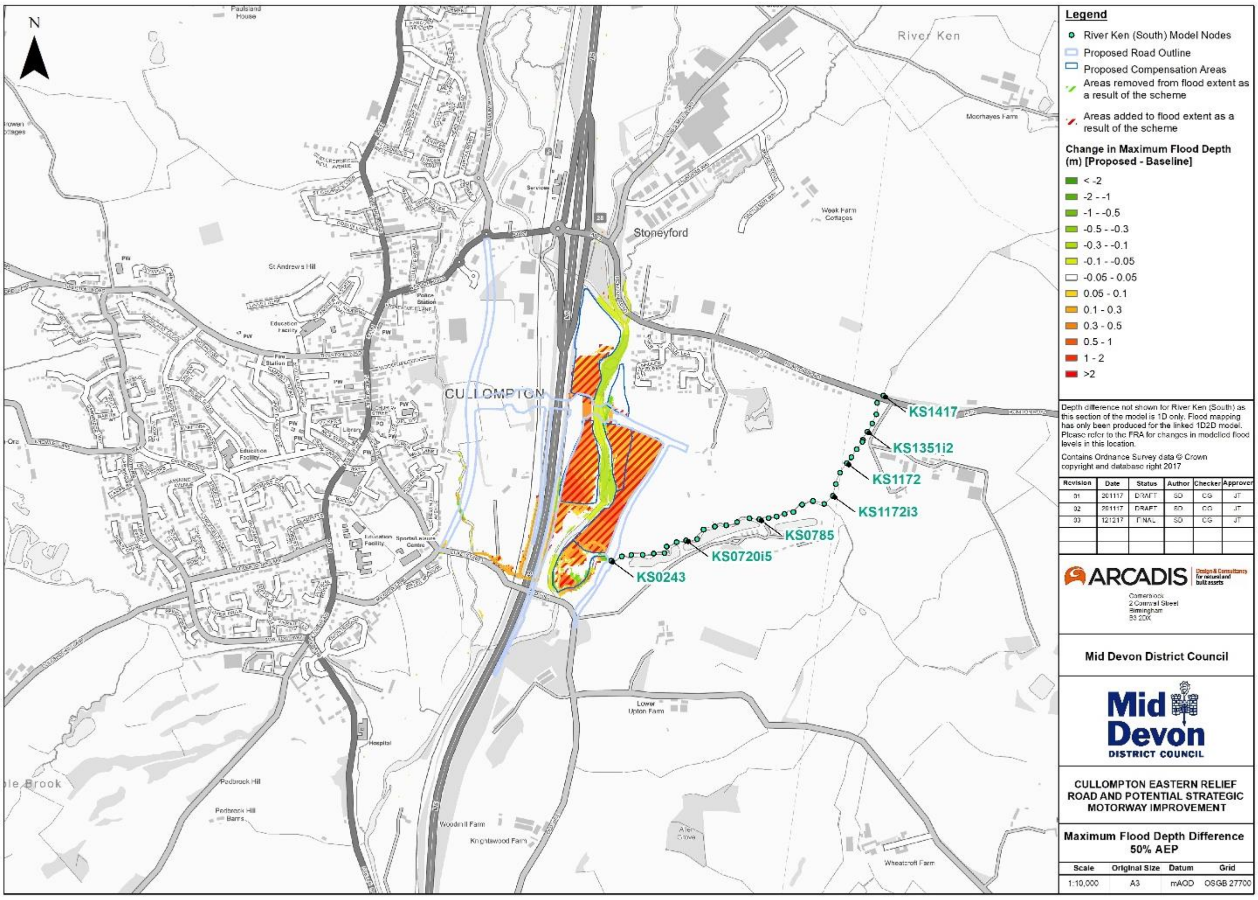

Figure 7-12 Maximum flood depth difference [proposed – baseline] for the 50% AEP flood event (Contains Ordnance Survey data © Crown copyright and database right 2017)

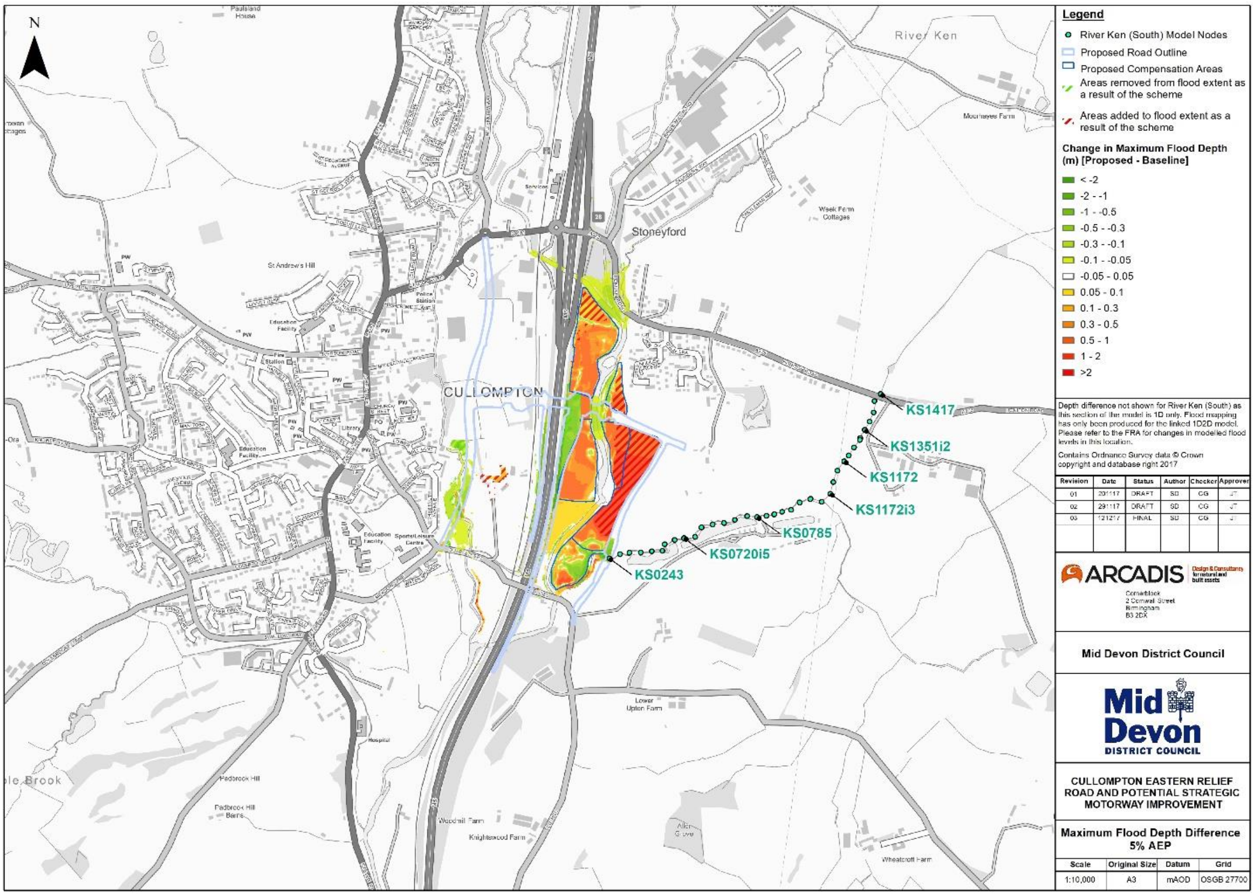

Figure 7-13 Maximum flood depth difference [proposed – baseline] for the 5% AEP flood event (Contains Ordnance Survey data © Crown copyright and database right 2017)

