M5 Junction 10 Improvements Scheme

Environmental Statement

Appendix 8.1 Flood Risk Assessment - Part 1 of 2

TR010063 – APP 6.15

Regulation 5 (2) (e)

Planning Act 2008

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

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Infrastructure Planning

Planning Act 2008

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

M5 Junction 10 Improvements Scheme

Development Consent Order 202[x]

6.15 Environmental Statement:

Appendix 8.1 Flood Risk Assessment - Part 1 of 2 (Clean)

Regulation Number:	Regulation 5(2)(e)
Planning Inspectorate Scheme Reference	TR010063
Application Document Reference	TR010063/APP/6.15
Author:	M5 Junction 10 Improvements Scheme Project Team

Version	Date	Status of Version
Rev 0	December 2023	DCO Application
Rev 1	March 2024	Section 51
Rev 2	October 2024	Deadline 5

Executive Summary

Site Name and Address	M5 Junction 10 Improvements Scheme		
Grid Ref	Site centred on SO 904 256	Size of study area	7.96 km^2 model domain 196 ha Scheme
Current Use	Mixture of current M5 motorway and farmland	Proposed use	Transport infrastructure, new A4019 highway widening with improved motorway junction and Link Road
Flood Zone	The Scheme encroaches into, and crosses, regions of Flood Zone 2 and 3		
Vulnerability class	Essential Infrastructure (Motorway and new link roads)		
Is it compatible?	Yes, Exception Test required		
Application of the Sequential test.	The risk-based Sequential Test is aimed at steering new development to areas at the lowest probability of flooding. The purpose of this Flood Risk Assessment (FRA) is to appraise the level of flood risk to and from the Scheme, and in its early stage informed the Technical Appraisal Report and the Route Assessment Report studies. The Scheme interacts with active floodplain of the River Chelt and Leigh Brook and their tributaries. The Scheme is justified by Gloucestershire County Council (GCC) to be located in the locality of the existing M5 Junction 10 area to improve local and national transport links. Although the works cross areas at risk of flooding, the national guidance on flood risk and coastal change[1] accepts that Essential Infrastructure may be permitted in Flood Zone 3 where the development passes the Exception Test.		
Exception test (Part B) Pass	Detailed hydraulic modelling has been undertaken to assess the risk of flooding to the Scheme and receptors. This has ensured that suitable embedded mitigation measures are incorporated by virtue of the flood storage area, compensatory floodplain and culverts through the new Link Road. These measures will safeguard the Scheme with it being designed and constructed to remain operational and safe in times of flood. The preliminary design does not increase flood risk elsewhere. The general impact is of a reduction in flood levels across a wide area, although there are localised areas where peak flood levels are increased. At the new Link Road, the Scheme excavates land to provide a new compensatory floodplain. This is inside the Order limits but outside the permanent land take such that the land has a temporary possession with a permanent right. On the west side of the link road, whilst the peak flood level is predicted to increase by up to 60 mm in places, the impact is of no change in flood risk (no increase in frequency of flooding or the consequences). At the farmland alongside the Staverton Stream, an area of flood compensation sits beside the watercourse, which is predicted to store an extra 10-30 mm of water during the 20% annual exceedance probability event (1 in 5-year return period) and 10% annual exceedance probability event (1 in 10-year return period). This land is inside the Order limits but outside the permanent land take such that it has a temporary possession with a permanent right. There is a non-material increase flood risk to three fields, with an associated indiscernible		

[1] https://www.gov.uk/guidance/flood-risk-and-coastal-change

	increase in flood frequency. The hydraulic modelling predicts no adverse impact in the design flood. Hence the Scheme is considered to pass the Exception Test: *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*.

Overview Statement
The Scheme proposes a new motorway junction improvement for the M5 Junction 10, new Link Road, and road widening for the A4019. Embedded mitigation includes a large flood storage area and compensatory floodplain. The Scheme is classified as Essential Infrastructure and is located within existing Flood Zones 2 and 3 and interacts with the River Chelt and Leigh Brook. The Scheme is permitted to be developed in Flood Zones 2 and 3, as detailed hydraulic modelling of the Scheme, with calibrated hydrology and hydraulic modelling, demonstrates that the Scheme will remain operational and safe for use during the design flood. Furthermore, the work has indicated that the Scheme will not increase flood risk elsewhere, noting that small increases in peak flood depths, on areas of farmland by the Staverton Stream which are already at flood risk, are non-material and can be permitted through the DCO.

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List of abbreviations

Term	Description
ABD	Areas Benefitting from Defences
AEP	Annual Exceedance Probability
BGS	British Geological Survey
CAD	Computer Aided Design (approach or software)
CBC	Cheltenham Borough Council
CDA	Critical Drainage Area
DCO	Development Control Order
DMRB	Design Manual for Roads and Bridges
DTM	Digital Terrain Model
EIA	Environmental Impact Assessment
ES	Environmental Statement
FEH	Flood Estimation Handbook
Flood Zone 1	Area with a low probability of flooding from either rivers or the sea (< 1 in 1,000 annual chance of flooding).
Flood Zone 2	Area with a medium probability of flooding from either rivers (1 in 100 – 1 in 1,000 annual chance of flooding) or the sea (1 in 200 – 1 in 1000 annual chance of flooding).
Flood Zone 3	Area with a high probability of flooding from either rivers (> 1 in 100 annual chance of flooding) or the sea (> 1 in 200 annual chance of flooding).
FRA	Flood Risk Assessment
GCC	Gloucestershire County Council
GIS	Geographic Information System
ha	Hectare
HEC RAS	Hydrologic Engineering Center – River Analysis System
HEDDMS	Highways England Drainage Data Management System
ICM	Integrated Catchment Model (AutoDesk software trade name)
J10	Junction 10, of the M5 motorway
JCS	Joint Core Strategy
LiDAR	Light Detection and Ranging
LLFA	Lead Local Flood Authority
M5	M5 motorway
m AOD	metres Above Ordnance Datum
MHCLG	Ministry of Communities and Local Government
NGR	National Grid Reference
NPS	National Policy Statement
NPPF	National Planning Policy Framework

Term	Description
NRFA	National River Flow Archive
PEIR	Preliminary Environmental Information Report
REFH	Revitalised Flood Hydrograph
RMA	Risk Management Authority
RoFSW	Risk of Flooding from Surface Water
SFRA	Strategic Flood Risk Assessment
SPD	Supplementary Planning Document
SWMP	Surface Water Management Plan
SoP	Standard of Protection
SuDS	Sustainable Drainage System
TBC	Tewkesbury Borough Council
WFD	Water Framework Directive

1. Introduction

1.1.1. This flood risk assessment (FRA) identifies if there are any flooding issues related to the M5 Junction 10 Improvements Scheme (hereafter referred to as 'the Scheme' or 'M5 Junction 10') which warrant further consideration through the design process.

1.1.2. As an FRA, it provides a site-specific flood risk assessment with an indication of whether the Scheme is located in an area appropriate for the type of development.

1.1.3. This document, as an Environment Statement (ES) FRA presents the information on the Scheme as presented for its Development Consent Order (DCO).

1.2. Scheme background

1.1.1. Gloucestershire faces significant challenges to achieve its vision for economic growth. The Joint Core Strategy (JCS) is a partnership between Gloucester City Council, Cheltenham Borough Council (CBC) and Tewkesbury Borough Council (TBC) which sets out a strategic planning framework for the three areas. The Adopted JCS 2011-2031 is a coordinated strategic development plan, adopted in December 2017, which shows how the region will develop and includes a shared spatial vision targeting 35,175 new homes and 39,500 new jobs by 2031.

1.1.2. Major development of new housing (c.9,000 homes) and employment land is proposed in the JCS in strategic and safeguarded allocations to the west and north-west of Cheltenham, these being: West Cheltenham (Golden Valley); North West Cheltenham (Elms Park); and safeguard land to the west and the north-west of Cheltenham (all shown in Figure 1-1 of Chapter 1 – Introduction (Application document TR010063 /APP/6.2). The West Cheltenham development, in turn, is linked to wider economic investment, including a government supported cyber business park (Cyber Central UK) adjacent to the Government Communications Headquarters (GCHQ) site in west Cheltenham.

1.1.3. The existing M5 Junction 10 only provides access and egress to and from the north, with no connectivity to M5 south; this causes existing traffic to cross Cheltenham through various routes to access and leave the M5 from the south using other M5 junctions. This contributes significantly to existing traffic flows across Cheltenham, with significant congestion at peak times. To unlock the housing and job opportunities, a highway network is needed that has the capacity to accommodate the increased traffic it will generate, within a sustainable transport context.

1.2.1. Upgrading M5 Junction 10 to an all movements junction has been identified as a key infrastructure requirement to enable the housing and economic development proposed by the JCS and supported in the Gloucestershire Local Enterprise Partnership's (GFirst LEP) Strategic Economic Plan and the transport network sought by GCC in the adopted Gloucestershire Local Transport Plan. Improvements to M5 Junction 10 are critical to maintaining the safe and efficient operation of the junction; and enabling the planned development and economic growth. A bid was submitted in March 2019 to Homes England to the Housing Infrastructure Fund (HIF), wherein an investment case was made for the following infrastructure improvements. Funding was successfully awarded by Homes England in March 2020 for:

- Element 1: Improvements to Junction 10 on the M5 and a new road linking Junction 10 to west Cheltenham.
- Element 2: A38/A4019 Junction Improvements at Coombe Hill.
- Element 3: A4019 widening, east of Junction 10.
- Element 4: An upgrade to Arle Court Park and Ride.

1.2.2. Elements 1 and 3 comprise the M5 Junction 10 Improvements Scheme (the Scheme). The upgrade to Arle Court Park and Ride (now known as the Arle Court Transport Hub) (Element 4) and the junction improvements at Coombe Hill (Element 2) were included as part of the package of improvements funded by Homes England. As they do not form part of the improvement of M5 Junction 10, and are located some distance from the junction,

GCC has decided to take these two elements forward as separate packages of work in order to accelerate the programme for these elements, and will deliver them through separate planning strategies.

1.2.3. An application for a Development Consent Order (DCO) under S.22 of the Planning Act 2008 has been submitted for the construction of improvement works to M5 Junction 10, consisting of a new all-movements junction; the widening of the A4019 east of the junction to the Gallagher Retail Park Junction; and a new Link Road from the A4019 to the B4634. A small section of the A4019 will be realigned to the west of the junction.

1.3. Site location

1.3.1. The M5 links the Midlands with the South West, running from Junction 8 of the M6 at West Bromwich near Birmingham to Exeter in Devon, and linking with the M4 north of Bristol. Junction 10 (of the M5) is located 76 km to the south of Birmingham, 64 km to the north of Bristol, 8 km to the south of Tewkesbury, 6.5km to the north-west of Cheltenham, and 8 miles to the north-east of Gloucester.

1.3.2. The junction is in a strategically important location for the region, particularly as northern and western Cheltenham are the sites of a number of large retail parks and employment areas, and the location of planned future housing and nationally significant business development.

1.3.3. The location of M5 Junction 10 is shown in Figure 1-1. The locations of the infrastructure improvements that make up the M5 Junction 10 Improvements Scheme are illustrated in Figure 1-2 below.

1.3.4. A geographical summary of the study area is given in Table 1-1.

Table 1-1 - Site location details

Site centroid grid reference	393494, 232220 for the study area
Maximum / minimum elevation	46.28 m AOD / 18.46 m AOD
Study area	7.96 km^2 model domain, 196 ha Scheme
Lead local flood authority	Gloucestershire County Council
Borough council	Tewkesbury Borough Council
River Basin District	Severn
Management catchment	Severn Vale

1.4. Project Scope

1.4.1. AtkinsRéalis was appointed by Gloucestershire County Council (GCC) as the designer for the Scheme. The scope was to develop Scheme proposals for the following elements of the Scheme which are related to the changes to the strategic road network (and indicated on Figure 1-2):

- An all-movements junction at M5 Junction 10 and a new Link Road from Junction 10 (element 1).
- Dualling of the A4019 to the East of the Link Road (element 3).

1.4.2. The overall purpose of the Scheme is to improve the highway network around the existing M5 Junction 10 with an overarching aim to ease traffic congestion and to facilitate development in the area.

1.4.3. The A38/A4019 junction improvements at Coombe Hill; and extension to Arle Court Park and Interchange are geographically located away from the M5 Junction 10 improvements and are within Gloucestershire County Council's (GCC) road network. These elements of the Scheme will not be appraised as part of this flood risk work.

Figure 1-1 - Location of the Scheme

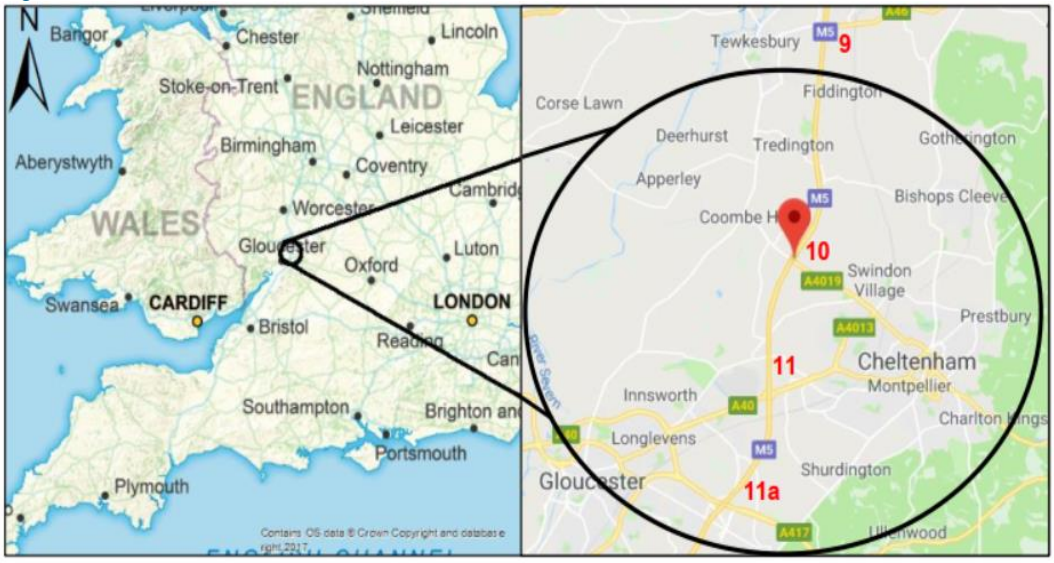


Figure 1-2 - The M5 Junction 10 Improvements Scheme

Figure provided in Appendix 8.1B at the end of this document.