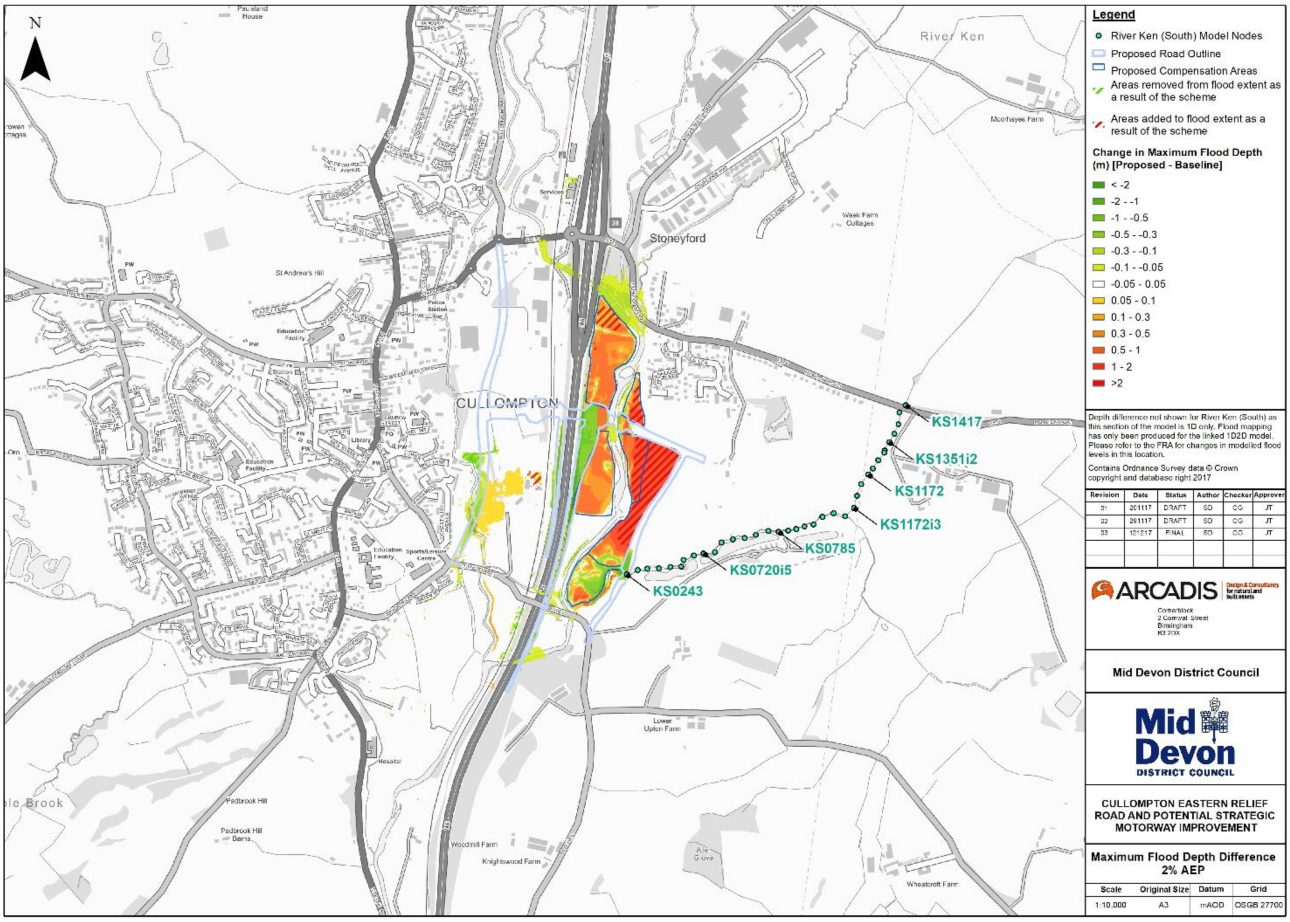

Figure 7-14 Maximum flood depth difference [proposed – baseline] for the 2% AEP flood event (Contains Ordnance Survey data © Crown copyright and database right 2017)

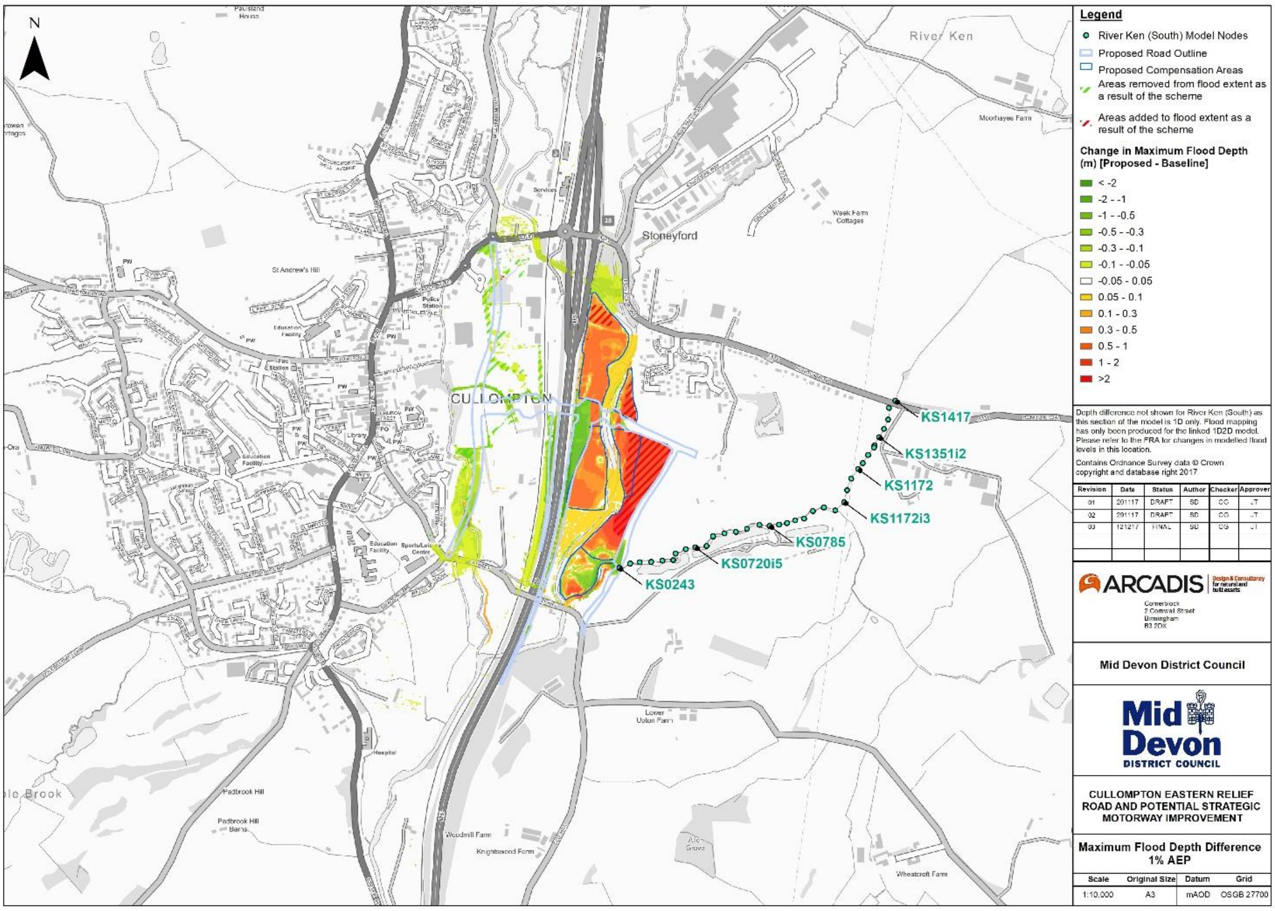

Figure 7-15 Maximum flood depth difference [proposed – baseline] for the 1% AEP flood event (Contains Ordnance Survey data © Crown copyright and database right 2017)

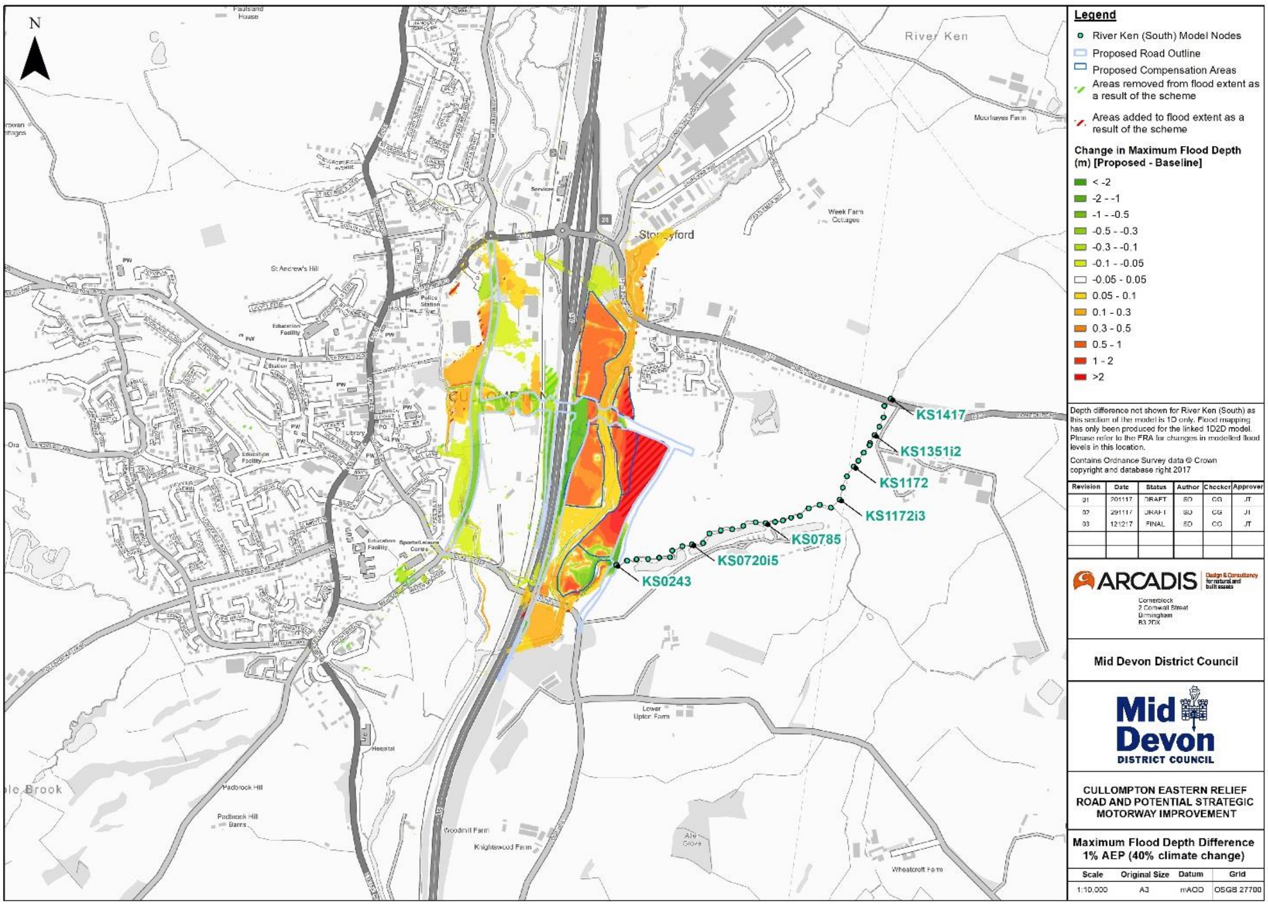

Figure 7-16 Maximum flood depth difference [proposed - baseline] for the 1% AEP (climate change) flood event (Contains Ordnance Survey data © Crown copyright and database right 2017)

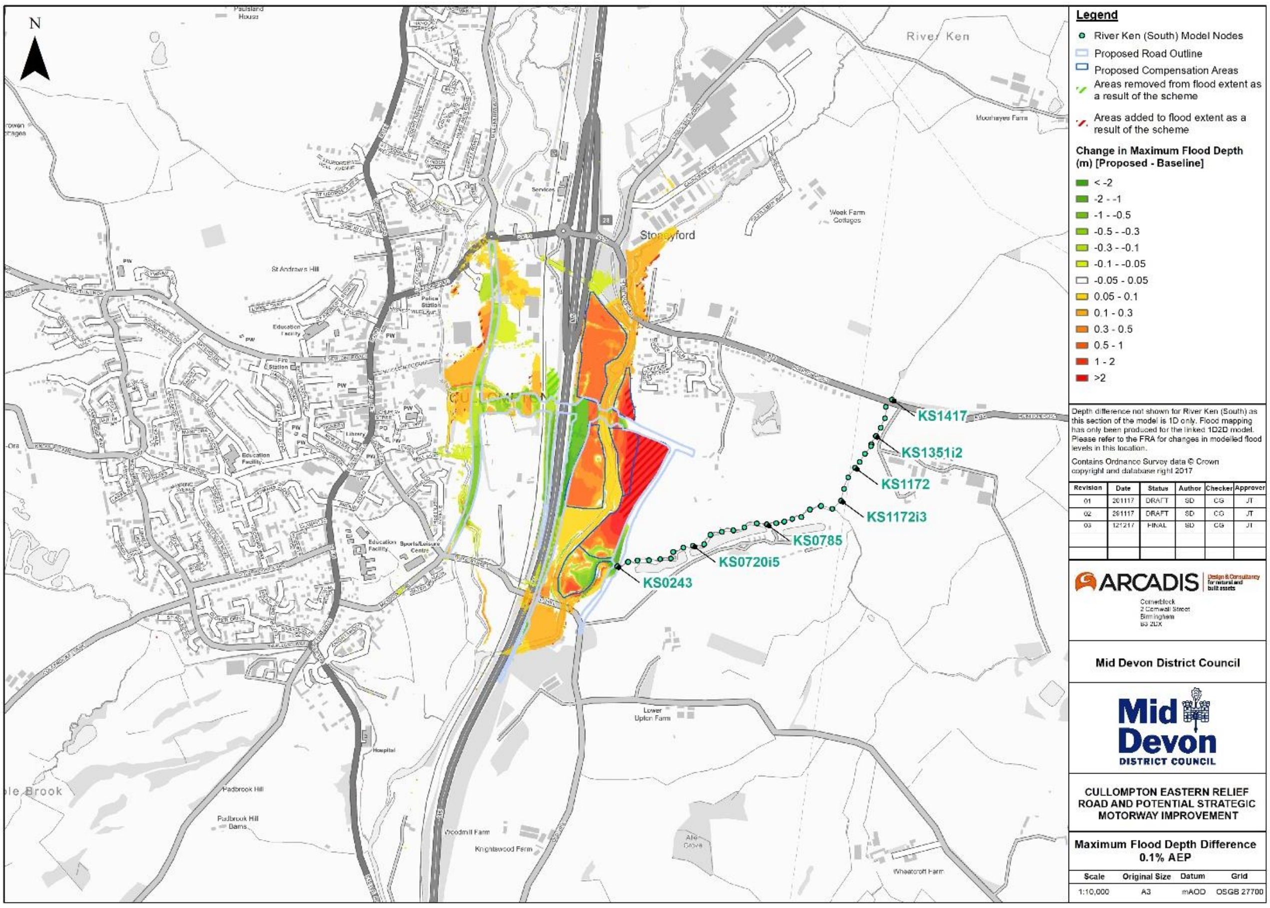

Figure 7-17 Maximum flood depth difference [proposed – baseline] for the 0.1% AEP flood event (Contains Ordnance Survey data © Crown copyright and database right 2017)

Node	Change in Flood Depth (m)					
	50% AEP	5% AEP	2% AEP	1% AEP	1% AEP +40%	0.1% AEP
KS1172i1	0.00	0.00	0.00	0.00	0.01	0.01
KS1172i2	0.00	0.00	0.00	0.00	0.04	0.04
KS1172i3	0.00	0.00	0.00	0.00	0.08	0.08
KS1172i4	0.00	0.00	0.00	0.00	0.11	0.12
KS1172i5	0.00	0.00	0.00	0.00	0.14	0.14
KS1172i6	0.00	0.00	0.00	0.02	0.15	0.15
KS1172i7	0.00	0.00	0.00	0.03	0.16	0.16
KS1172i8	0.00	0.00	0.01	0.04	0.16	0.16
KS0835	0.00	0.00	0.01	0.04	0.16	0.17

Node	Change in Flood Depth (m)					
	50% AEP	5% AEP	2% AEP	1% AEP	1% AEP +40%	0.1% AEP
KS0835i1	0.00	0.00	0.01	0.05	0.16	0.17
KS0785	0.00	0.00	0.01	0.05	0.16	0.17
KS0785i1	0.00	0.00	0.01	0.05	0.16	0.17
KS0720	0.00	0.00	0.01	0.05	0.17	0.17
KS0720i1	0.00	0.00	0.01	0.05	0.17	0.17
KS0720i2	0.00	0.00	0.01	0.05	0.17	0.17
KS0720i3	0.00	0.00	0.01	0.05	0.17	0.17
KS0720i4	0.00	0.01	0.01	0.05	0.17	0.17
KS0720i5	-0.01	0.01	0.02	0.06	0.17	0.17
KS0491	-0.01	0.01	0.02	0.06	0.17	0.18
KS0491i1	-0.01	0.02	0.02	0.07	0.18	0.18
KS0491i2	-0.01	0.04	0.03	0.07	0.18	0.18
KS0491i3	-0.01	0.05	0.04	0.08	0.18	0.19
KS0491i4	0.00	0.06	0.04	0.08	0.19	0.19
KS0491i5	0.00	0.07	0.05	0.08	0.19	0.19
KS0491i6	0.01	0.07	0.05	0.08	0.19	0.19
KS0243	-0.01	0.06	0.05	0.08	0.19	0.19

Table 7-2 Change in maximum flood depths (m) on the River Ken (South) as a result of implementing the Scheme

For all modelled events, increases in flood depths are observed in the flood storage areas included as part of the Scheme. During the 50% AEP, a reduction in flood depths, predominantly in channel, is observed in the vicinity of the Scheme. There is a negligible impact on flood levels in the River Ken (South) for the 50% AEP.

In addition to the reductions observed in the 50% AEP, some further reductions in flood depths on the River Culm floodplain are observed during the 5% AEP as the distribution of flood water changes due to the presence of the Scheme. However, flood depths are increased by around 0.2m at the Cullompton Community Association buildings 200m south of the proposed east west crossing. There is an associated increase in extents of around 25m onto the access track to the west of the buildings. This increase is also observed for the 2% AEP. Increases on the River Ken (South) are recorded upstream of the Scheme crossing (Table 7-2).

Hydraulic modelling of the Scheme and associated mitigation has been initially optimised for the 1% AEP and therefore these model results show extensive areas across the Culm floodplain where flood depths and extents are reduced. Flood depths on Duke Street are reduced by around 0.09m and by around 0.07m in the fields to the west of the M5 in the vicinity of the proposed Scheme.

Model results from the 1% AEP plus 40% and the 0.1% AEP events predict increases in flood depths and extents upstream of Stoneyford Bridge, on the River Ken (North) as well as to the areas around the Mobile Home site / east of Tesco. Maximum flood depth differences for the 1% AEP plus 40% and 0.1% AEP events at the former two locations are shown in Figures 7-18 and 7-19 respectively.