1.4.4. The Scheme upgrades the M5 Junction 10 and provides a new Link Road running south from the A4019 to the B4634 (element 1) and widens the A4019 through Uckington (element 3). Element 2 (A38/A4019 Junction Improvements at Coombe Hill) and Element 4 (Upgrade to Arle Court Park and Ride) are not part of this particular project and are the subject of separate planning applications. The following sections describe the different elements of the Scheme.

M5 Junction 10

1.4.5. The improvements to M5 Junction 10 are to increase the capacity of the junction, and to upgrade the currently northbound only junction to an all-movement junction. To enable travel both south and north on the M5, the two existing Junction 10 exit slip roads will be removed, and four new slip roads will be constructed to provide access and egress to the M5 in all directions.

1.4.6. Two new overbridges will be constructed over the M5, centred either side of the existing overbridge (carrying the A4019 over the M5), which will then be demolished. The new overbridges will create a new elongated shaped roundabout junction over the M5. The A4019 will be realigned to provide an appropriate entry angle to the new roundabout. A dedicated route for cyclists and pedestrians will be provided at grade through the junction (see the section below on the A4019 Widening). Extensions will be required for the Piffs Elm and Leigh Brook culverts, that pass under the M5, as a result of the new slip roads. The planned alignment of the new slip roads means that an extension of the River Chelt culvert under the M5 will not be required.

Link Road

1.4.7. The West Cheltenham Link Road (the ‘Link Road’) will be a new two lane road, with a segregated cycleway and footway, from the B4634 to the A4019. The Link Road is intended to provide greater connectivity between the reconfigured M5 Junction 10 and both the West Cheltenham Strategic Allocation, safeguarded land and the proposed Cyber Park.

1.4.8. The Link Road crosses predominantly agricultural land. The design of the Link Road includes flood relief structures across the floodplain to the north of the River Chelt, and a single span bridge over the River Chelt. The current design of this bridge is a structure that will be set back from the riverbanks (by 4 m on each side of the river), and will have

a clearance of 2.8 m between the underside of the bridge and the top of the river banks.

1.4.9. To connect the Link Road with the existing A4019 (to the north) and the B4634 (to the south), two new junctions will be constructed:

- A4019 - a four-arm signalised junction with the northern arm providing access to the new developments to the north of the A4019, as safeguarded in the JCS. Pedestrian and cycle access over this junction will be incorporated into the signal phasing for this junction. The DF3 design will identify the requirements for pedestrian and cycle crossings at this location.
- B4634 - a new four arm signalised junction is proposed on the B4634 to connect both the Cyber Park and the Strategic Allocation and safeguarded land to the M5 Junction 10 via the Link Road and the A4019. The location of this junction is close to Hayden Hill Farm on the B4634, approximately 300 m east of the junction for Withybridge Lane.

A4019 Widening

1.4.10. The A4019 links the M5 Junction 10 to north-west Cheltenham. Currently, the A4019 is a dual carriageway over the M5 Junction, returning to single carriageway east of the junction to serve the turning into Withybridge Lane. The A4019 continues eastwards to Cheltenham as a single carriageway, where it ties into an existing dual carriageway at the Gallagher Retail Park. A bus lane will be provided eastbound on the A4019 between the West Cheltenham Fire Station and the B4634 (Hayden Road) junction (the Gallagher junction).

1.4.11. The section of the A4019 covered by the Scheme runs from just west of the M5 Junction 10 eastwards through to the existing dual carriageway at Gallagher Retail Park.

1.4.12. As part of the highway improvements incorporated into the Scheme, the A4019 will be widened from Withybridge Lane, eastwards through to the Gallagher Retail Park, where the Scheme will tie into the existing dual carriageway. Widening of the A4019 through Uckington will be to the southern side of the A4019. Widening to the east of Uckington will be to the northern side of the A4019.Two new signalised junctions will be created on the A4019 (between Uckington and the Gallagher Retail Park) as accesses from the A4019 into the future North West Cheltenham Development Area (also referred to as the Elms Park Development site). Changes will also be made (as part of the Scheme) to the layout of the junction of the A4019 with the B4634 at the eastern end of the Scheme (referred to as the Gallagher junction).

1.4.13. For residents and businesses whose current access is directly onto the A4019 (for example those in Uckington, and along the southern side of the A4019 in north-west Cheltenham), short sections of new access roads will be created alongside the widened A4019 to facilitate ease of access both westbound and eastbound.

1.4.14. The Scheme will include a segregated cycleway and footway adjacent to the A4019, which will extend for the full length of the A4019 widening, and will provide connectivity for pedestrians and cyclists between north-west Cheltenham and the junction of the A4019 and Stanboro Lane (west of M5 Junction 10), where it will connect to an existing footway.

1.5. Flood risk scope and context

1.5.1. The Scheme has the potential to increase flood risk and change floodplain dynamics. Detailed hydraulic modelling has therefore been undertaken to:

- understand the Baseline flood risk in the area.
- determine the impact of the Scheme on flood risk.
- determine the flood risk to the Scheme.

1.5.2. Reporting of flood risk has been separated into stages to enable individual updates and timely delivery throughout the project. This FRA is described, in the context of this reporting, as:

- a **Baseline Hydraulic Modelling Report** (Application document TR010063/APP/9.18) describes the development of a flood model for the Baseline associated with the River Chelt and Leigh Brook in the vicinity of the Scheme.
- a **Scheme Hydraulic Modelling Report** (Application document TR010063/APP/9.19) reflecting the development and testing of a with-Scheme flood model.
- a technical note on the **Flood risk impacts at the B4634 Old Gloucester Road** (Application document TR010063/APP/9.20) reflecting the standalone hydraulic assessment of the minor watercourses at the B4634 at the southern end of the Link Road.
- This **FRA report** documenting the assessment of flood risk for the Scheme in line with regulatory guidelines and requirements.
- The **Preliminary Environmental Information Report**[2] (PEIR) documenting the interim/early environmental impact assessment specifically here in relation to flood risk.
- The **Environmental Statement** (ES) (Chapter 8 Road Drainage and Water Environment, Application document TR010063/APP/6.6) documenting the environmental impact assessment specifically here in relation to flood risk.

1.5.3. This FRA report documents the assessment of flood risk with regards to the National Planning Policy Framework (NPPF[3]). Section 2.3 below describes this policy with regards to flood risk.

1.5.4. The December 2014 National Policy Statement for National Networks[4] (NN NPS) sets out the need for, and Government's policies to, deliver development of nationally significant infrastructure projects (NSIPs) on the national road and rail networks in England. This relates back to the NPPF and guidance from the Environment Agency. The Scheme is considered to be an NSIP. Hence this FRA complies with any relevant requirements in the NN NPS.

1.5.5. The purpose of this FRA report is to:

- support the Environmental Statement.
- set out the flood risk policy and legislation relevant to this Scheme.
- consider all sources of flooding and screen those relevant to the Scheme.
- assess the actual flood risk and how it might change over the lifetime of the development.
- consider how flood risk may be managed.
- describe the residual risks of flooding beyond the design standard.

River Chelt catchment

1.5.6. In its headwaters, the River Chelt's catchment is steep and rural, before it flows into Dowdeswell reservoir, which is managed by the Environment Agency as one of three flood storage areas on the River Chelt (with facilities at Cox's Meadow and Sandford Park). The catchment then becomes urbanised as it flows through the town of Cheltenham, which suffered severe flood damage in the summer of 2007.

1.5.7. West of Cheltenham, both the River Chelt and Leigh Brook catchments are low-lying and rural. Both watercourses are culverted under the existing M5 motorway. Downstream of the M5, the channel becomes perched on both the Leigh Brook and the River Chelt with raised embankments separating the farmland from the conveyance channels. The Leigh

[2] Gloucestershire County Council (September 2021) Preliminary Environmental Information Report, GCCM5J10-ATK-WEV-ZZ-RP-LW-000002, Atkins.
[3] Department for Levelling Up, Housing, Communities (December 2023) National Planning Policy Framework (NPPF)
[4] Department for Transport (December 2014) National Policy Statement for National Networks. Reference ID P2689507 12/14

Brook joins with the River Chelt near Wainlode Hill, some 550 m before discharging into the River Severn near Fletcher's Leap and Cobney Meadows. At this location the floodplain is dominated by the River Severn, with a large area of floodplain incorporating the disused Coombe Hill Canal west of the A38 highway. The A38 itself sits on a ridge of high ground.

1.5.8. There was previously one gauging station within the study area on the River Chelt (Slate Mill, National River Flow Archive (NRFA) number 54026). However, the Slate Mill gauge was decommissioned and removed in 2010 due to its poor quality of data.

Environmental Statement FRA limitations

1.5.9. The main purpose of this FRA is determined by Regulation 12(2)(b) of the Environmental Impact Assessment (EIA) Regulations 2017, which requires an Environmental Statement to contain information that is 'reasonably required for the consultation bodies to develop an informed view of the likely significant environmental effects of the development (and of any associated development)'.

1.5.10. This FRA represents the extent of our findings on the current Scheme, but is subject to a number of limitations, which are set out below. Despite these limitations, it is considered that this FRA presents a sufficient level of assessment to meet the requirements of Regulation 12(2)(b) of the EIA Regulations 2017.

1.5.11. The assessment of fluvial risk to infrastructure elements is for the 1% annual exceedance probability event (1 in 100-year return period) with climate change scenario, as required by the NPPF. It is acknowledged that less extreme annual exceedance probability events (e.g. the 1 in 2-year, 1 in 5-year, 1 in 10-year, 1 in 25-year and 1 in 50-year return periods) should be considered, and are described in the Scheme Modelling Report (Application document TR010063/APP/9.19). Assessments of residual risk arising from exceedance events (i.e., those of greater magnitude than the design event), and from blockage scenarios at the Scheme (culverts etc) have also been considered in that report.

1.5.12. This FRA considers surface water (pluvial) flood risk from rainfall based on the existing Environment Agency mapping, noting that this does not use the with-Scheme topography. However, it is also recognised that the published data does not fully reflect flooding from the River Chelt (see Section 2). No direct-rainfall modelling has been undertaken for this project, but instead considers the overland flooding predicted via detailed fluvial modelling. This was found to indicate the worst case extent of flooding.

1.5.13. This FRA presents a quantitative appraisal of the risk and effects associated with surface water management and drainage infrastructure.

Assessing flood risk

1.5.14. An FRA should consider all types of flooding to satisfy the following three key objectives:

- To assess flood risk to the Scheme and to demonstrate that any residual risks to the development and its users would be acceptable.
- To assess the potential impact of the Scheme on flood risk elsewhere and to demonstrate that the development would not increase flood risk elsewhere.
- To satisfy the requirements of the NPS NN section of Flood Risk and the National Planning Policy Framework (NPPF) (see Section 2.3).

1.5.15. Flood risk should be considered alongside other spatial planning issues such as transport, housing, economic growth, natural resources, regeneration, biodiversity, the historic environment and the management of other hazards.

1.5.16. CIRIA C624[5] , from 2004, provides guidance on the implementation and good practice in assessing flood risks through the development process. The aim of C624 is to promote developments that are sustainable with regard to flood risk. The document recommends that an FRA should be undertaken in phases so that the type of development corresponds

[5] Lancaster, J.W., Preene, M. & Marshall, C.T. (2004) Development & Flood Risk – Guidance for the Construction Industry. CIRIA publication C624.

with the detail required.

1.5.17. There are three levels of assessment:

- **Level 1 FRA (Screening Study):** To identify if there are any flooding issues related to a development site which may warrant further consideration. The screening study will ascertain whether a Level 2 or Level 3 FRA is required.
- **Level 2 FRA (Scoping Study):** Undertaken if a Level 1 study indicates that the site may lie within an area which is prone to flooding or that the site may increase flood risk due to increased runoff; and to confirm the possible sources of flooding which may affect the site. The Scoping Study will identify any residual risks that cannot easily be controlled and, if necessary, will recommend that a Level 3 FRA is undertaken. It is typically a qualitative assessment using available data.
- **Level 3 FRA (Detailed Study):** Undertaken if the Level 2 study concludes that quantitative analysis is required to assess flood risk issues related to the development site. This may include detailed hydraulic modelling of rivers or drainage systems.

1.5.18. This report forms a Level 3 FRA. Hence this report provides a site specific assessment of the risks arising to the Scheme as a result of its location and design. Further quantitative assessment has also been made to assess the risk from the Scheme. Specifically, this report seeks to address the 'key questions':

- Is the site likely to be at risk of flooding from: a watercourse, the sea, an estuary, groundwater, overland flow, an artificial drainage system, infrastructure failure?
- Is the Scheme likely to obstruct the maintenance access requirements or affect the integrity of an existing flood defence?
- Is the Scheme likely to increase flood risk elsewhere due to increased runoff rates and volumes from the site?
- Given the above and the nature of the development, is continued promotion of a possible development at the site appropriate?

1.5.19. The report has been completed in line with the NPPF and makes use of readily available information from the following sources:

- Environment Agency Spatial Data Catalogue (Environment Agency, 2022).
- Environment Agency online flood map for planning.
- Environment Agency online long term flood risk map.
- Environment Agency online historical flood map.
- LiDAR data for the site obtained from the .Gov website.

Consultation and regulatory review

1.5.20. Consultation with the Environment Agency on flood risk has been undertaken. Further details are included in Section 2.4). Similarly, consultation has also been started with Gloucestershire County Council as the Lead Local Flood Authority (LLFA), although principle matters have been dealt with by the Environment Agency.

1.5.21. The Baseline and Scheme models feeding the FRA were reviewed by the Environment Agency to ensure that they meet with their approval having adhered to their guidelines and applies and agrees with their local knowledge of the River Chelt, a designated Main River. This is important, as the Flood Risk Assessment with the Environmental Statement will be used in support of the planning process. Gloucestershire County Council, as Lead Local Flood Authority, have also reviewed the work, as it includes the Ordinary Watercourse of the Leigh Brook.

2. Flood Risk Policy

This section outlines flood risk planning policy and guidance.

2.1. National Policy Statement for National Networks

2.1.1. The December 2014 National Policy Statement for National Networks[4] (NPS NN) sets out the need for, and Government's policies to, deliver development of NSIPs on the national road and rail networks in England. It provides planning guidance for promoters of nationally significant infrastructure projects on the road and rail networks, and the basis for the examination by the Examining Authority and decisions by the Secretary of State.

2.1.2. The NPS NN is consistent with the National Planning Policy Framework (NPPF), particularly with regards to matters of flood risk (see confirmation in NPS NN paragraphs 1.17 to 1.21). The NPS NN itself describes the pertinent issues and requirements relating to flood risk in its paragraphs 5.90 to 5.115.

2.2. National planning policy overview

2.2.1. The National Planning Policy Framework[6] (NPPF) is the overarching document in relation to development and flood risk and sets out the Government's policy on development relating to flood risk for planning in England. It was first published by the now Ministry of Communities and Local Government (MHCLG) in March 2012 and revised most recently in December 2023.