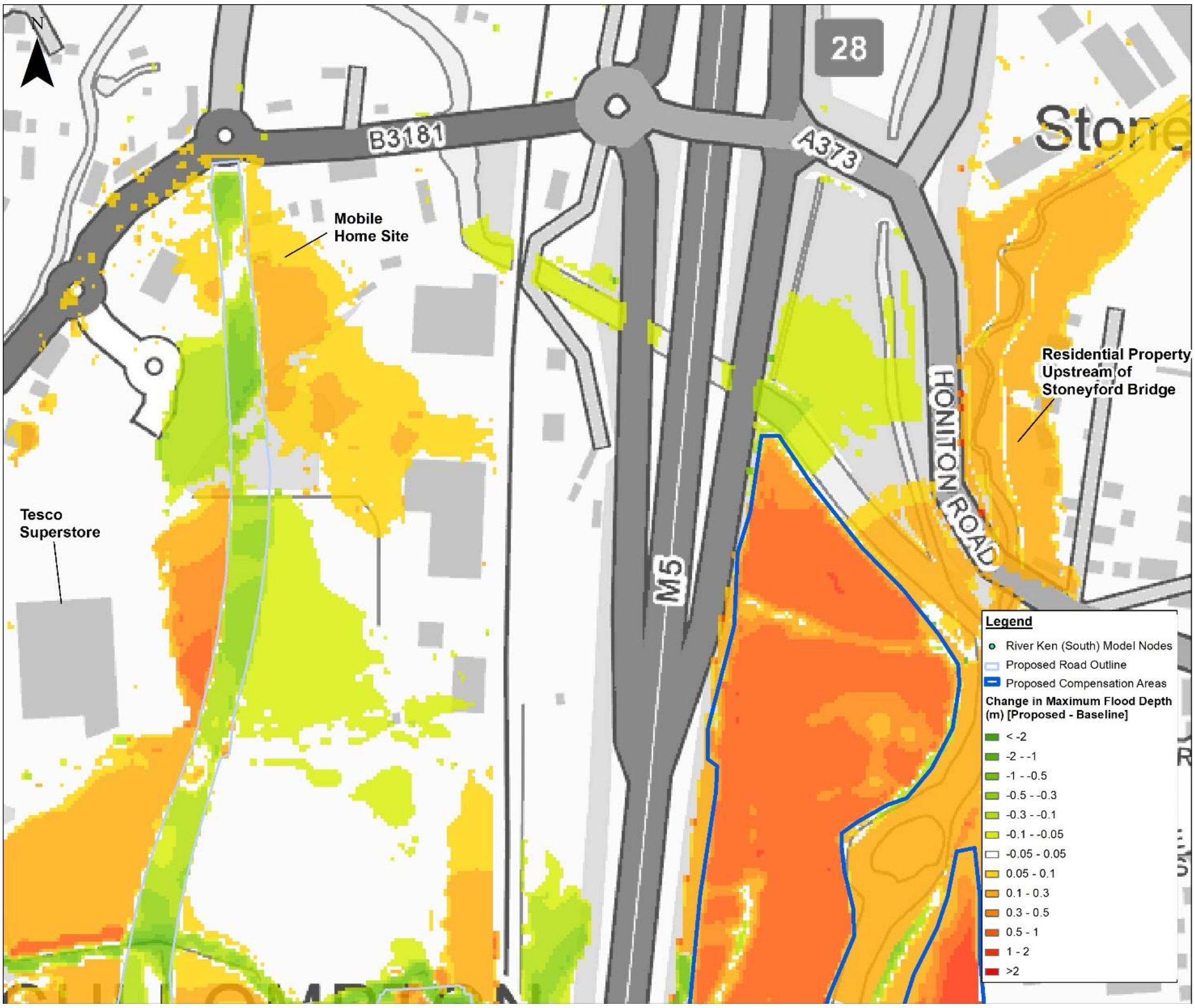

Figure 7-18 Change in maximum flood depth at key locations for the 1% AEP (40% climate change) event (Contains Ordnance Survey data © Crown copyright and database right 2017)

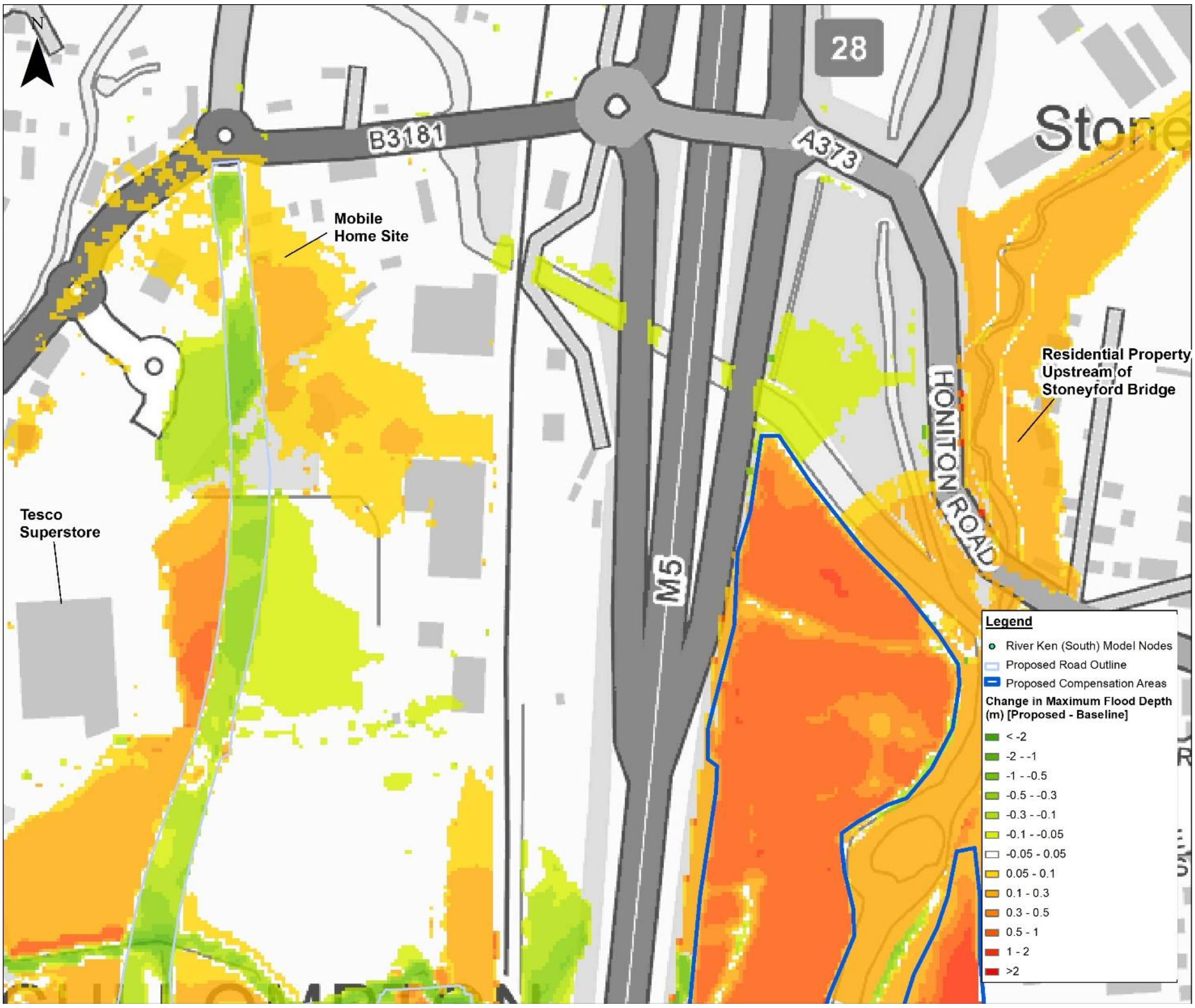

Figure 7-19 Change in maximum flood depth at key locations for the 0.1% AEP event (Contains Ordnance Survey data © Crown copyright and database right 2017)

Increases in maximum flood depths of up to 0.19m are also observed on the River Ken (South) for both events. The topography of the floodplain in this location is such that these increases in flood depth do not result in any notable changes in flood extents. Ground levels in the vicinity of Upton Fishing Lakes are, as a minimum, 0.5m higher than the peak 0.1% 'with Scheme' water level (based on available LiDAR data). Therefore, it is not predicted that the Scheme will increase flood risk to third parties in this location.

Velocity plots are shown in Appendix E for both the baseline and 'with Scheme' model runs. The results show that the effect of the Scheme is a reduction in overall velocities for all modelled events. This is due to the provision of storage areas on the floodplain which attenuate and slow the flow of water. There are no locations where the inclusion of the Scheme has significantly increased velocities.

Stage plots are shown in Appendix F for the baseline and 'with Scheme' model results. The following locations were reviewed:

- Existing A373 culvert over the River Culm
- Existing Amco flood relief culverts adjacent to the A373 culvert
- Proposed River Culm Culvert
- Proposed Spratford Mill Stream Culvert (north of Duke Street)

- Proposed River Ken (South) Culvert
- Proposed flood relief culverts through the east - west link road over the railway line / M5
- Proposed flood relief culverts through the north south link road on the west of the M5

Table 7-3 summarises the difference in peak stage upstream and downstream of the culverts at the locations shown in Figure 7-20 for the ‘with Scheme’ and baseline (where relevant) models.

Culvert		50%	5%	2%	1%	1% CC	0.1%
Existing A373 culverts (Baseline model)	Eastern	0.07	0.11	0.11	0.12	0.14	0.16
	Western	0.03	0.08	0.09	0.10	0.21	0.23
Existing A373 culverts (‘with Scheme’ model)	Eastern	0.07	0.11	0.11	0.12	0.14	0.16
	Western	0.03	0.08	0.09	0.11	0.21	0.24
Proposed River Culm Culvert		0.13	0.17	0.11	0.08	0.04	0.04
Proposed Spratford Mill Stream Culvert		0.01	<0.01	<0.01	<0.01	0.02	0.02
Proposed River Ken (South) Culvert		<0.01	0.05	0.05	0.03	0.12	0.12
Proposed flood relief culverts through the north south link road on the west of the M5	1	Dry	Dry	Dry	Dry	0.02	0.02
	2	Dry	Dry	Dry	Dry	0.08	0.06
	3	Dry	Dry	Dry	Dry	0.11	0.09
Proposed flood relief culverts through the east - west link road over of the M5	4	Dry	Dry	Dry	Dry	0.30	0.30
	5	Dry	Dry	Dry	Dry	0.21	0.22
	6	<0.01	0.03	0.06	0.07	0.05	0.05
	7	<0.01	0.04	0.09	0.09	0.08	0.09
	8	<0.01	0.06	0.13	0.13	0.12	0.12
	9	Dry	Dry	Dry	Dry	0.25	0.25

Table 7-3 Change in peak stage (m) at key locations for the ‘with Scheme’ model as shown in Figure 7-20 [upstream-downstream]

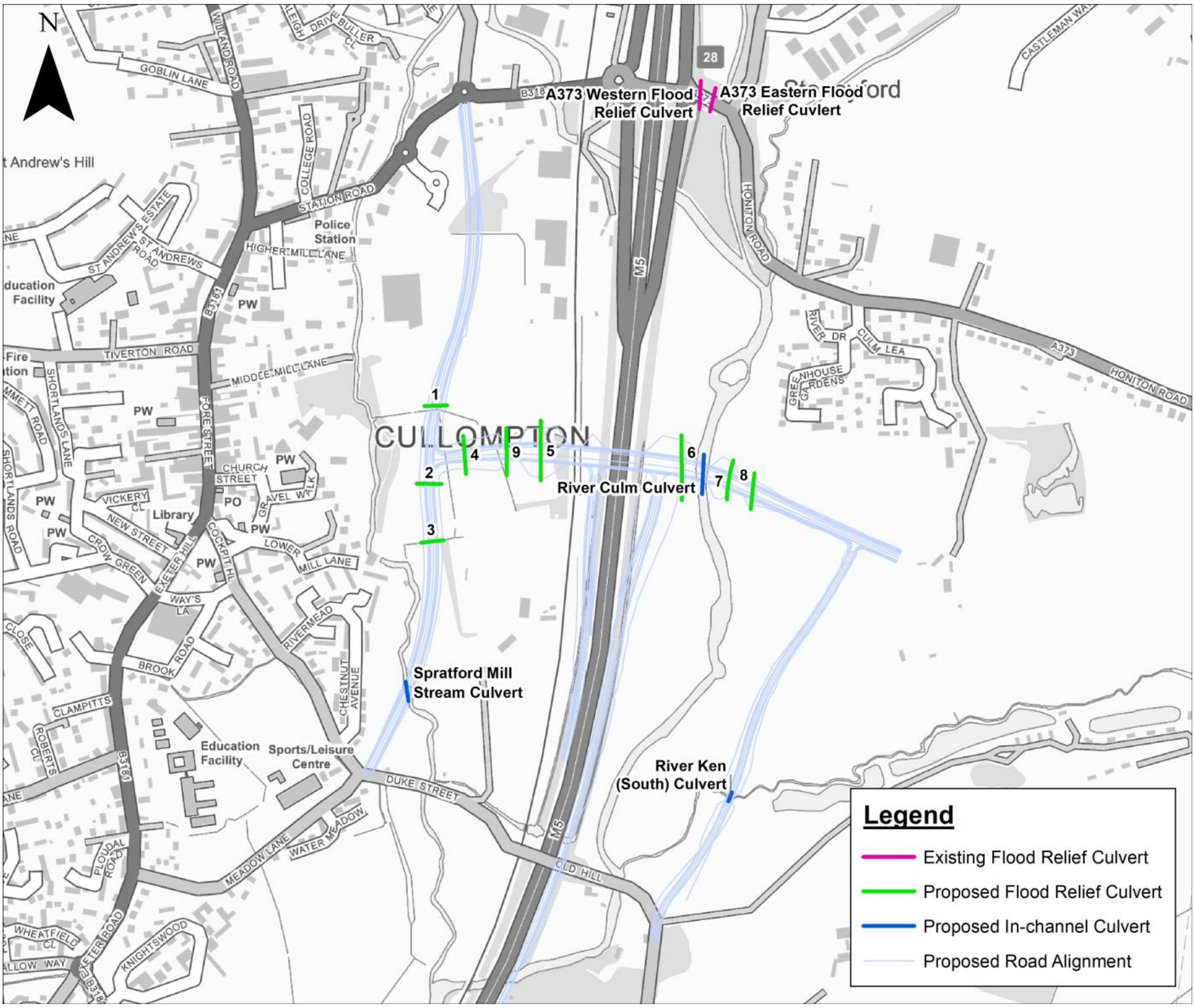

Figure 7-20: Location of proposed and existing culverts (Contains Ordnance Survey data © Crown copyright and database right 2017)

Key conclusions from Table 7-3 are:

- The Scheme does not change the head loss across the A373 culvert compared with the baseline model.
- The proposed Spratford Mill Stream Culvert is large enough to pass all modelled flows with a minimal head loss across it.
- The proposed River Ken (South) culvert predicts a head loss of more than 10cm for the 1% AEP plus climate change and the 0.1% AEP events. This suggests that the culvert size should be increased to accommodate the predicted higher flood flows without increasing flood levels upstream.
- Proposed flood relief culverts 1, 2,6 and 7 demonstrate minimal (less than 10cm) head loss across them during all modelled events. This suggests that they are of an appropriate size to convey the necessary flood flows without increasing flood risk upstream.
- Proposed flood relief culverts 4, 5 and 9 predict a head loss of more than 10cm for events during which they convey flow. This suggests that the culvert size should be increased to accommodate the predicted higher flood flows and thus minimise any increases in upstream flood risk.
- Proposed flood relief culvert 8 predicts a head loss of less than 10cm for the 50% and 5% AEP events and more than 10cm for the remaining modelled events. This suggests that the culvert size should be

increased to accommodate the predicted higher flood flows and thus minimise any increases in upstream flood risk.

- Proposed flood relief culvert 3 predicts a head loss of less than 10cm for the 0.1% AEP and just over 10cm for the 1% AEP CC event (the only two events for which it conveys flow). This suggests that it is of an appropriate size to convey the necessary flows without increasing flood risk upstream.

7.3.3 Key Receptors

The Environment Agency provided a list of key receptors to be reviewed. Results are set out in Tables 7-4 to 7-13 and locations shown in Figure 7-21. To summarise the tables below, implementation of the Scheme does not change the AEP at which any of the receptors are first predicted to flood. Only the 'Residential Property Upstream of Stoneyford Bridge', the 'Mobile Home Site' and the 'M5 between First and Last Bridge (Old Hill Overbridge)' experience increases in flood level greater than 0.05m as a result of implementing the Scheme. These increases are only observed during larger magnitude events.