2.2.2. The NPPF is supported by the Planning Practice Guidance[7] (replacing the NPPF technical guidance which was withdrawn from use in March 2014). The Planning Practice Guidance is a web-based resource that was launched by the now Department for Levelling Up, Housing and Communities (DLUHC), and the MHCLG in March 2014 to support the NPPF. Guidance relating to flood risk is provided in the Flood Risk and Coastal Change document which was last updated August 2022.

2.2.3. The aim of the NPPF is to ensure that development is not at an unacceptable risk of flooding. Where development is unavoidable in areas at risk from flooding, the NPPF ensures that the development is safe without increasing flood risk elsewhere and where possible reducing flood risk overall.

2.2.4. In accordance with Paragraph 173 of the NPPF, a site-specific FRA is required for development:

- in Flood Zone 2 or 3 including minor development and change of use.
- more than 1 hectare (ha) in Flood Zone 1.
- less than 1 ha in Flood Zone 1, including a change of use in development type to a more vulnerable class (for example from commercial to residential), where they could be affected by sources of flooding other than rivers and the sea (for example surface water drains, reservoirs).
- in an area within Flood Zone 1 which has critical drainage problems.

2.2.5. The FRA must then satisfy five objectives. These are listed below in Table 2-1, along with how this report addresses those objectives.

2.2.6. The promoter of a development must prove to the Local Planning Authority and the Environment Agency that any existing flood risk or flood risk associated with the Scheme can be satisfactorily managed. The national guidance also requires that assessment of flood risk must be carried out considering the potential impacts of climate change on

[6] Department for Levelling Up, Housing, Communities (last updated 20 December 2023) National Planning Policy Framework (NPPF) s.n, s.l. Available at https://assets.publishing.service.gov.uk/media/65a11af7e8f5ec000f1f8c46/NPPF_December_2023.pdf [Accessed 27 March 2024].
[7] Department for Levelling up, Housing and Communities and Ministry of Housing, Communities and Local Government (last updated 25 August 2022) Guidance: Flood Risk and Coastal Change s.n., s.l. Available at: https://www.gov.uk/guidance/flood-risk-and-coastal-change [Accessed 27 March 2024].

flooding over the lifetime of the development.

Table 2-1 - Site-specific Flood Risk Assessment (FRA) objectives

Objective from the NPPF	How the objective is addressed in this FRA
Establish whether a Scheme is likely to be affected by current or future flooding from any source.	Assessment of the existing and future sources of flood risk to the Scheme.
Establish whether it will increase flood risk elsewhere.	Assessment of the impact on flood risk to third party receptors as a result of development of the Scheme.
Establish whether the measures proposed to deal with these effects and risks are appropriate.	Identification of any mitigation measures to manage the above risks that could be incorporated into the detailed design.
Establish the evidence for the Local Planning Authority to apply (if necessary) the Sequential Test.	Summary of evidence which supports the Sequential Test[8].
Establish whether the development will be safe and pass the Exception Test, if applicable.	Assessment of whether the Exception Test is required and, if required, whether the Scheme meets the requirements of the Exception Test.

2.2.7. The NPPF assigns a vulnerability classification to land use in terms of its vulnerability to the impact of flooding. The vulnerability types range from water-compatible to essential infrastructure. The vulnerability of the Scheme will dictate the flood risk zones within which it is compatible. The definitions for vulnerability type, and Flood Zone compatibility, is available on the gov.uk website.

Flood zones

2.2.8. The Environment Agency's Flood Map is divided into three separate Flood Zones (defined in Table 2-2). These Flood Zones are used by NPPF in determining the appropriateness of developments when considering flood risk through the application of the Sequential Test. They represent the probability of flooding without flood defences in place.

Table 2-2 - Definitions of Environment Agency Flood Zones

Flood Zone	Definition
Flood Zone 1: Low Probability	Land where the annual chance of flooding is lower than 0.1% for either fluvial or sea flooding.
Flood Zone 2: Medium Probability	Land where the annual chance of flooding is between 0.1 and 1.0% for fluvial flooding. Or, land where the annual chance of flooding is between 0.1 and 0.5% for flooding from the sea.
Flood Zone 3a: High Probability	Land where the annual chance of flooding is 1.0% or greater for fluvial flooding. Or, land where the annual chance of flooding is 0.5% or greater for flooding from the sea
Flood Zone 3b: Functional Floodplain	Land where water has to flow or be stored in times of flooding. Local planning authorities identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. The August 2022 update to the Planning Practice Guidance expanded this to the 3.3% annual exceedance probability event (1 in 30-year return period).

2.2.9. The Environment Agency's Flood Map also defines Areas Benefitting from Defences (ABDs) within Flood Zone 3; however, this category is not expressly determined within NPPF or the Sequential Test process.

2.2.10. The assessment of Flood Zone for the Scheme is in Section 3.2.

[8] Gloucestershire County Council (February 2021) West Cheltenham Link Road Route Corridor Assessment, Atkins.

Compatibility

2.2.11. The table below (Table 2-3) sets out the NPPF flood risk vulnerability and Flood Zone compatibility assessment, as taken from Table 3 of the NPPF Planning Practice Guidance. The definitions for vulnerability type, and Flood Zone compatibility, are available on the Gov.uk website.

2.2.12. The table indicates which development types are appropriate within each Flood Zone.

2.2.13. More vulnerable development, for example residential, would be unsuitable for construction in areas at risk from flooding, however water-compatible development types such as water based recreation might be considered acceptable (if the development does not increase flood risk elsewhere).

Table 2-3 - Flood Risk Vulnerability and Flood Zone Compatibility

Flood Zones	Flood Risk Vulnerability Classification				
	Essential Infrastructure	**Highly vulnerable**	**More vulnerable**	**Less vulnerable**	**Water compatible**
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	Exception Test required	✓	✓	✓
Zone 3a †	Exception Test required †	✗	Exception Test required	✓	✓
Zone 3b *	Exception Test required *	✗	✗	✗	✓ *

✓ Development is appropriate ✗ Development should not be permitted

† In Flood Zone 3a essential infrastructure should be designed and constructed to remain operational and safe in times of flood.

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

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

2.2.14. The assessment of Flood Zone compatibility for the Scheme is described in Section 4.3.

Sequential Test

2.2.15. The Sequential Approach is a simple decision-making tool designed to ensure that areas at little or no risk of flooding are developed in preference to areas at higher risk.

2.2.16. The NPPF states that the risk-based Sequential Test should be applied at all stages of planning. Its aim is to steer new development to areas with the lowest probability of flooding. Development should be directed to Flood Zone 1 wherever possible, and then sequentially to Flood Zones 2 and 3, and then to the areas of least flood risk within Flood Zones 2 and 3.

2.2.17. The Sequential Test is a key component of the hierarchical approach to avoiding and managing flood risk. It is a decision making tool designed to ensure that sites at little or no risk of flooding are developed in preference to areas at higher risk. The Sequential Test can be applied at a number of levels – from Local Authority Planning decisions to site specific flood risk assessments:

- Local Authority level – the Sequential Test will assist in the defining of development zones, seeking to locate all new development to Flood Zone 1. If a development zone was selected that was in a higher flood risk zone, there would be a requirement to demonstrate that there are no less vulnerable sites available to accommodate the development, and that the development provides wider sustainability benefits which outweigh the risk from flooding (the Exception Test).

- Site Specific level – A Sequential approach should also be applied on a site specific basis, providing a tool to ensure the correct placement of development. Consideration of flood risk at the earliest opportunity in the planning process will enable the location, layout and design of the development to deliver maximum reductions in flood risk.

2.2.18. Appendix 8.1A i provides information relating to application of the Sequential Test for this Scheme. Section 4.3 provides information relating to application of the Sequential Test with regards to flood risk.

Exception Test

2.2.19. The Exception Test should be informed by a strategic or site-specific flood risk assessment, depending on whether it is being applied during plan production or at the application stage. For the Exception Test to be passed it should be demonstrated that:

A. the development would provide wider sustainability benefits to the community that outweigh the flood risk.
B. 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. This report is the first stage in this process.

2.2.20. Both elements of the Exception Test should be satisfied for development to be allocated or permitted.

2.2.21. Appendix 8.1A ii provides information relating to application of the Exception Test. Section 4.3 provides information relating to application of the Exception Test with regards to flood risk.

Design flood

2.2.22. The NPS NN and NPPF focus attention on the Design Flood. This is a flood event of a given annual flood probability, which is generally taken as:

- fluvial (river) flooding likely to occur with a 1% annual exceedance probability event (1 in 100-year return period) or,
- tidal flooding with a 0.5% annual exceedance probability event (1 in 200-year return period), against which the suitability of a proposed development is assessed and mitigation measures, if any, are designed.

2.2.23. These annual probabilities must be designed for over the lifetime of the development, and hence must include for the impacts of climate change. See above, and Section 4.4.

2.2.24. Whilst the various engineering elements for the Scheme are based on different life expectancies (traffic using a 15 year growth prediction, surfacing designed for 20 years, and structural elements for 120 years) the true period of time the works are anticipated to be in existence is in excess of 100 years. This is because they will serve the planned residential and commercial developments around the existing Junction 10 site.

The design flood for this Scheme is the 1% annual exceedance probability event (1 in 100-year return period) with allowance for climate change.

Climate Change

2.2.25. The NPPF sets out how the planning system should help minimise vulnerability and provide resilience to the impacts of climate change. This includes demonstrating how flood risk will be managed now and over the development's lifetime, taking climate change into account. Local planning authorities refer to this when preparing local plans and considering planning applications.

2.2.26. Climate change allowances are predictions of anticipated change for: peak river flow; peak rainfall intensity; sea level rise; offshore wind speed and extreme wave height. They are based on UK climate change projections. There are different allowances for different epochs or periods of time over the next century.

2.2.27. In line with the NPPF, the design flood for the Scheme is the 1% annual exceedance probability event (1 in 100-year return period) **with an allowance for future climate change**. The Environment Agency's climate change guidance at the time of writing was the July 2021 (described in Section 4.4), which correlates with UKCP18 data. The guidance recommends using the higher central climate change allowance (+53% increase in flow) for a Scheme of this type in this location. Both the flood modelling and this ES FRA include the application of those Environment Agency's climate change allowances.

2.2.28. A range of allowances are provided based on percentiles. 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. The:

- Central allowance is based on the 50th percentile.
- Higher Central allowance is based on the 70th percentile.
- Upper End allowance is based on the 90th percentile.

2.2.29. An allowance based on the 50th percentile is exceeded by 50% of the projections in the range. At the 70th percentile it is exceeded by 30%. At the 95th percentile it is exceeded by 5% of the projections in the range.

2.2.30. The flood risk vulnerability classification (above and Section 4.3) is used to decide which allowance applies to the development, be it the Central, Higher Central or Upper End allowances.

2.2.31. The Environment Agency advice includes climate change requirements for the sizing of compensatory floodplain. Compensatory floodplain storage is proposed with this Scheme due to the loss in available floodplain caused by the alignment of the relief road and the raising of road levels above the current floodplain.

2.2.32. An explanation of the climate change allowances applied to this project is given in Section 4.4 below.

2.3. Ministerial Statement (HCWS161)

2.3.1. Paragraph 173 and paragraph 175 of National Planning Policy Framework gives priority to the use of sustainable drainage systems. The requirements of the policy are set out in the Written Ministerial Statement (HCWS161), whereby all 'major' planning applications being determined from April 2015 must consider sustainable drainage systems. As a national infrastructure project passing through the Development Consent Order process, the Scheme is by definition Major development. Consequently, a drainage strategy that considers Sustainable Drainage System (SuDS) is required.

2.3.2. Approved document Part H of the Building Regulations 2010 defines the hierarchy for disposing of surface water as follows:

- Discharge to the ground (for example using soakaways). Where the intention is to discharge to the ground it must be shown to be feasible through an assessment carried out under the Building Research Establishment Digest 365 (BRE 365).
- Discharge to a surface water body (for example a river or lake).
- Discharge to a surface water sewer, highway drain, or another drainage system.
- Discharge to a combined sewer.

2.3.3. The Lead Local Flood Authority in the study area is Gloucestershire County Council.

2.4. Consultation with the flood risk management authorities

Environment Agency advice

2.4.1. The Environment Agency advice for a flood risk assessment is available at: https://www.gov.uk/guidance/flood-risk-assessment-for-planning-applications.

2.4.2. Consultation with the Environment Agency on flood risk has been undertaken. Up to this

stage, the consultation has included:

- Telephone meeting 7 August 2019.
- Telephone meeting 17 January 2020.
- Telephone meeting 9 February 2021.
- Telephone meeting 29 April 2021.

2.4.3. The Environment Agency was also supplied with copies of the Baseline and Scheme models and their accompanying reports for review. The models and the hydrology were reviewed by external consultants on behalf of the Environment Agency (Baseline model 14 April 2021 and Scheme model 15 July 2022). The Environment Agency has deemed both models appropriate, such that the results from these models can be used to support this Flood Risk Assessment and the Environmental Statement.

2.4.4. The proposed compensatory floodplain was reviewed by the Environment Agency to validate it as a level-for-level provision. The Environment Agency responded on 14 March 2023 reporting that whilst the proposed compensation to the east of the new Link Road was not on a strictly level for level basis, that it would prove almost impossible to achieve due to the alignment of the road. It concluded that it was content for the design principals to be adopted as part of the final detailed proposals and the modelling outputs produced to be included within the supporting planning documents.

Lead Local Flood Authority advice

2.4.5. Consultation was undertaken with Gloucestershire County Council as the Lead Local Flood Authority (LLFA), specifically for the flood risk elements relating to the Leigh Brook (an Ordinary Watercourse) and the minor watercourses at the B4634.

2.4.6. Specific consultation with the LLFA on flood risk was undertaken on:

- Telephone meeting 17th September 2020.
- Telephone meeting 14th May 2021.
- Telephone meeting 3rd May 2022.

2.4.7. For matters relating to the River Chelt and Leigh Brook, the LLFA referred to the Environment Agency. For the minor watercourses, at the B4634, the LLFA challenged the findings and further modelling was undertaken. The resulting technical note**Error! Bookmark not defined.** and findings were subsequently accepted by the LLFA with no objections.

2.5. Local planning policy overview

Joint Core Strategy

2.5.1. The adopted Joint Core Strategy (JCS) is a strategic development plan that has been prepared through a partnership between Gloucester City Council, Cheltenham Borough Council and Tewkesbury Borough Council. The JCS provides a co-ordinated strategic plan for this joint administrative area during the period up to the year 2031. The JCS has an extensive and up-to-date evidence base, including Strategic FRAs which provide a detailed assessment of multiple flood sources for specific broad locations within the JCS area.

2.5.2. Whilst the JCS provides the strategic level policies for development in the area, this will be supplemented at individual district level by locally specific plans. In Tewkesbury Borough, the council has begun preparation of the Tewkesbury Borough Plan, which is at a relatively early stage of development.

Supplementary Planning Document

2.5.3. The Flood and Water Management Supplementary Planning Document (SPD)[9] details guidance on the approach that should be taken to manage flood risk and the water environment as part of new development proposals. The SPD highlights the documents

[9] Tewkesbury Borough Council (2018), Flood and Water Management Supplementary Planning Document

which will be required to accompany planning applications including site specific FRAs and Drainage Strategies (incorporating an appropriate approach to surface water drainage including suitability evidence).

2.5.4. The SPD restates the definition of a 'Design Flood' as, "the fluvial flood level likely to occur with a 1% annual probability, or 0.5% tidal, plus climate change allowance, should be used to inform the sequential approach, including appropriate location of built development; consideration of flood risk impacts, mitigation/enhancement and ensure 'safe' development."

2.5.5. The document requires an assessment of the 1% annual probability flood event, with 70% allowance added to 'peak river flows' to account for climate change. For surface water drainage design it advocates the same allowance when sizing attenuation storage [ie the same 70% as written in the SPD above] but "as a minimum, a 40% allowance [which is taken to mean 40% on rainfall and not 40% on flow] to be made as per Environment Agency guidance for the 'upper estimate' in their [2011] 'Adapting to Climate Change' document…"

Gloucestershire standing advice

2.5.6. The Standing Advice and Development Guidance by Gloucestershire County Council Lead Local Flood Authority advises that, "the National Planning Policy Framework (NPPF) and accompanying Technical Guidance (TG) provides guidance on the consideration of flood risk. It includes information on climate change (Section 10 of NPPF and para. 11 of TG)." Note that the references here are out of date and do not reflect the right paragraphs in the current published material.

2.5.7. The remainder of the guidance is written around drainage design. Contrary to the SPD it only requires attenuation feature to be designed for flows up to and including the 1 in 100 year event + 40% for climate change.

3. Sources of Flooding

The NN NPS and the NPPF state that all types of flooding should be considered. The extent to which these should be considered will vary and depends on whether they are considered as significant at the spatial planning scale, and in setting constraints on development in certain areas. This section of the report assesses the risk of flooding to the Scheme and identifies those sources of flooding that require further consideration.

3.1. History of flooding

3.1.1. Past evidence of flooding at or near the site helps to reinforce flood risk information provided by the Risk Management Authorities (RMAs). For example, the fact that a site has been reported to have flooded twice in the last 50 years, even if the actual flood levels and flows are unknown, is useful and can be used as a broad 'sensibility' check on any modelling results. However, the fact that a site has not flooded, even for the last 50 years (for example) is not in itself evidence that it will not flood.

3.1.2. The Environment Agency holds a GIS dataset containing historic flood risk information. This dataset has been interrogated to establish if the development site has flooded in the past. Figure 3-1 shows the historical flood outline in the vicinity of the Scheme.

3.1.3. The data shows previously occurring flooding associated with the River Chelt. Much of this data is referenced as being from July 2007. The historic flood outline shows flooding:

- from the River Chelt to the west of the M5 motorway, covering the farmland as far as the existing Junction 10 of the M5 motorway.
- upstream of the River Chelt culvert under the M5 and the fields alongside the river to the east.
- of the Moat residences in Uckington.

Figure 3-1 - Environment Agency's historical flood mapping

Figure provided in Appendix 8.1B at the end of this document.

3.1.4. Flooding of this area in July 2007, and at other times, was also recorded by local landowners. During the project we have engaged with local landowners to validate the assessment of risk based on their observations and anecdotal evidence.

3.1.5. The Cheltenham Surface Water Management Plan[10] reports, "The summer of 2007 represented one of the most significant flooding incidents across England, and significant flooding occurred throughout Cheltenham. The June flood has been assessed as having a 1.33% (or 1 in 75 year) probability of occurring in any year. **The July flood has been assessed as having less than 0.8% (or 1 in 125 year) likelihood of occurring in any year**. Property flooding occurred in Cheltenham from surface water, the River Chelt and other rivers, including Hatherley Brook and Wymans Brook...".

3.2. Flooding from rivers

3.2.1. Flooding from rivers (fluvial flooding) occurs following exceedance of the flow capacity of river channels, leading to overtopping of the riverbanks and inundation of the surrounding land.

3.2.2. The Environment Agency Flood Map for Planning identifies Flood Zones, ignoring the presence of defences. Flood Zone 1 has the lowest probability of flooding from the rivers

[10] Gloucestershire County Council (December 2011). Cheltenham Surface Water management Plan. Halcrow & Richard Allitt Associates

or sea, whereas Flood Zone 3b has the highest probability of flooding[11] . The map indicates that the highways associated with the Scheme cross Flood Zone 3 and Flood Zone 2. The published Environment Agency flood map does not indicate the presence of any Flood Zone 3b in this area.

3.2.3. The Environment Agency map for Flood Risk from Rivers or the Sea identifies the probability of river and sea flooding, accounting for the presence of defences.

- Low risk means that each year this area has a chance of flooding of between 0.1% and 1%.
- Medium risk means that each year this area has a chance of flooding of between 1% and 3.3%.
- High risk means that each year this area has a chance of flooding of greater than 3.3%.

3.2.4. The Environment Agency flood map for planning is shown in Figure 3-2. This flood map was updated in August 2022, indicating a much smaller Flood Zone related to the River Chelt on the west of the M5 motorway. The map indicates that the Scheme will cross areas of Flood Zone 3 and 2. This relates to the Link Road which crosses the River Chelt, and the improvement works at the motorway junction.

3.2.5. The land to the north of the A4019, alongside the Leigh Brook, is identified within Flood Zone 1. However, this relates to the Ordinary Watercourse and it is likely that no flood mapping has been undertaken for the area.

3.2.6. Significant areas of land just south of the A4019 and east of the M5 motorway are classified as Flood Zone 2 and 3. These floodplain areas are associated with the River Chelt. Part of the residential area at Withybridge Gardens, is classified as Flood Zone 3, although some is predicted in Flood Zone 1. To the south of the River Chelt, the floodplain is less extensive and most of the land is identified as Flood Zone 1.

3.2.7. Land to the west of M5 Junction 10, including the hamlets of Knightsbridge, Coombe Hill and Boddington, is classified as Flood Zone 2 with narrower areas under Flood Zone 3.

3.2.8. Flood Zone 3b is described as the functional floodplain and is a legally defined area published by the Environment Agency. It is described in paragraph 077 and table 1 of the August 2022 guidance[7] as, " … *land having a 3.3% or greater annual probability of flooding or is designed to flood*." Prior to August 2022 the definition was for land having a 5% or greater annual probability of flooding. In this location, there is no published Flood Zone 3b as it was not assessed as part of the Strategic Flood Risk Assessment[12] (SFRA). Therefore, an assessment of the baseline Flood Zone 3b has not been included within this report.

3.2.9. However, the Scheme, and Baseline, assessment has investigated flooding in the 4% AEP event (1 in 25 year) which was a precautionary representation of the functional floodplain during the assessment prior to August 2022 This has not been updated but remains as a proxy to flood zone 3b. This is also described in the Baseline Modelling Report (Application document TR010063/APP/9.18).

Figure 3-2 - Environment Agency's flood map for planning

Figure provided in Appendix 8.1B at the end of this document.

3.2.10. The following table quantifies the Scheme footprint that lies inside each Environment Agency Flood Zone, and hence at various degrees of flood risk.

Table 3-1 - The Scheme and Environment Agency Flood Zones

Note that the Environment Agency Flood Zones do not reflect the full extent of flooding.

[11] The Flood Zones shown on the Environment Agency's Flood Map for Planning (Rivers and Sea) do not take account of the possible impacts of climate change and consequent changes in the future probability of flooding.
[12] Cheltenham Borough Council (2008) Strategic Flood Risk Assessment, Halcrow Group Limited

Scheme footprint based on Design Fix 3.4 design in June 2022.

Flood Zone	Footprint of the Scheme
1	336,048 m2
2	61,737 m2
3	39,056 m2
Total	436,841 m2

The Scheme crosses Environment Agency Flood Zone 3 and 2.

3.2.11. The Environment Agency's Flood Risk from Rivers or the Sea mapping (Figure 3-3) indicates a similar pattern of flooding, although reflects the risk west of the M5 as per the former Environment Agency flood map for planning.

3.2.12. The flood risk from the River Chelt to Boddington and the surrounding area was modelled by Edenvale Young Associates[13]. This work was undertaken to challenge the published Environment Agency flood map, and was subsequently approved by the Environment Agency. The work (identified a much greater floodplain to the east of the M5 motorway with floodwater being held behind the highway embankment. The work also identified areas of flood risk associated with the Leigh Brook, showing large areas at risk of flooding in the 1% annual exceedance probability event (1 in 100-year return period).

3.2.13. Flood risk from the River Chelt and Leigh Brook has been identified as a major consideration in this area by the Environment Agency.

The Scheme crosses areas at a high risk of fluvial flooding.

Figure 3-3 - Environmental Agency's flood risk from rivers or the sea

Figure provided in Appendix 8.1B at the end of this document.

3.3. Flooding from surface water

3.3.1. The presence of a Critical Drainage Area alone would indicate that a detailed FRA was required. Surface water flooding (sometimes referred to as pluvial flooding) can be caused by overland flow / runoff, and includes water flowing over the ground that has not reached a natural or artificial drainage channel. This can occur when intense rainfall exceeds the infiltration capacity of the ground because rainfall has fallen on ground so highly saturated that it cannot accept any more water.

3.3.2. Surface water flooding can also be caused when intense rainfall exceeds the surface water drainage capacity in an urban area, such that ponding and overland flow occurs. This can also be referred to as surface water sewer flooding. Surface water flooding can be caused by water originating from either on-site or from adjacent sites.

3.3.3. The Environment Agency's map showing the Risk of Flooding from Surface Water (Environment Agency, 2020) categorises it into a Low, Medium and High category.

- Low risk means that each year this area has a chance of flooding of between 0.1% and 1%.
- Medium risk means that each year this area has a chance of flooding of between 1% and 3.3%.
- High risk means that each year this area has a chance of flooding of greater than 3.3%.

3.3.4. The mapping, shown on Figure 3-4, indicates medium and high flood risk (i.e., 1% to 3.33% Annual Exceedance Probability (AEP) events respectively) in areas immediately north-east and south-east of the M5 Junction 10, with the highest risk located against the

[13] Edenvale Young (2019). Boddington Model Report - Flood map challenge.

motorway embankment. In particular, surface water appears to pond along the north-east border of the M5 Junction 10 southbound off slip road and extend approximately 750 m north from the junction. This ponding is shown to affect properties on the north bank of the Leigh Brook.

3.3.5. An area of low to high surface water flood risk (0.1% to 3.33% AEP) is located at the M5 motorway crossing of the River Chelt, approximately 800 m south from the M5 Junction 10. Surface water is shown to pond within this area, sitting beside the motorway off either bank and extending south to the unnamed watercourse that passes through the Staverton culvert. This flooding affects several residential properties at Butlers Court.

Figure 3-4 - Environment Agency's flood risk from surface water

Figure provided in Appendix 8.1B at the end of this document.

Parts of the Scheme are at high risk from surface water flooding.

3.4. Flooding from the sea

3.4.1. Inundation by high tides, storm surges and waves along coastal regions is described as coastal flooding. The propagation of high tides and storm surges up estuarine channels can lead to overtopping of the river banks and inundation of the surrounding land. This is referred to as tidal flooding.

3.4.2. The study area is located over 9 km from the nearest tidal watercourse (the River Severn at Gloucester) and is not at risk of flooding from the sea.

The Scheme is outside a Flood Zone associated with coastal/tidal flooding.

3.5. Flooding from groundwater

3.5.1. Emergence of groundwater at the surface (and subsequent overland flows) or into subsurface voids as a result of abnormally high groundwater levels is referred to as groundwater flooding. This can have a direct impact on buildings and buried services, as well as an indirect impact by increasing infiltration of groundwater into sewers and soakaways (reducing their capacity to convey surface water runoff).

3.5.2. According to the 1:50,000 mapped geology (BGS, 2020[14]), there is moderate superficial deposit coverage, consisting of Alluvium and Cheltenham Sand and Gravel. The eastern portion of the study area is largely underlain by the Charmouth Mudstone Formation bedrock with the western portion underlain by the Rugby Limestone Member.

3.5.3. Lithological descriptions of both superficial and bedrock geology and a generalised geological sequence are provided in Table 3-2 below. Further detail particularly regarding made ground, soils and local geology can be found in ES Chapter 10 - Geology and Soils (Application document TR010063/APP/6.8).

Table 3-2 - Generalised geological sequence for the Scheme

Period	Formation / Sub-unit	Lithological Description (BGS, 2020)	Environment Agency Aquifer Designation (EA, 2020b)
Quaternary	Cheltenham Sand and Gravel	Fine-medium grained of quartroze sand with seams of poorly sorted limestone gravel.	Secondary A
	Alluvium	Unconsolidated clay, sand and silt.	

[14] British Geological Survey (BGS). Geology Of Britain Viewer [online]. Available at: https://mapapps.bgs.ac.uk/geologyofbritain/home.html [Accessed 02 October 2020].

Period	Formation / Sub-unit	Lithological Description (BGS, 2020)	Environment Agency Aquifer Designation (EA, 2020b)
Triassic	Charmouth Mudstone Formation	Dark grey laminated shales, blue/grey mudstones with local concretions and argillaceous limestone beds with some sandy layers at the base of the stratigraphy.	Secondary Undifferentiated
	Rugby Limestone Member	Grey argillaceous mudstones and limestones.	Secondary A

3.5.4. The study area is underlain by Secondary A and Secondary (undifferentiated) bedrock aquifers (Environment Agency, 2020b). These bedrock aquifer designations are associated with the Charmouth Mudstone Formation and the Rugby Limestone Member. The Scheme is also underlain by discreet areas of Secondary A superficial aquifer associated with the Alluvium and Cheltenham Sand and Gravel. Secondary A aquifers are defined as “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”. Secondary B aquifers are defined as “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”. Secondary (undifferentiated) aquifers are assigned by the EA where it has not been possible to attribute either category A or B to a rock type.

3.5.1. Therefore, the Baseline conditions have been identified using both interpretation of the ground investigation data and online publicly available data. The BGS susceptibility to groundwater flooding maps show that the Scheme is at high to medium-high risk of groundwater flooding. Further assessment is provided in Section 4.6.

The Scheme is at medium risk from groundwater flooding.