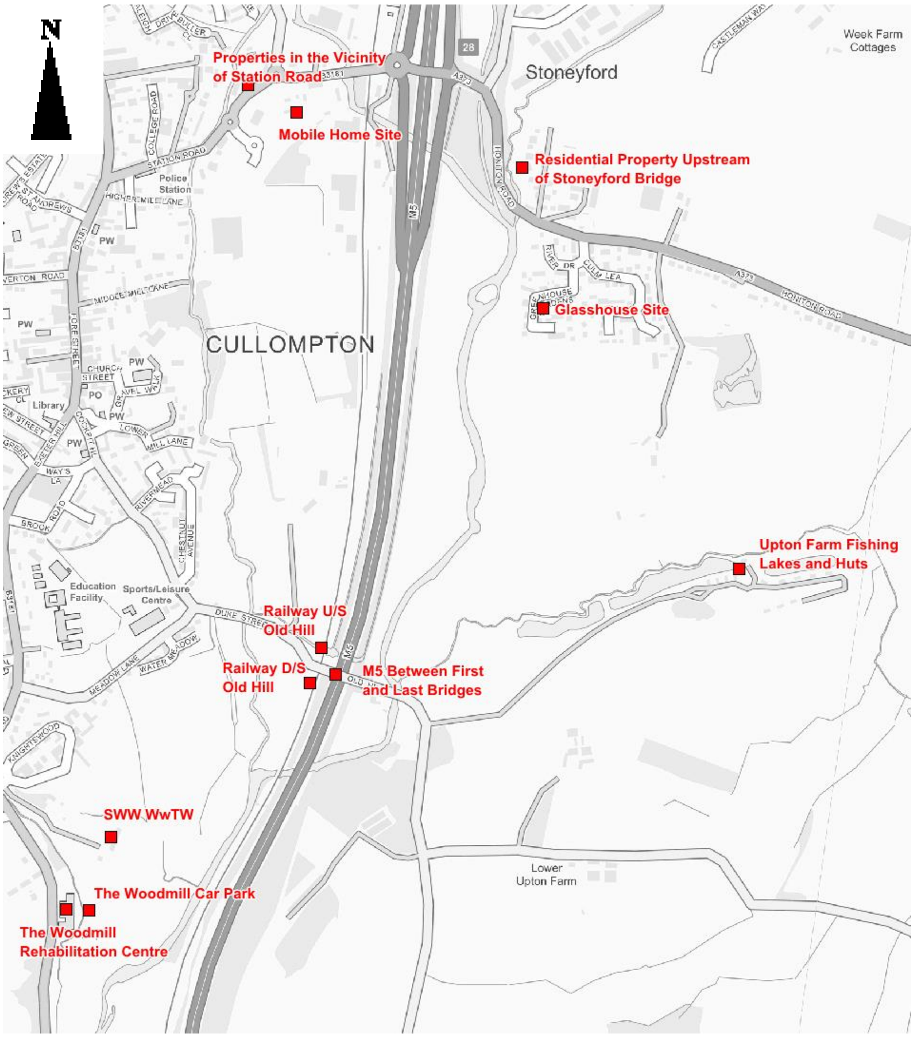

Figure 7-21 Key Receptor Locations (Contains Ordnance Survey data © Crown copyright and database right 2017)

Glasshouse Site

Parameter	Baseline	'With Scheme'
AEP at which Flooding First Occurs	Does not flood	Does not flood

Table 7-4 Impact Assessment: The Glasshouse Site

The Woodmill Rehabilitation Centre Building (west bank of the Cole Brook)

Parameter	Baseline	'With Scheme'
AEP at which Flooding First Occurs	Does not flood	Does not flood

Table 7-5 Impact Assessment: The Woodmill Rehabilitation Centre Building

The Woodmill Rehabilitation Centre Car Park (east bank of the Cole Brook)

Parameter	Baseline	'With Scheme'
AEP at which Flooding First Occurs	5% AEP	5% AEP
Peak 50% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 5% AEP Stage (mAOD)	47.61	47.61
Peak 2% AEP Stage (mAOD)	47.80	47.79
Peak 1% AEP Stage (mAOD)	47.95	47.93
Peak 1% AEP (Climate Change) Stage (mAOD)	48.45	48.45
Peak 0.1% AEP Stage (mAOD)	48.47	48.49

Table 7-6 Impact Assessment: The Woodmill Rehabilitation Centre Car Park

South West Water WwTW

Parameter	Baseline	'With Scheme'
AEP at which Flooding First Occurs	5% AEP	5% AEP
Peak 50% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 5% AEP Stage (mAOD)	47.65	47.65
Peak 2% AEP Stage (mAOD)	47.94	47.92
Peak 1% AEP Stage (mAOD)	48.13	48.09
Peak 1% AEP (Climate Change) Stage (mAOD)	48.60	48.59

Parameter	Baseline	'With Scheme'
Peak 0.1% AEP Stage (mAOD)	48.62	48.63

Table 7-7 Impact Assessment: South West Water WwTW

Residential property upstream of Stoneyford Bridge

Parameter	Baseline	'With Scheme'
AEP at which Flooding First Occurs	1% AEP (Climate Change)	1% AEP (Climate Change)
Peak 50% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 5% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 2% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 1% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 1% AEP (Climate Change) Stage (mAOD)	51.54	51.67
Peak 0.1% AEP Stage (mAOD)	51.54	51.69

Table 7-8 Impact Assessment: Residential property upstream of Stoneyford Bridge

Mobile Home Site

Parameter	Baseline	'With Scheme'
AEP at which Flooding First Occurs	1% AEP	1% AEP
Peak 50% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 5% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 2% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 1% AEP Stage (mAOD)	51.36	51.35
Peak 1% AEP (Climate Change) Stage (mAOD)	51.77	51.86
Peak 0.1% AEP Stage (mAOD)	51.78	51.87

Table 7-9 Impact Assessment: Mobile Home Site

Properties in the Vicinity of Station Road

Parameter	Baseline	'With Scheme'
AEP at which Flooding First Occurs	1% AEP (Climate Change)	1% AEP (Climate Change)
Peak 50% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 5% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 2% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 1% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 1% AEP (Climate Change) Stage (mAOD)	51.86	51.91
Peak 0.1% AEP Stage (mAOD)	51.88	51.93

Table 7-10 Impact Assessment: Properties in the Vicinity of Station Road

M5 and Railway Between First and Last Bridges (Old Hill Overbridge)

Parameter	Baseline	'With Scheme'
AEP at which Flooding First Occurs	M5:1% AEP (Climate Change) Railway: 1% AEP	M5:1% AEP (Climate Change) Railway: 1% AEP
Peak 50% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 5% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 2% AEP Stage (mAOD)	Does not flood	Does not flood
Peak 1% AEP Stage (mAOD)	M5: Does not flood Railway: 49.13 (U/S Old Hill) Railway: 48.78 (D/S Old Hill)	M5: Does not flood Railway: 49.07 (U/S Old Hill) Railway: 48.46 (D/S Old Hill)
Peak 1% AEP (Climate Change) Stage (mAOD)	M5 at Old Hill Overbridge: 50.28 Railway: 49.37 (U/S Old Hill) Railway: 48.79 (D/S Old Hill)	M5 at Old Hill Overbridge: 50.39 Railway: 49.33 (U/S Old Hill) Railway: 48.78 (D/S Old Hill)
Peak 0.1% AEP Stage (mAOD)	M5 at Old Hill Overbridge: 50.28 Railway: 49.40 (U/S Old Hill) Railway: 48.80 (D/S Old Hill)	M5 at Old Hill Overbridge: 50.41 Railway: 49.38 (U/S Old Hill) Railway: 48.81 (D/S Old Hill)

Table 7-11 Impact Assessment: M5 and Railway Near Last Bridge

Residential Properties at Rivermead

Parameter	Baseline	'With Scheme'
AEP at which Flooding First Occurs	Does not flood	Does not flood

Table 7-12 Impact Assessment: Residential Properties at Rivermead

Upton Farm Fishing Lakes and Huts

Parameter	Baseline	'With Scheme'
AEP at which Flooding First Occurs	Does Not Flood	Does Not Flood

Table 7-13 Impact Assessment: Upton Farm Fishing Lakes and Huts

In addition to the specific locations above, the Environment Agency also asked that the FRA consider more generally the risks to the M5 and the Bristol to Exeter railway line within the study area.

The M5 is not within the modelled flood extents (baseline or 'with Scheme') for the 50% AEP, 5% AEP, 2% AEP or the 1% AEP. However, increasing flows by 40% to account for climate change places the M5 within the modelled flood extent in the vicinity of Last Bridge (baseline and 'with Scheme'). This flooding is also observed in the 0.1% AEP. Further details on the flooding in the Last Bridge Area are discussed in Table 7-11.

The Bristol to Exeter railway line is not within the modelled flood extents for the 50% AEP or 5% AEP (baseline and 'with Scheme'). The railway line is within the modelled flood extents for the 2% AEP, 1% AEP, 1% AEP plus climate change and 0.1% AEP upstream of Station Road. The 'with Scheme' modelled flood depths are around 2 – 3mm lower than baseline flood depths. The railway line is also within the modelled flood extents at Last Bridge (see Table 7-11 for details).

7.3.4 Storm Duration Sensitivity

To test the sensitivity of the model to changes to the input hydrographs, 9 hour and 19 hour storm durations were run for the baseline and 'with Scheme' models as described in Section 5.5. The difference grids showing the results for the 1% AEP 9 hour and 19 hour storm durations are shown in Figures 7-22 and 7-23. The difference grids for the different storm durations give very similar results to those for the 14-hour hydrograph (Figure 7-15). The EA have been consulted and have confirmed that they are happy with the results from the 14-hour hydrographs and do not require any additional work to be carried out to assess the impacts of different storm durations.

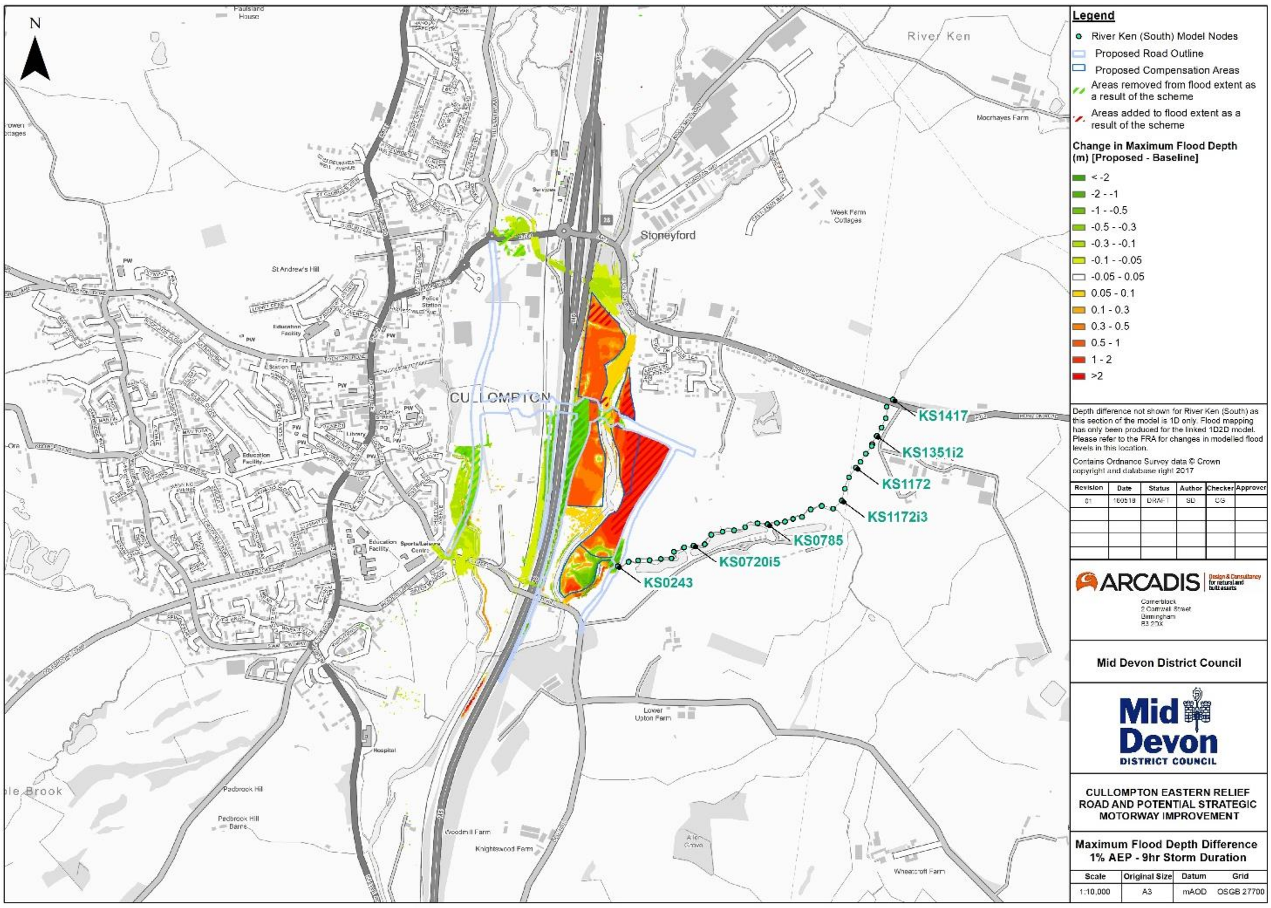

Figure 7-22 Maximum flood depth difference [proposed – baseline] for the 1% AEP 9 hour flood event (Contains Ordnance Survey data © Crown copyright and database right 2017)

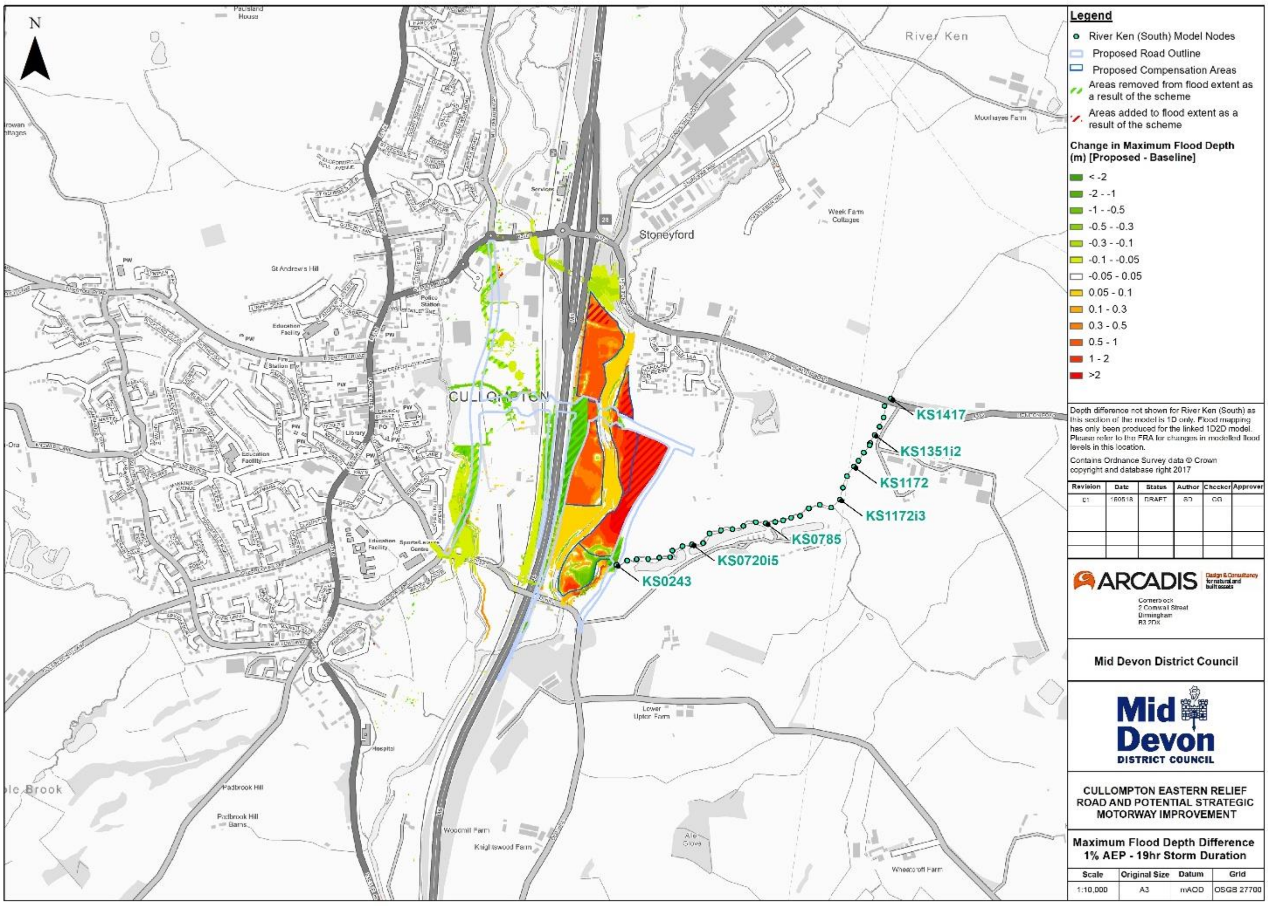

Figure 7-23 Maximum flood depth difference [proposed – baseline] for the 1% AEP 19 hour flood event (Contains Ordnance Survey data © Crown copyright and database right 2017)

7.3.5 Summary of Impacts

Sections 7.3.2 and 7.3.3 demonstrate that the Scheme does increase flood risk to third parties in some locations at a range of event magnitudes. Model results demonstrated both reductions and increases in flood risk in the vicinity of the Scheme across a range of design events assessed. Mitigation was optimised for the 1% AEP and, as a result, the reductions in flood risk are more extensive than the increases in flood risk for this event.

The modelling carried out to date has been undertaken in consultation with the EA and has considered a series of designs for the Scheme and associated compensation works. The designs have formed an iterative approach to the Scheme modelling, which has successively reduced the impacts of the Scheme on third parties. The results reported in this FRA represent those which have thus far demonstrated the smallest increase in flood risk to third parties. This iterative approach to the modelling has shown that there is potential to constrain the increases in flood risk to limit negative impacts on third parties as well as reducing flood risk elsewhere. Given that the Scheme design is currently only at the outline stage, it is recommended that the mitigation measures are refined and enhanced as part of the detailed design process to ensure a robust assessment of flood risk.

In meeting the second part of the NPPF Exception Test, this FRA has assessed the impact of the Scheme on third parties and demonstrated that there is the potential to constrain increases in flood risk arising from the Scheme implementation, albeit that further work is required to fully develop the mitigation proposals.

7.4 Management of Residual Risk

7.4.1 Risk to the Scheme

Although the majority of the Scheme is not at risk of flooding in the events assessed, a residual risk of flooding remains for three locations. Table 7-14 summarises the maximum flood depths in each location for all modelled events.

Location	50% AEP	5% AEP	2% AEP	1% AEP Flood Depth	1% AEP (CC)	0.1% AEP
Western Relief Road: Duke St Junction	0.27m *(flooding extends 40m northwards from the junction)*	0.28m *(flooding extends 40m northwards from the junction)*	0.42m *(flooding extends 60m northwards from the junction)*	0.53m *(flooding extends 75m northwards from the junction)*	1.14m *(flooding extends to Spratford Mill Stream crossing)*	1.19m *(flooding extends to Spratford Mill Stream crossing)*
Immediately East of Tesco Superstore	Not Flooded	Not Flooded	Not Flooded	Not Flooded	0.25m	0.26m
Between Tesco Petrol Station and Mobile Home Site	Not Flooded	Not Flooded	Not Flooded	0.07m	0.59m	0.60m

Table 7-14 Residual Flood Depths ('with Scheme' model)

In order to manage the risks associated with this flooding, measures must be put in place to provide suitable warnings and restrictions on road usage. These could include, but are not limited to:

- Formal road closure procedures linked to / in conjunction with EA flood warning systems
- Automated road signs linked to suitable river telemetry
- Use of social media to inform local residents of any closures
- Use of local radio / traffic announcements to broadcast closures to wider road users
- Evacuation plans for any users who do become trapped by flood waters; these should be produced in consultation with relevant emergency planning staff and in line with the National Flood Emergency Framework for England[17].