3.6. Flooding from sewers

3.6.1. Flooding from sewers (open or culverted) is caused by exceedance of sewer capacity and / or a blockage in the sewer network. In areas with a combined sewer network system there is a risk that land and infrastructure could be flooded with contaminated water. In cases where a separate sewer network is in place, sites are not sensitive to flooding from the foul sewer system. Sewer flooding can occur for a number of reasons including blockage or localised infrastructure failure.

3.6.2. National Highways Drainage Data Management System (HEDDMS) has records of eight flood events occurring on the motorway and trunk roads in the area of the M5 Junction 10 since 2011. These flood events typically occur in late summer/autumn (August to November), and vary in severity with a rating of 0 to 7 (where 10 is the maximum flood severity). The severity of the flood events are shown in Figure 3-5. The A4019 within the study area has been classified with a ‘very low’ flood hotspot status. The status of flood events is shown in Figure 3-6 below.

The Scheme is not at risk from sewer flooding.

Figure 3-5 - National Highways DDMS Flood Events Severity

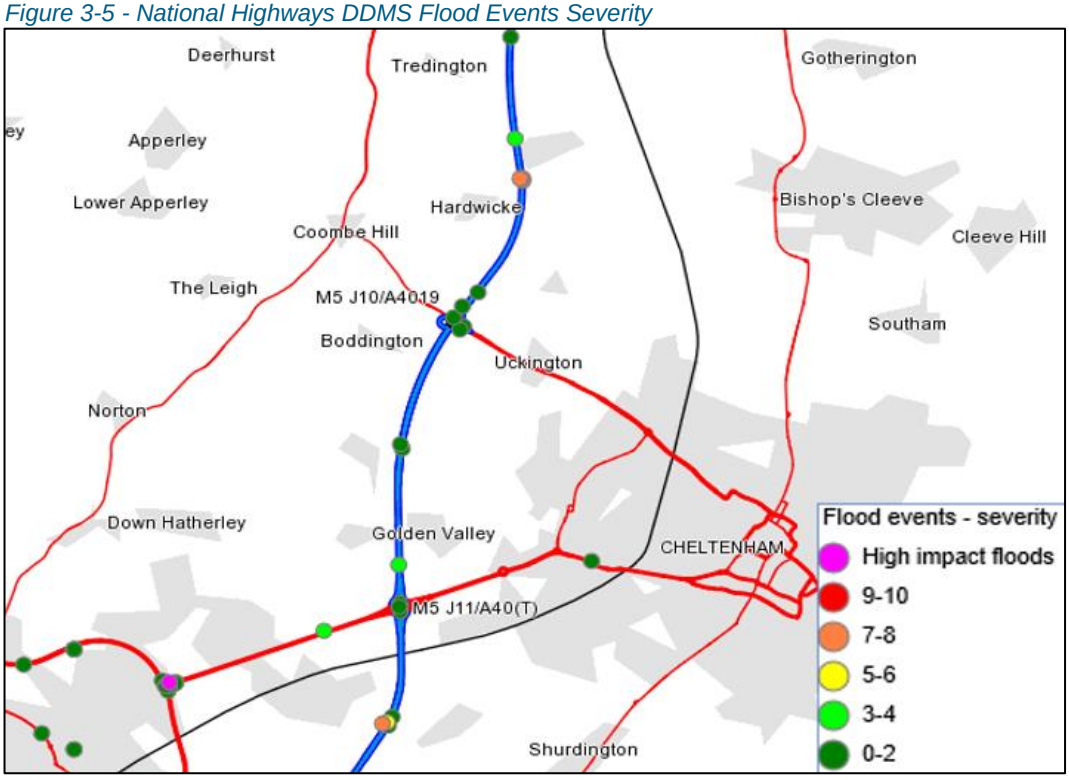
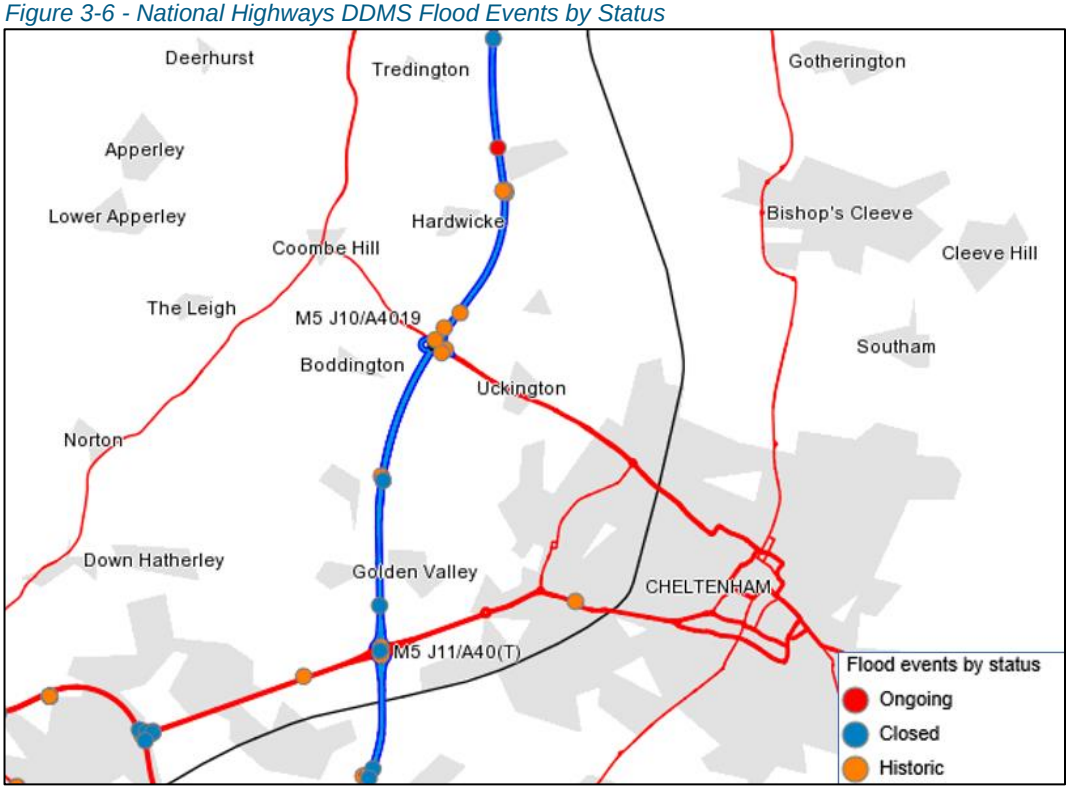


Figure 3-6 - National Highways DDMS Flood Events by Status



3.6.3. According to the Strategic Flood Risk Assessment[12] , the study area is considered to have a low level risk of flooding from sewers. Mapping of historical incidents of sewer flooding in the vicinity of the Scheme (as mapped in the SFRA) has been obtained from Gloucestershire County Council.

3.6.4. It is not known whether there are other sewers within the study area; no records of sewer flooding have been seen. However, the risk of sewer flooding in this rural location is low.

3.6.5. Given the low number of incidents shown, it is considered likely that previous incidents on the M5 motorway were due to a localised problem rather than a wider capacity issue. The risk of sewer flooding impacting on users of the Scheme is therefore considered to be negligible. Furthermore, detailed drainage work is being undertaken for the Scheme which will comply with the relevant statutory and local requirements.

3.7. Flooding from other sources

Flooding from water transmission infrastructure

3.7.1. Flooding from water transmission infrastructure is caused by a blockage, failure or generally an under-capacity system. Water companies are required to report on the current number of properties in their areas at risk of flooding within the DG5 register.

3.7.2. There is a water distribution main running along, and besides the A4019 in the study area. If this main was to fail, it would likely lead to flooding of the highway. Severn Trent Water, as sewerage and water undertaker in this area, manage the potential failure of their systems to an acceptable level and hence the flood risk from water transmission infrastructure is considered low.

3.7.3. Nevertheless, the location of water transmission infrastructure will be determined by the Contractor prior to commencement of the works. If water transmission infrastructure is located in this area, the construction method statement will propose an approach to ensure no impact on this existing infrastructure.

The Scheme is not at risk from water transmission infrastructure.

Flooding from reservoirs

3.7.4. Figure 3-7 indicates that the study area is at risk of flooding from the Dowdeswell reservoir, should the dam fail. This reservoir is located approximately 10 km to the south west of M5 Junction 10, on the eastern side of Cheltenham. This artificial waterbody is regulated by the Reservoirs Act 1975, and as such the risk of breach (dam failure) is very low.

The site is at risk from flooding from reservoir failure although this is unlikely due to regulation imposed by Reservoirs Act.

3.7.5. It should be noted that whilst this published map, and the above flood data, indicates that the M5 motorway impounds floodwater from the River Chelt and Leigh Brook, that the floodplain is not described as a large, raised reservoir under the Reservoirs Act 1975. Existing road embankments are exempt from the Act unless actions are undertaken to impound additional volumes. The implications of the Reservoirs Act are discussed in this FRA.

Flooding from canals

3.7.6. There are no canals in the vicinity that may otherwise pose a flood risk to the site. The Scheme is more than 2.5 km away from the disused canal at Coombe Hill and thus it is not considered to be at risk.

The Scheme is not at risk from a canal.

Figure 3-7 - Environment Agency's flood risk from reservoirs

Figure provided in Appendix 8.1B at the end of this document.

Failure of flood defences

3.7.7. The Scheme is outside an Area Benefiting from Defences, and hence would be unaffected by any failure of an existing flood defence. There are raised defences indicated by the Environment Agency mapping at Withy Bridge, although these provide service to the properties there and would not affect the Scheme.

The Scheme is not at risk from any flood defence failure.

3.8. Summary of flood risk sources

3.8.1. Table 3-3 below summarises the likely sources of flood risk to this Scheme.

Table 3-3 - Sources of flood risk summary

Flood risk	Baseline risk	Commentary
Fluvial	High	Flood risk from the River Chelt and its tributaries.
Tidal	None	Not applicable - no tidal influences.
Surface Water	High	Surface water flood risk arising from runoff from the south. Road alignment intercept overland flow paths.
Groundwater	Medium	Medium risk. Given the presence of Secondary A and B aquifers underlying some of the study area there is potential for flooding from groundwater. A groundwater assessment has been undertaken to consider likely effects of the Scheme on groundwater flood risk.
Sewers	Low	Low risk in rural area.
Other sources	Low	Risk of flooding from the Dowdeswell Reservoir should failure occur. Reservoirs Act requirements reduce this risk to an acceptable level.

3.8.2. The predominant risk of flooding to the site arises from fluvial and surface water flooding.

4. Assessment of flood risk

The previous section identified those sources of flooding requiring further consideration based on a desk study review of published data. This section details the investigations undertaken to assess the flood risk posed by those sources.

This assessment is written in support of the ES.

4.1. Study area

4.1.1. The M5 Junction 10 study area defined for flood risk is shown in Figure 4-1 and contains:

- the extent of the material works.
- a downstream (outlet) boundary sufficiently remote from the Scheme to ensure any uncertainties would not impact on model predictions of Scheme impact or performance.
- an upstream (inflow) boundary sufficiently remote from the Scheme to ensure is represents the contributing watershed.

4.1.2. In its upstream extent the study area boundary lies at the roundabout of the B4634 Old Gloucester Road with the A4019 near the retail park at Kingsditch. The study boundary follows the B4634 south west towards Hayden, under the M5 motorway, before joining Church road to Staverton, and then extending due North to Boddington, meeting the A4019 at Piffs Elm. The boundary then passes north along the B class road towards Hardwicke, crossing the Leigh brook before turning east and following the watershed close to the C class road to Elmstone Hardwicke along the road named “The Green”. The boundary then continues to follow the catchment boundary of the Leigh Brook, back to the A4019 and B4634 roundabout.

Figure 4-1 - Study Area and indicative Scheme

Figure provided in Appendix 8.1B at the end of this document.

4.2. Existing site topography

4.2.1. The existing topography reflects a wide floodplain associated with both the River Chelt and Leigh Brook. The land falls from east to west with the River Chelt being the main conveyance channel. The Leigh Brook has its headwaters in the study area but flattens to a wide floodplain at the M5 motorway. The M5 motorway runs on a raised embankment across the floodway.

4.2.2. The key features of the site topography, as defined by LiDAR (2019) and shown in Figure 4-2 are as follows:

- The minimum ground level in the study area is approximately 18 m AOD near the downstream boundary towards the former Slate Mill gauging station.
- The maximum ground level in the study area is ~38 m AOD at the upstream boundary by the B4634 Old Gloucester road.
- The M5 motorway runs across the study area falling from south to north, with a level at the River Chelt crossing of 26.8 m AOD, and at the Leigh Brook crossing of 25.5 m AOD.
- The M5 motorway is raised across the topography, running north-south over the general east-west fall of the land.
- The maximum difference in ground levels across the study area is approximately 18 m.

Figure 4-2 - Site topography

Figure provided in Appendix 8.1B at the end of this document.

4.2.3. The upstream boundary of the study area with a ground level of ~38 m AOD is more than 14 m higher than the land beside the M5 motorway (~24 m AOD) and nearly 13 m higher than the estimated 1% annual exceedance probability event (1 in 100-year return period) flood level (of approximately 25 m AOD). The boundary is located sufficiently far away from the Scheme for it not to have an impact on it. This is demonstrated in the Baseline Hydraulic Modelling Report (Application document TR010063/APP/9.18).

4.2.4. The downstream boundary for the study area is some 950 m west (downstream) of the M5 motorway. It is located upstream of the confluence with a minor watercourse arising from Boddington, and some 600 m upstream of the former river gauge at Slate Mill. The terrain falls towards the downstream boundary at a typical slope of 1 in 211 away from the M5 motorway.

4.2.5. Based on the inference from the Environment Agency published flood mapping, there is a depth of water on the floodplain of approximately 600 mm besides the Boddington Lane during the 1% annual exceedance probability event (1 in 100-year return period). The influence of water levels at this boundary do not influence flood risk at the Scheme and is described in the Baseline Hydraulic Modelling Report (Application document TR010063/APP/9.18): Variation in water levels at the downstream boundary do not influence flooding at the Scheme.

4.3. Initial assessment

4.3.1. The primary source of flood risk for consideration with the Scheme is fluvial and surface water. The risk of surface water flooding is connected with the fluvial flood risk. These have been described in more detail below.

4.3.2. The Scheme will be part of a transport infrastructure that can be described as a key transport link with junctions to the existing road network. Under the NPPF guidance, the development can be classified as Essential Infrastructure.

The Scheme is considered by this FRA to be classified as Essential Infrastructure.

4.3.3. Given the presence of Secondary A and B aquifers underlying some of the study area for the Scheme, there is potential of flooding from groundwater. A groundwater assessment has been undertaken to consider likely effects of the Scheme. Site specific intrusive groundwater investigation/monitoring has been completed and used to inform the preliminary assessment.