It is recommended that a detailed plan to manage these risks is produced and agreed with the Emergency Planning team at Devon County Council.

This section of the FRA has therefore demonstrated, in support of the second part of the Exception Test, that:

- The majority of the Scheme will be safe for its lifetime and that suitable measures can be put in place to mitigate the risks for the locations that are at risk of flooding.
- Flood warnings and evacuation plans will be required for the new link road to the west of the M5.

7.4.2 Risk to Third Parties

Section 7.3 identifies that, in large flood events, an increase in flood risk to a section of the M5, some residential properties upstream of Stoneyford Bridge and in the vicinity of Station Road, the Mobile Home Site and property owned by the Community Association would occur. Any significant increases will require adequate mitigation to be put in place prior to the development of the Scheme. Options to manage and / or

[17] https://www.gov.uk/government/publications/the-national-flood-emergency-framework-for-england

further reduce these risks would require detailed investigation and modelling, but could potentially include (though are not limited to):

- Enhancing the existing flow capacity under existing infrastructure; options to be explored include local roads, the M5 and the railway
- Refinement of the proposed compensation storage areas to further reduce predicted impacts
- Localised defence works
- Flood compensation storage along the River Ken (South)
- Flood warning and evacuation procedures

8 Drainage Strategy

8.1 Planning Policy Requirements

The NPPF stipulates that development should be safe from flooding during its lifetime, should not cause any increase in flood risk and, where possible, should make a contribution to reducing flood risk in its local catchment. As the Scheme involves construction of built development on existing greenfield land, changing the existing land drainage regime, management of surface water runoff from the highway is necessary to satisfy these requirements of the NPPF.

Standards for highway drainage design are set out in HD33/16 Design of Highway Drainage Systems[18]. These standards stipulate that peak discharge rates must be controlled and appropriate attenuation storage provided within the system to accommodate the design 1% AEP storm, inclusive of an allowance for climate change. The consequences of exceedance during storms with a magnitude in excess of the 1% AEP must also be considered.

8.2 Existing Drainage

Within the area directly affected by the Scheme proposals, land is predominantly agricultural and the fields either drain directly into the watercourses, or via a network of field boundary ditches.

8.3 Surface Water Drainage Strategy

An appropriate surface water drainage strategy is being prepared by WSP. It is understood that the drainage strategy will incorporate a series of swales along the edges of the roads and their embankments which will provide some attenuation as well as conveyance. Surface water will be discharged to the existing watercourses at appropriate rates. The drainage strategy will be submitted as a separate document in support of the planning application.

[18] Highways England, 2016 http://www.standardsforhighways.co.uk/ha/standards/dmrb/vol4/section2/hd3316.pdf

9 Conclusions

1. This FRA has been commissioned by Devon County Council, supported by Mid Devon District Council, to support the planning application to consider the construction of a relief road and motorway junction system, referred to henceforth as ‘the Scheme’, to the east of Cullompton town centre, Devon.
2. The Scheme lies within the floodplain of the River Culm and Spratford Stream, and will cross the River Culm, its tributary the Spratford Mill Stream and the River Ken (South).
3. The area in which the Scheme will be developed is, at present, predominantly occupied by a series of fields bounded by mature hedges. The Scheme will connect with existing roads within the urban area of Cullompton.
4. Flooding has occurred historically in Cullompton, with the most recent severe flooding occurring in 2012.
5. The EA Flood Map for Planning (Rivers and Sea)[1] shows that the majority of the Scheme is located within Flood Zone 3, defined as land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) in any year.
6. The Scheme is classified as Essential Infrastructure. The location of this type of development is deemed appropriate in Flood Zones 1, 2 and 3, subject to satisfaction of the NPPF Exception Test in Zone 3.
7. The Scheme passes the NPPF Sequential Test as its location is fixed by the requirement for the Scheme to alleviate traffic within Cullompton town centre, to serve the employment and housing land allocations to the east of the M5 and to increase capacity entering and leaving the M5.
8. The wider sustainability benefits provided by the Scheme demonstrate that the first part of the Exception Test has been passed.
9. The Scheme is at risk of fluvial flooding. It is at low risk of flooding from surface water, groundwater and artificial sources and it is not at risk of flooding from coastal sources.
10. A detailed hydrological assessment of the Culm and its tributaries was carried out for this FRA and inflows derived for 14 flow estimation points.
11. Selection of the final flow estimation methodology was informed by the requirement to calibrate the model results from the 2% AEP event with the observed flooding from the November 2012 event. The final agreed methodology was based on a 20% reduction of the Devon Hydrology Strategy (DHS) flows for the Culm and the Spratford Stream.
12. A bespoke hydraulic model of the River Culm and tributaries was developed by Arcadis over a number of years to inform this FRA.
13. Results from the 2% AEP design event gave a good match with observed flooding from the November 2012 event and, as a result, the Environment Agency signed off the baseline hydraulic model in June 2017.
14. The Scheme was incorporated into the baseline model in order to assess the impacts on flood risk resulting from its construction. In addition to the road and associated embankments, culverts have been included to maintain floodplain connectivity and compensation areas added to more than offset the floodplain storage lost as a result of the Scheme. Overall, the Scheme results in a net gain in floodplain storage of 52,080m^3.
15. Results from the ‘with Scheme’ model demonstrated both reductions and increases in flood risk in the vicinity of the Scheme across a range of design events assessed. Mitigation was optimised for the 1% AEP and, as a result, the reductions in flood risk are more extensive than the increases in flood risk.
16. A sensitivity test was carried out to look at the impact of the Scheme on flood risk during different storm durations (9 hour and 19 hour). Results from the 1% AEP event demonstrated that there was a negligible difference in impacts when comparing the two storm durations to the 14 hour hydrograph.
17. The design of the Scheme and associated mitigation is currently optimised for the 1% AEP and therefore model results from this design event show extensive areas across the Culm floodplain where flood depths and extents are reduced.
18. Key locations where flood risk has the potential to increase as a result of the Scheme are: Upstream of Stoneyford Bridge, property owned by the Cullompton Community Association the M5 at Old Hill Overbridge and the area between Tesco and the Mobile Home site.

19. Implementing the Scheme has a negligible impact on flood risk to the majority of the M5 or the Exeter to Bristol railway line. At the Old Hill Overbridge, increases in flood depths on the M5 of 0.11m and 0.13m are observed during the 1% AEP plus 40% and the 0.1% AEP events respectively. The Scheme is predicted to reduce predicted flood depths on the railway line.
20. The iterative Scheme modelling carried out to date, in discussion with the EA, has shown that there is the potential to constrain the increases in flood risk to avoid negative impacts on third parties as well as reducing flood risk elsewhere.
21. By optimising the design of the Scheme for the 1% AEP event, the increase in flood risk to third parties as a result of the Scheme is negligible. Furthermore, flood risk has been reduced in the vicinity of Station Road and on the Cullompton Community Association Fields to the south.
22. The FRA demonstrates, in support of the second part of the Exception Test, that:
    - The impact of the Scheme on third parties has been assessed and it has been demonstrated that it is possible to mitigate for increases in flood risk arising from the Scheme implementation, albeit that further work is required to fully develop the mitigation proposals.
    - The majority of the Scheme will be safe for its lifetime and that suitable measures can be put in place to mitigate the risks for the locations that are at risk of flooding.
    - Flood warnings and evacuation plans will be required for the road to the west of the M5.
23. An appropriate surface water drainage strategy is being prepared by WSP. It is understood that the drainage strategy will incorporate a series of swales along the edges of the road and the embankments which will provide some attenuation as well as conveyance. Surface water will be discharged to the existing watercourses at appropriate rates.

10 Recommendations

1. The detailed design of the Scheme should consider groundwater levels and the impacts they may have on construction work.
2. Given that the Scheme design is currently only at the outline stage, it is recommended that the mitigation measures are refined as part of the detailed design process to ensure a robust assessment of flood risk.
3. Any changes to the proposed design of the road and associated mitigation measures should be re-assessed to determine their impacts on flood risk and an updated FRA / Addendum Report prepared and submitted to the EA.
4. In order to manage the risks associated with flooding on the new road, measures must be put in place to provide suitable warnings and restrictions on road usage.
5. An appropriate drainage strategy should be finalised and submitted as a separate document in support of the planning application.

APPENDIX A

Mid Devon District Council Exception Test Documentation

APPENDIX B

Hydrology

APPENDIX C

Hydraulic Modelling

APPENDIX D

Wrack Mark Calibration

APPENDIX E

Velocity Results

APPENDIX F

Stage Results at Culverts

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