Sequential Test

4.3.4. The Scheme has been designated as a ‘critical’ development to improve transport infrastructure at both a regional (by Gloucestershire County Council) and national (by National Highways) level.

4.3.5. Alternative options were considered for the Scheme. These are described in the Technical Appraisal Report[15] prepared at the option identification stage.

4.3.6. The Route Assessment Reports undertaken for the Scheme[16] indicates that the Scheme satisfies the application of the Sequential Test to justify the location of the development. Appendix 8.1 A provides some of the investigations that explain how the Sequential Test was applied.

4.3.7. Table 4-1, below, addresses the steps in the Sequential Test.

[15] M5 Junction 10 improvement scheme: Volume 1 report -Technical Appraisal Report, Atkins. September 2020.
[16] West Cheltenham Link Road route assessment report, Atkins. April 2021

Table 4-1 - NPPF Sequential Test application on the Scheme

Sequential Test step	Test step question	Test outcome
1	Can development be allocated in Flood Zone 1?	No, the road has to cross the floodplain. See options assessment reports (ref [15 and 16])
2	Can development be allocated in Flood Zone 2?	No, the road has to cross the floodplain. See options assessment reports (ref [15 and 16])
3	Can development be allocated within lowest risk sites available in Flood Zone 3?	No, the road has to cross the floodplain at this location to serve the intended developments and traffic movements. See options assessment reports (ref [15 and 16])
4	Is development appropriate in remaining areas?	Yes. Development considered to be "Essential Infrastructure" (NPPF, Table 2, Paragraph 066) Located in Flood Zone 3b "Functional Floodplain (NPPF, Table 1, Paragraph 065 Development should be allocated to area subject to passing of Exception Test (NPPF, Table 3, Paragraph 067)

4.3.8. Based on its Essential Infrastructure vulnerability classification and crossing Environment Agency Flood Zone 3 (Section 3.2 above Flooding from rivers), Table 2-3 indicates that the Scheme is compatible with the flood risk but requires the Exception Test.

The Scheme is compatible with the flood risk but requires application of the Exception Test.

4.3.9. It should be noted that paragraph 5.102 of the NPS NN accepts that there will be cases where, "…infrastructure is being provided connecting two points that are not in flood risk areas, but where the most viable route between the two passes through such an area."

Exception Test

4.3.10. As the Scheme requires application of the Exception Test, the Scheme will require further assessment to demonstrate:

A. wider sustainability benefits to the community that outweigh the flood risk.
B. 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.

4.3.11. It is also noted in the NPPF that as the Scheme crosses Flood Zone 3a it should be designed and constructed to remain operational and safe in times of flood. Furthermore, as it crosses Flood Zone 3b (functional floodplain and watercourse) it should be designed and constructed to:

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

4.3.12. If this can be demonstrated and appropriate mitigation measures are undertaken as may be required, the Scheme will be acceptable.

4.3.13. The application of the Exception Test for the M5 Junction 10 Improvements Scheme is outlined below in Table 4-2.

4.3.14. The Scheme passes the Exception Test subject to implementation of the flood mitigation measures as per this FRA and drainage strategy.

4.4. Climate change allowances

4.4.1. The Scheme will be designed to be flood free during the 1% annual exceedance probability event (1 in 100-year return period) with climate change allowance, ensuring hydraulic conveyance of both fluvial and surface water flows. As such, climate change

should have no specific impact on this Scheme.

4.4.2. The Environment Agency advice on climate change for a flood risk assessment is available at: Flood risk assessments: climate change allowances - GOV.UK (www.gov.uk). It is this that is referred to in Paragraph 166 of the NPPF, *"… and take account of advice from the Environment Agency and other relevant flood risk management authorities, such as lead local flood authorities and internal drainage boards."*

4.4.3. Environment Agency guidance on climate change was updated in line with the UKCP18 data in July 2021. This ES FRA includes the application of those Environment Agency's climate change allowances (Environment Agency, 2021).

Table 4-2 - NPPF Exception Test application on the Scheme.

Exception Test Part	Part description	Application to the Scheme
A	It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment where one has been prepared	The Scheme will aid in unlocking economic potential and encourage growth and job creation (Scheme Objective 1 and the Joint Core Strategy), otherwise restricted by limited accessibility to the area. The Scheme will allow for improved climate change resilience in the area (Scheme Objective 4). The draft Sustainability Statement[17] considers the schemes performance under various sustainability topics, including financial, human, natural, social and manufactured capital. Assessments are contained in the full Environmental Statement, which includes aspects of the wider socio-economic benefits and impacts on the population and human health.
B	A site-specific flood risk assessment 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 site specific FRA has been undertaken, as documented in this report. It has been demonstrated by computational modelling that the Scheme will not increase flood risk elsewhere.

Peak river flow allowances for fluvial/river assessment

4.4.4. Peak river flow allowances show the anticipated changes to peak flow by river basin district. The Scheme lies in the Severn River Basin district. With a flood risk vulnerability classification of 'Essential Infrastructure' and the site crossing Flood Zone 3, it is required to use the **Higher Central allowance** for climate change. This means a +53% increase in peak flows for the years 2070 to 2115.

4.4.5. The Environment Agency did indicate that a lower climate change allowance might be acceptable for the Link Road element of the Scheme: however, for practical purposes the higher +53% allowance has been retained throughout the assessment.

4.4.6. It should be recalled that modelling results at the time of writing the PEIR FRA applied the former (precautionary) allowance of +70% increase in peak flows. The updated allowance of +53% increase in peak flows has been used in this ES FRA.

4.4.7. Assuming a 100 year life for the Scheme, into the 2120s, requires extension of the third epoch (from the 2080s) to cover the lifetime of this assessment. This is standard practice

[17] Gloucestershire County Council (October 2022) Sustainability Statement, Atkins.

at the time of writing. Future Environment Agency guidance may provide additional data.

4.4.8. It is noted that, as an NSIP, further sensitivity testing is encouraged with the Upper End scenario (credible maximum), which at this location is a +94% increase in peak flows. Testing with the Upper End scenario is contained within the Scheme Modelling Report (Application document TR010063/APP/9.19), which demonstrates no 'cliff-edge' effects from the higher flows and measures to adapt the Scheme should a worse case future climate arise.

4.4.9. The table below contains the climate change allowances for the Severn Vale management catchment within the Severn River Basin district, which indicates the range of allowances which need to be considered.

Table 4-3 - Climate change predictions on river flow for the Scheme site

Allowance category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2115)
Peak river flows (Severn River Basin District, Severn Vale management catchment)			
Higher Central	20%	28%	53%
Upper End (credible maximum)	34%	52%	94%

A +53% increase in peak flow has been applied to design for flood risk arising from future climate change over the next 100 years which relates to the Environment Agency guidance (Higher Central allowance) in early summer 2021.

Peak rainfall intensity allowances for pluvial/surface water assessment

4.4.10. Increased rainfall affects river levels and land and urban drainage systems.

4.4.11. The anticipated changes in peak rainfall intensity in small catchments (less than 5 km^2), or urbanised drainage catchments are shown below in Table 4-4. For flood risk assessments the Environment Agency advice is to assess both the central and upper end allowances to understand the range of impact.

Table 4-4 - Climate change predictions on rainfall intensity for the Scheme site

Allowance category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2115)
Rainfall intensity in small catchments (less than 5km^2), or urbanised drainage catchments			
Upper End	10%	20%	40%
Central	5%	10%	20%

4.4.12. The Design Manual for Roads and Bridges[18] (DMRB) technical note on the Design of Highway Drainage Systems[19] states that drainage designs shall be developed on the basis that all new road drainage has a minimum design lifetime of 60 years, unless otherwise instructed. And with a 20% uplift in peak rainfall intensity as the basic climate change factor. It also recommends a sensitivity test with 40% uplift in peak rainfall intensity to establish a robust drainage design that accounts for the inherent uncertainty in the estimation of flow and climate change impacts on rainfall.

4.4.13. For this project, the more onerous guidance set out in the Tewskesbury SPD[9] has been

[18] National Highways et al.
[19] National Highways et al (March 2020 Revision 2) Design of Highway Drainage Systems, CG501 formerly HD 33/16, TA 80/99

applied, using +40% in peak rainfall intensity, and +70% as a sensitivity test. The latter value has been applied in design to test the 300 mm freeboard in the drainage attenuation ponds.

A +40% increase in peak rainfall intensity was applied to design for flood risk arising from future climate change over the next 100 years.

4.5. Baseline flood risk: fluvial/surface water

4.5.1. The Baseline Hydraulic Modelling Report (Application document TR010063/APP/9.18) describes how the fluvial systems were numerically modelled using UK standard approaches and following the published guidance of the Environment Agency. The location of the main hydraulic features are indicated in Figure 4-3.

Figure 4-3 - Main hydraulic features

Figure provided in Appendix 8.1B at the end of this document.

4.5.2. All flood modelling for the Scheme was based on a model developed for Boddington (downstream of the M5 motorway) in 2019. This model was approved by the Environment Agency in 2020 for a flood map challenge. The model was itself developed from the available Environment Agency models of the River Chelt through Cheltenham.

4.5.3. The 1D-2D linked hydraulic model was developed further using the industry standard ESTRY-TUFLOW software. Fundamentally this now incorporates the Leigh Brook (and its interactions with the River Chelt) which was missing form all previous hydraulic modelling in this area.

4.5.4. The hydraulic model uses the following input data in addition to that contained in the Boddington model – more detail is provided in the Baseline Hydraulic Modelling Report (Application document TR010063/APP/9.18):

- LiDAR – Composite digital terrain model (DTM) 2019, 1m resolution.
- cross sections – Environment Agency Middle Chelt Model (2012).
- cross sections – Infomap surveys and Mapping (December 2017) survey of River Chelt near Boddington.
- cross sections – Infomap surveys and Mapping (November 2019) survey of Leigh Brook.
- hydraulic structures – Infomap surveys (November 2019).
- aerial survey – Atkins (March 2021) survey of critical areas near M5 Junction 10.

4.5.5. The hydraulic model is driven by hydrology derived using the UK's Flood Estimation Handbook (FEH) and following the Environment Agency Flood Estimation Guidelines[20]. The following input data was applied - more detail is provided in the Baseline Hydraulic Modelling Report (Application document TR010063/APP/9.18):

- Recorded rainfall for the Environment Agency Dowdeswell rainfall gauge.
- Recorded stage and flows for the former Environment Agency gauge at Slate Mill.
- Design rainfall parameters from the FEH web service accessed 29 September 2020.
- Catchment descriptors from the FEH web service accessed 29 September 2020
- Hiflows database (version 9), which includes data for water year 2019/2020 Released on 24 September 2020.
- Combined sewer overflow data from Severn Trent Water for its outfall at Arle.
- Revitalised Flood Hydrograph (ReFH) 2.3 version (version 3.0.7270.30847) software.
- WINFAP (version 4) software.

[20] Environment Agency (July 2020) Flood estimation guidelines. LT 11832

4.5.6. The hydrology and hydraulics were calibrated using event data from:

- 20 July 2007 (as the largest event on record).
- 13 December 2008 (as recommended by the Environment Agency).

4.5.7. Data from the now discontinued river flow gauge at Slate Mill was used to calibrate the hydrology with the hydraulic model. The 1% annual exceedance probability event (1 in 100-year return period) was estimated to generate a peak flow of:

- 24.5 m^3/s in the River Chelt at the M5 motorway.
- 2.5 m^3/s in the Leigh Brook at the M5 motorway.

4.5.8. The hydraulic model was then calibrated with field observations (landowner reports and photographs) and Environment Agency recorded wrack mark data for the River Chelt.

4.5.9. The results of the hydraulic modelling demonstrate the Baseline (actual) flood risk in the study area. Further details are described in the Baseline Hydraulic Modelling Report (Application document TR010063/APP/9.18).

4.5.10. The Baseline flood model was tested with the 3.3% annual exceedance probability event (1 in 30-year return period) to provide an indication of the current Flood Zone 3b (functional floodplain). This shows the River Chelt overtopping its banks and flowing to the farmland at Junction 10. The resulting flood map is shown in Figure 4-4.

Figure 4-4 - Flood extent for 3.3% AEP (functional floodplain)

Figure provided in Appendix 8.1B at the end of this document.

4.5.11. The results show that flooding occurs on the Leigh Brook floodplain during the 1% annual exceedance probability event (1 in 100-year return period). There is out of bank flooding just west of the upstream point of the Leigh Brook watercourse, resulting in flooding to the properties near Uckington Farm. There is also flooding in the Leigh Brook floodplain just upstream of Leigh Brook culvert that passes under the M5 motorway, as well as downstream of the motorway, continuing west along the watercourse to the downstream model boundary. Widespread flooding occurs on the Chelt floodplain in the same event. Water exits the River Chelt channel at the eastern end of the Chelt floodplain and 8.2 m^3/s passes over Withybridge Lane into the fields east of the motorway. Flooding is largely contained in the Chelt floodplain. No water overtops the A4019 and there is no flow passing under the road through the A4019 culverts.

4.5.12. There is significant flooding held east of the motorway, particularly upstream of the Piffs Elm, River Chelt and Staverton culverts under the M5 motorway. Flows of 18.3 m^3/s pass through the River Chelt culvert under the M5 during this event (1.2 m^3/s more than that in the 4% annual exceedance probability event (1 in 25-year return period)).

4.5.13. Flooding upstream of the Staverton culvert extends south to the upstream point of the Staverton tributary and spreads east to Withybridge Lane. Downstream of the Staverton culvert there is further flooding which extends to the confluence between the River Chelt and the Staverton tributary and west up to Boddington Manor. There is also out of bank flooding in the fields to the east of Boddington Manor.

4.5.14. Flooding downstream of the Piffs Elm culvert extends west to the downstream boundary at Boddington Lane, where 3.0 m^3/s overtops this road (the road is not overtopped in the 4% annual exceedance probability event (1 in 25-year return period)). The A4019 at Piffs Elm is also flooded in the 1% annual exceedance probability event (1 in 100-year return period).

4.5.15. The 1% annual exceedance probability event (1 in 100-year return period) with 53% increase in peak flows to account for future climate change is marginally smaller than the present day 0.1% annual exceedance probability event (1 in 1,000-year return period). This is evidenced with the peak flow passing through the River Chelt culvert, being 21.5 m^3/s compared to 21.7 m^3/s. The flood extent north of the A4019 is very similar.

4.5.16. Perhaps the biggest impact of climate change in the River Chelt catchment at this location is the instigation of flow over the A4019 highway into the catchment of the Leigh Brook. This cross catchment transfer leads to much greater flooding on the eastern (upstream)

side of the M5 motorway at the Leigh Brook culvert. The impact was predicted in the sensitivity testing on both upstream inflow and climate change allowance, even with the lowest change tested (a +20% increase in inflow) causing this phenomenon: that increase in flow from 0 m^3/s in the present day, to 1.1 m^3/s in 100-years' time creates a significant increase in flood risk to the land north of the A4019. Similarly, this event overtops the A4019 at Piffs Elm, leading to flooding of the properties north of the highway.

4.5.17. Selected point results are tabulated below to give an indication of the flood depths (Table 4-4) and flood flows (Table 4-6). The location of these points are shown in Figure 4-5.

Figure 4-5 - Location of points for result reporting

Figure provided in Appendix 8.1B at the end of this document.

4.5.18. It should be noted that the results tabulated in this report are based on the peak stage/flows from a 100-hour simulation period which allows for peak levels to fall in the Scheme arrangement. Those described in the Baseline Modelling report (Application document TR010063/APP/9.18) were described for a 50-hours simulation period, and hence do not match those in this report at certain locations.

Table 4-5 - Baseline flood depths

Location	Depth (m)		
	1% AEP	1% AEP with climate change	0.1% AEP
1 Leigh Brook nr Leigh Brook culvert	0.000	0.708	1.046
2 Leigh Brook existing slip road	0.000	0.750	1.085
3 Leigh Brook nr A4019	0.000	0.234	0.426
4 A4019	0.000	0.254	0.287
5 Withybridge Gardens	0.811	1.427	1.474
6 north of Butlers Court	0.140	0.721	0.760
7 Eastern end of River Chelt floodplain	0.184	0.257	0.265
8 nr Staverton culvert	0.304	0.431	0.448
9 Boddington Lane	0.433	0.469	0.473

Table 4-6 - Baseline flood flows

Location	Flow (m^3/s)		
	1% AEP	1% AEP with climate change	0.1% AEP
A Leigh Brook culvert	2.2	9.4	10.2
B Piffs elm culvert	3.0	3.7	3.7
C River Chelt culvert	18.3	21.5	21.7
D Staverton culvert	2.7	2.8	2.8
E A4019 culvert	0.0	1.6	1.6
F A4019 over the top	0.0	10.3	13.3
G Withybridge Lane	8.2	20.6	22.4
H Boddington Lane	3.0	5.9	6.4

4.5.19. The flood depth maps for the 1% annual exceedance probability event (1 in 100-year return period) with and without future climate change are shown in Figure 4-6 and Figure 4-7.

Minor watercourse flood risk at the B4634

4.5.20. The published Environment Agency mapping for surface water flooding indicates an area at risk from a series of minor watercourses near the hamlet of Hayden, south of the B4634 highway – see Figure 3-4. The flat and low lying area is drained by small field drains, classified as Ordinary Watercourses. This area was not considered in the hydraulic modelling for the River Chelt and Leigh Brook, with the River Chelt model focusing on Main River and other flooding at the primary works site. No flooding is indicated in the Environment Agency's Flood Map for Planning, or Flood Risk from Rivers or the Sea.

4.5.21. Separate hydraulic modelling was completed for these minor streams, using the Integrated Catchment Model (ICM) software, with the hydrology as applied to the wider model was retained for this tributary. The modelling and results are described in a Technical Note. That work confirmed the extent of flooding shown on the surface water flood map, with water ponding upstream of (south of) the B4634 and in large events flowing over the highway. The B4634 is flooded in its baseline conditions during the 20% annual exceedance probability event (1 in 5-year return period).

Figure 4-6 - 1% AEP Baseline flood risk depth map – present day
1% annual exceedance probability event (1% AEP or 1 in 100-year return period)

Figure provided in Appendix 8.1B at the end of this document.

Figure 4-7 - 1% AEP Baseline flood risk depth map – future with 53% climate change
1% annual exceedance probability event (1% AEP or 1 in 100-year return period) with climate change

Figure provided in Appendix 8.1B at the end of this document.

4.6. Baseline flood risk: groundwater

4.6.1. The baseline conditions are described in the technical note Groundwater conditions at flood storage[21] which considers both desk-based information and interpretation of the site wide ground investigation. The encountered geology differs from the mapped geology:

- Both superficial deposits (Alluvium and Cheltenham Sands and Gravels) are water bearing.
- The ground investigation shows the superficial deposits to be more widespread and laterally persistent than initially suspected based on mapping. Multiple deposits overlie each other in some locations: Alluvium consistently overlies the Cheltenham Sands and Gravels, meaning both are present and the spatial extent is greater than mapped.
- Alluvium ranges from 0 to 2.15 m thick and the Cheltenham Sands and Gravels is between 0 and 1.95 m thick adjacent to the M5 motorway and Junction 10.
- The ground investigation (borehole logs and cross sections) suggests there is less superficial deposit cover than previously assumed in the northern part of the Scheme area.

[21] Gloucestershire County Council (September 2022) Groundwater conditions at flood storage, Atkins.

5. Managing flood risk

For flood risks in general, there is a hierarchy that should be applied for flood risk management, with avoidance or prevention being the preferred first measure to reduce flood risk. Table 5-1 presents the flood risk management hierarchy.

Table 5-1 - Flood risk management hierarchy

Flood Risk Management Hierarchy		What it means
1	Assess	Undertake studies to collect data at the appropriate scale and level of detail to understand what the flood risk is.
2	Avoidance / Prevention	Allocate development to areas of least risk and apportion development types vulnerable to the impact of flooding to areas of least flood risk.
3	Substitution	Substitute less vulnerable development types for those compatible with the degree of flood risk.
4	Control	Implement flood risk management measures to reduce the impact of new development on flood frequency and use appropriate design.
5	Mitigation	Implement measures to mitigate residual risks.

5.1. Assess

5.1.1. The Baseline flood risk has been assessed through hydraulic modelling. This is described above in Section 1.

5.1.2. The Scheme Hydraulic Modelling Report (Application document TR010063/APP/9.19) describes in detail how the Scheme was applied and tested in the hydraulic model, using UK standard approaches and following the published guidance of the Environment Agency. That report also describes in detail the results of the testing. The below text (Sections 5.15.4.66 to 5.7) is a summary of the with-Scheme flood risk.

5.1.3. The Scheme described in this report is based on Design Fix 3.4 (DF3) from June 2022.

Scheme design

5.1.4. The design information is limited to vertical and horizontal alignments of the Scheme as part of a wider 3D CAD model (DF3). Preliminary design information has been used to inform this report and make the assessment of flood risk. This includes:

- M5 J10 All movements layout with engineering constraints, GCCM5J10-ATK-HGN-ZZ-DR-CH-00001, revision C04.
- M5 J10 All movements layout with engineering constraints, GCCM5J10-ATK-HGN-ZZ-DR-CH-00002, revision C04.
- M5 J10 All movements layout with engineering constraints, GCCM5J10-ATK-HGN-ZZ-DR-CH-00003, revision C04.
- M5 J10 All movements layout with engineering constraints, GCCM5J10-ATK-HGN-ZZ-DR-CH-00004, revision C04.
- M5 J10 All movements layout with engineering constraints, GCCM5J10-ATK-HGN-ZZ-DR-CH-00065, revision C01.
- M5 J10 All movements layout with engineering constraints, GCCM5J10-ATK-HGN-ZZ-DR-CH-00066, revision C01.
- A4019 Dualling 3D CAD model, GCCM5J10-ATK-HML-L1_ML_Z-MR-CH-000003, August 2022, revision P09.1.

- B4634 and Link Road Junction 3D CAD model, GCCM5J10-ATK-HML-J3_JN_Z-MR-CH-000003, October 2022, revision P07.1.
- A4019 and Link Road Junction 3D CAD model, GCCM5J10-ATK-HML-J2_JN_Z-MR-CH-000003, August 2022, revision P09.1.
- Link Road 3D CAD model, GCCM5J10-ATK-HML-L2_ML_Z-MR-CH-000003, June 2022, revision P07.1.
- M5 Junction 10 3D CAD model, GCCM5J10-ATK-HML-J1_JN_Z-MR-CH-000003, October 2022, revision P08.1.
- Gallagher Junction 3D CAD model, GCCM5J10-ATK-HML-J4_JN-MR-CH-000002, August 2022, revision P07.1.
- Access Roads 3D CAD model, GCCM5J10-ATK-HML-ZZ_SR-MR-CH-000003, October 2022, revision P09.1.

5.1.5. The general arrangement plans are contained in document application TR010063/APP/2.9.

5.1.6. The Scheme provides a new elevated roundabout on the A4019 over the M5 motorway with four new slip roads connecting traffic with the M5 motorway below. To provide increase headroom over the motorway, the roundabout and its bridges will be raised. As such, the A4019 is also raised, and regraded, before reconnecting to existing road levels some distance from the motorway east and west. The A4019 is then widened as far as the new Fire Station at Uckington. A new junction on the A4019 provides access onto the Link Road, which passes south across the River Chelt floodplain, east of the existing Withybridge Lane, to the B4634 near Hayden Hill, south of the River Chelt.

Possible construction effects on flood risk

5.1.7. Implementation of the Scheme will see construction work on the floodplains of the River Chelt and Leigh Brook: this will require work in Flood Zone 2 and 3. No specific hydraulic modelling of temporary construction conditions has been undertaken.

5.1.8. A change in flood risk during construction of the Scheme, that may impact on the works or 3rd party receptors, where no embedded mitigation is included, could arise from:

- Blockages within the floodplains and/or narrowing of the watercourses themselves will reduce their floodwater storage and conveyance capacity. Excavation adjacent to the banks of the watercourses will increase the frequency of overtopping and/or the risk of breach of the bank (by locally lowering the level of protection or decreasing the integrity of the bank or flood risk asset). This can increase the flood risk to adjacent land and property. Many of the River Chelt banks in this area are slightly raised above the local floodplain.
- Temporary stockpiling of material in the floodplain could result in a loss of flood storage and/or divert existing overland flow routes to areas that are not currently affected.
- Sediment runoff from the site construction could settle in the watercourses and existing structures if not managed through standard site controls. Any temporary settlement lagoons to hold construction water and manage sediment could cause flooding in the event of overtopping or a breach. These temporary settlement lagoons should be located outside of the floodplain where possible.
- Construction activities that extend below ground have the potential to be affected by groundwater and affect groundwater flooding. Sections of the Scheme are located within areas susceptible to groundwater flooding. The effect of this will be considered once the ground investigation has completed.
- Construction of the Scheme will take place over more than a year, with some works undertaken during winter when watercourse flows are typically highest. Any site compounds that might be required will need to be located outside Flood Zone 3, or on temporary works platforms with accompanying compensatory floodplain.

Possible operational effects on flood risk

5.1.9. Operation of the Scheme will see new roads and associated infrastructure on the

floodplains of the River Chelt and Leigh Brook in Flood Zones 2 and 3.

5.1.10. Without any appropriate embedded mitigation the Scheme would have significant impacts on flood risk to 3rd party land and local infrastructure. That impact can be summarised as:

- the footprint of the Scheme displacing floodwaters elsewhere, raising the depth, duration and frequency of flooding on 3rd party land and infrastructure.
- the obstruction of the existing culverts under the M5 motorway and the A4019, blocking flow paths and increase flood depths to the east of the motorway.
- the Link Road crossing the River Chelt floodplain raising the depth, duration and frequency of flooding on 3rd party land and infrastructure upstream of it.
- the raising of the A4019 severing the existing overland flow path between the River Chelt and Leigh Brook, causing increased flood levels to the south of the A4019 (immediately east of the M5 motorway) and over Withybridge Lane and the surrounding land.

5.1.11. The hydraulic modelling has demonstrated that the Scheme is not at risk of flooding itself from the 1% annual exceedance probability event (1 in 100-year return period) with a 53% increase in peak flow to account for future climate change (i.e., over lifetime of the development).

5.2. Avoid

5.2.1. The M5 Junction 10 improvements and Link Road cannot be allocated in areas of lower flood risk. It is not possible for the Scheme to avoid crossing the floodplain of the River Chelt or Leigh Brook.

5.3. Substitute

5.3.1. The M5 Junction 10 improvements and Link Road consist of transportation infrastructure. Less vulnerable development cannot be substituted with those compatible with the degree of flood risk predicted at this site.

5.4. Control

5.4.1. The Scheme includes for embedded mitigation and controls to reduce its impact on flood risk. These are described below (paragraphs 5.4.3 to 5.4.105).

5.4.2. Flood risk assessment work on this Scheme confirms the embedded mitigation to reduce, remove or compensate for adverse impacts identified on flood risk.

Construction phase

5.4.3. Measures to control effects during the construction period will include:

- Development of a flood management plan to ensure the construction sites can be safely operated and evacuated and will not be unacceptably affected in the event of a flood. It will not be possible to avoid floodplain working.
- Development of a construction drainage strategy to address the temporary management of surface waters to ensure flood risk to the surrounding area is not increased (and pollution is controlled).
- Temporary land-take for the construction will need to include for adequate areas of land set aside for robust flood control measures, for example sustainable drainage control and additional land take to compensate any haul roads etc.
- An assessment of the temporary works access and haul roads will be required.
- Temporary flood compensation areas will need to be put in place in advance of any earthworks resulting in loss of floodplain.
- Appropriate management of sediment runoff from the site will be required during construction to reduce risk of blockage in the River Chelt and Leigh Brook culverts under the M5 motorway.

- Any temporary ponds constructed for runoff and sediment management will need to be located to avoid the risk of flooding watercourses or adjacent land in the event of overtopping or a breach.
- The construction site should receive flood warning information from the Environment Agency, such that the site can be cleared of labour, plant and materials in advance of a forecast event.

5.4.4. As some of the construction works are located within and adjacent to a Main River, they would require a temporary Flood Risk Activity Permit (under the Environmental Permitting Regulations 2016). The DCO does not disapply the Environment Agency permitting requirements, and therefore the Applicant will need to seek this consent outside of the DCO process to comply with legal requirements.

5.4.5. Sequencing of construction activities will likely have an impact on the requirements for compensatory storage. However, it is expected that the permanent flood compensation works will provide sufficient floodplain compensation during the construction phase (see section below on embedded mitigation). This floodplain compensation will ideally be excavated prior to any construction within the floodplain. If the sequencing of the proposed works differ to this, or if found that further storage is required in the temporary case, then specific temporary compensation may be required. This will be identified following detailed modelling of the proposed sequencing of the construction activities. The detailed modelling will be a requirement of the temporary construction phase Flood Risk Activity Permit (under the Environmental Permitting Regulations 2016).

5.4.6. There would also be a requirement for a temporary Land Drainage Consent (under the Land Drainage Act (LDA) 1991) in relation to the ordinary watercourse of the Leigh Brook. To then obtain approval it will be necessary to demonstrate that the construction works for the Scheme will not have an adverse impact on flood risk. However, the DCO seeks to disapply Section.23 of the LDA 1991 (prohibition on obstructions etc. in watercourses). Notwithstanding this, consideration will need to be given in the appointed contractor's method statement to aspects such as phasing of the works, the locations of any construction compounds and storage areas, any other temporary works and flood warning and response procedures. Further assessment of temporary works may need to be undertaken post DCO where the Contractor may require temporary access culverts etc to suit their method of working.

5.4.7. As flood risk during construction is to be considered as part of a separate consenting process it has not been assessed in detail in this FRA. Construction of the works in accordance with the relevant consents described above would mean that there is no significant adverse impact of the Scheme on third parties.

Operation phase

5.4.8. Embedded mitigation measures are included in this Scheme to control the flood risk. The flood modelling has shown that the Scheme will displace floodwater and impact on the flood risk of its neighbours if the embedded mitigation is not implemented. The embedded mitigation included in the design is described below.

5.4.9. As some of the permanent works are located within and adjacent to a Main River, they will require a Flood Risk Activity Permit (under the Environmental Permitting Regulations 2016). The DCO retains the Environment Agency permitting requirements. To obtain the permit it will be necessary to demonstrate that the Scheme will not have an adverse impact on flood risk – as documented in this FRA report.

5.4.10. The DCO seeks to disapply the Section.23 (Land Drainage Act 1991) requirement for an LLFA Ordinary Watercourse consent in relation to the works alongside the Leigh Brook and the minor watercourse at the B4634.

Embedded mitigation

5.4.11. The guidance is clear that embedded mitigation should be the best practice design approach. Embedded mitigation covers the project design principles adopted to avoid or prevent adverse environmental effects, whereas Essential/Additional mitigation are those measures subsequently required to reduce and if possible offset likely significant adverse

environmental effects, in support of the reported significance of effects in the environmental assessment.

5.4.12. Thus, embedded mitigation covers good-practice environmental measures that would occur without input from the EIA feeding into the design process. It includes actions that would be undertaken to meet other existing legislative requirements, or that are considered to be standard practices or design principles. For example, embed mitigation could include: the appropriate design of river crossings or realignments; and the provision and design of compensatory floodplain storage.

5.4.13. Anything project specific is described as essential mitigation – being the extra-over to step away from a significant environmental impact.

5.4.14. For M5 Junction 10 in terms of flooding, the embedded mitigation includes:

- A drainage strategy to enhance the water quality of the surface water runoff and limit the peak rate and overall volume of discharge.
- Compensatory floodplain and storage being provided to offset the volume of water displaced by the Scheme, prior to the removal of any existing floodplain.
- The new permanent watercourse crossing of the River Chelt being designed to convey the 1% annual exceedance probability event (1 in 100-year return period) including an allowance for climate change (+53% in flow) with a minimum of 600 mm freeboard to soffit.
- The Link Road including a crossing, or crossings, of the River Chelt floodplain. The number/size of openings will be defined to balance impact with cost.
- All M5 watercourse culverts being extended to suit the new roads, either at the same size & slope as the existing culverts or varied to suit the receiving watercourse, all with buried inverts. The existing Staverton and Chelt culverts do not require extending as part of this Scheme.
- Two new culverts laid under the B4634 to convey floodwaters under the highway at the southern end of the Link Road.
- Any new channels or channel realignment being designed to appropriately accommodate flows (including flood flows), providing spatially variable aquatic habitat and with connectivity to a riparian zone.

5.4.15. These embedded mitigation features are discussed below.

5.4.16. The hydraulic modelling was used to inform the design of the embedded mitigation and test various solutions to the obvious impacts that the Scheme could cause without embedded mitigation.

Drainage strategy

5.4.17. A detailed drainage design is being prepared in accordance with the various design standards to manage the risk of flooding of the road itself (i.e., from the Scheme's surface, drainage etc.). This is described in the Scheme's drainage strategy[22]. This will limit discharges from the new highways such that they do not exceed the present day greenfield runoff rates or volumes even when applying future climate change allowances.

5.4.18. The DMRB CG 501[19] outlines the standards relating to the design, assessment and operation of motorway and trunk roads in the United Kingdom. The DMRB states that for road runoff within drainage systems, the following criteria must apply:

- 100% annual exceedance probability event (1 in 1-year return period) – no surcharge of the drainage system.
- 20% annual exceedance probability event (1 in 5-year return period) – no flooding from the drainage system.
- All drainage systems shall be designed so that highway surface water flooding does not extend beyond the highway boundary up to the 1% annual exceedance probability event (1 in 100-year return period) rainfall event.

[22] Gloucestershire County Council (2021) M5 J10 Improvements Scheme – Drainage strategy report, Atkins

- Pre-earthworks ditches and filter drains will be designed against 1 in 75-year event with no flooding.
- All criteria apply to the lifetime of the development, and hence a 20% uplift in peak rainfall intensity together with a sensitivity test to 40% increase in rainfall.

5.4.19. The road drainage is being designed to restrict peak runoff from the new paved surfaces to the current greenfield runoff and provide additional betterment where possible. The developing Scheme design includes for six drainage attention ponds, fitted with flow controls. However, the design has not ruled out infiltration but is subject to infiltration testing being carried out as part of the ground investigation.

5.4.20. The agreement with the LLFA was that existing catchments would be restricted to existing rates, with new catchment areas restricted to greenfield rates with climate change allowance applied only to new areas. Whilst it is not feasible to restrict the existing road drainage catchments to greenfield runoff rates, due to space constraints for storage, betterment will be sought to those catchments where possible.

5.4.21. In accordance with as per section 5.7.7 of Tewkesbury District Council's Flood & Water Management Supplementary Planning Document[9], peak outflows from the attention ponds will be limited to greenfield runoff rate (QBAR) for all events up to the 1% annual exceedance probability event (1 in 100-year return period) with an allowance of 70% applied for climate change. In practice this means that the ponds will store the 1% annual exceedance probability event (1 in 100-year return period) plus 40% increase in rainfall for climate change with a 300 mm freeboard, and the Freeboard checked to ensure that it holds the +53% increase in rainfall with no flooding.

5.4.22. A volumetric restriction will be applied to control the additional volume of runoff generated by the new road surfaces. This will either be applied, as above, by reducing all peak flows to no more than the present day mean-annual flood, or providing separate design elements to deal with long term storage.

5.4.23. Under these design rules, the road drainage will not increase the rate or volume of runoff being discharged into the existing watercourses.

5.4.24. The drainage design will be applied to the Scheme hydraulic modelling as will be described in the Scheme Hydraulic Modelling Report (Application document TR010063/APP/9.19). In essence:

- No discharges from the attenuation ponds will be added to the hydraulic model. With the design standards ensuring no increase in greenfield runoff (rate or volume) modification of the FEH catchments to reflect field scale changes was not necessary.
- The attenuation ponds will be included in the with-Scheme terrain model, reflecting any changes in ground levels, hence enabling an assessment of their impact on flood risk and their safety from river flooding.

5.4.25. A piped drainage connection is required from the southern end of The Green, in Uckington, to the realigned roadside drainage ditch off the A4019. At this location the highway works reduce the discharge of water from the Leigh Brook onto the A4019: the pipe ensures continuity of this flow path away from The Green. This is included in the flood model as a 300mm diameter pipe.

5.4.26. The potential effect of the drainage scheme on the existing surface water drainage system will also be assessed where flood levels are predicted to be increased. Mapping of surface water outfalls (using the Environment Agency's AIMS database) and of the surface water sewer system (obtained from Severn Trent Water) could be used to identify whether there are any locations where the Scheme could impact on the existing drainage system.

5.4.27. The fluvial flood risk requirements of the DMRB are independent of the requirements set out in LA 113.

Compensatory floodplain / flood storage

5.4.28. Compensatory flood storage works are required where the Project would otherwise reduce the available volume of flood storage. CIRIA 624[23] (Section A.3.3.10, 2004) states that:

"Compensatory flood storage must become effective at the same point in a flood event as the lost storage would have done (McPherson, 2002). It should therefore provide the same volume and be at the same level relative to flood level, as the lost storage. This requirement is often referred to as "level for level" or "direct" compensation".

5.4.29. Replacement floodplain is required to offset the losses under the footprint of the Scheme. Losses are predicted on both the River Chelt and Leigh Brook floodplains. The hydraulic modelling was used to quantify the losses in terms of plan area and contained volume of floodplain.

- Area of Scheme footprint in Flood Zone 3 = 39,056 m^2.
- Area of Scheme footprint in the Baseline floodplain[24] = 97,630 m^2.
- Volume of the Scheme occupying the Baseline floodplain[24] = 46,718 m^3.

5.4.30. The issue of compensatory floodplain is complicated for this Scheme by the existing inter-catchment transfer at the design event (from the River Chelt into the Leigh Brook over the existing A4019), and the severance of this transfer by the raising and widening of the A4019. Severance of this flow path brings a notable reduction in flood risk to the Leigh Brook catchment, yet prevents over 153,573 m^3 of floodwater leaving the River Chelt floodplain that would otherwise flow north over/under the A4019. The Environment Agency has requested that compensatory floodplain is provided on a level for level basis for the Link Road. It should be noted that once water leaves the River Chelt and flows towards the Link Road, that any displacement of floodwater by that road embankment will not affect the spillage of water from the river: in this way a level for level compensation is not necessary, although has been developed.

5.4.31. Compensatory floodplain for the Link Road will thus be provided in the fields to the east (upstream) of the Link Road, adjacent to the existing floodplain.

5.4.32. A level for level assessment was applied to quantify the incremental losses for a range of flood events between the present day threshold of flooding (approximately 5% annual exceedance probability event (1 in 20-year return period)) and the design event. It should be noted that Baseline flood levels vary across and along the floodplain and hence a level for level replacement is not straight forward. An approach was developed to assess the frequency of flooding and then apply a level-for-level assessment as described in CIRIA 624[23]:

- The hydraulic model results were used to calculate the volume displaced by the embankment for a range of return periods.
- Incremental volumes for each incremental flood frequency band were calculated, giving a frequency-volume relationship.
- The corresponding volumes were re-provided for each flood frequency band, setting back the existing flood contours into dry land. Hence dry land of a certain area would be excavated to flood to a given depth in each frequency band, providing the same displaced volume over an area that is currently flood free.
- A CAD/GIS approach was used to shape the storage area.
- This shape was incorporated into the hydraulic model as a new terrain surface and tested (validated) for a range of return periods.

5.4.33. The Scheme design will ensure the hydraulic connectivity of the floodplain across the Link Road (from east to west) via a series of box culverts in the embankment, ensuring that the overland flow paths seen in the Baseline case are maintained in the with Scheme

[23] CIRIA (2004) Development and flood risk – guidance for the construction industry, C624.
[24] Referenced here as the Design Flood, being the 1% annual exceedance probability event (1 in 100-year return period) with +53% allowance on peak flow for future climate change over the next 100 years.

scenario.

5.4.34. For the remainder of the Scheme in the floodplain (the motorway junction), the Environment Agency has agreed that level for level floodplain compensation is not appropriate, given the mechanism of flooding at this site where floodwater leaves the River Chelt and flows away from the watercourse with the general topography. Displacement of floodwater besides the M5 motorway and A4019 has no impact on the flow passing downstream along the River Chelt and Leigh Brook, and hence third party receptors. Without any compensatory storage, the impact of this would be to increase peak flood levels across the floodplain (east of the M5), increasing flows through the Piffs Elm culvert, widening the floodplain extents and impacting some built receptors.

5.4.35. Compensatory storage will thus be provided in the fields to the east (upstream) of the M5 motorway, immediately south of the A4019, where floodwaters accumulate in the Baseline. This will retain the same volume of water leaving the River Chelt and not displace it elsewhere, and fundamentally not change how water passes on to the floodplain.

5.4.36. The Scheme provides an excavated flood storage area which may be developed as a wetland bowl. The flood storage area will drain through the existing Piffs Elm culvert and hence a minimum excavated level similar the invert of the east extension to the existing Piffs Elm culvert (22.76 m AOD). Additional excavation below this level may be provided for biodiversity and habitat enhancement, enabling a permanent body of water to be retained. However, the storage provided beneath the invert level of the Piffs Elm culvert has not been included in the hydraulic model and does not affect the results.

5.4.37. The flood storage accommodates the volume of River Chelt floodwater displaced by the Scheme footprint, being 31,512 m^3 during the design flood. The full sizing similarly provides storage for the floodwater prevented from accessing the Leigh Brook floodplain, being 153,573 m^3. The maximum storage required is not the sum of these, as the relative timing of the inflows and outflows mean that the total volume cannot be simply combined (superposition of total volume is not appropriate).

5.4.38. The flood storage was thus developed with an iterative approach, using the hydraulic model to seek no detriment to 3rd party receptors but balance the sustainability of implementation (land take, environment, cost). Tests were undertaken with different sized flood storage areas, varying the key parameters (plan area/shape, depth and cut slopes).

5.4.39. A balance was struck between oversizing the flood storage and a subsequent reduction in flood levels, and under sizing the flood storage and a subsequent increase in flood levels. The small areas of farmland predicted to incur increased flooding will have a right to increase flood levels through the DCO and are included in the Order limits. Consultation with the landowners is being undertaken. The Scheme thus balances the sustainability of further excavation to provide extra flood storage with the magnitude of detriment and vulnerability of the receptors: the permanent scale, cost and impact of additional excavation for flood storage would be significant when compared the temporary impact of the additional floodwater.

5.4.40. The resulting outline design was proven in the model. It includes for side slopes around the flood storage area of 1 in 3, with a 118,801 m^2 organic planform that includes bays, inlets and islands, so promoting a future wetland area. See Figure 5-1. The design provides a total excavation below existing ground level (and hence storage volume) of 190,298 m^3 (to Piffs Elm culvert invert level). This is an excavated depth of ~1.5 m along the western perimeter and ~3 m along the eastern perimeter.

5.4.41. The flood storage area also provides volume to offset the small loss in floodpain volume associated with the minor watercourses near the B4634 at the southern end of the Link Road. The loss, at that location, of some 1,143 m^3 is offset by the 190,298 m^3 provison, with the redundant provision evidenced by the reduction in peak flow leaving the River Chelt model at its downstream boundary (see Table 5-5).

5.4.42. The influence of the groundwater regime on the flood storage area was reviewed alongside the ground investigation data. This is described in the groundwater technical note[26] which determined that, assuming a closed system (no outfall), water levels in the

storage area would settle at between 300 mm and 700 mm deep.

5.4.43. A theoretical inflow to the excavated flood storage area was also determined. Using the worst case scenario (high groundwater table vs empty flood storage area) an inflow of 0.558 l/s was calculated for the eastern perimeter of the flood storage area. With the 1.2 m diameter Piffs Elm culvert draining the flood storage area, the groundwater inflow amounts to some 0.03% of the outflow capacity.

Figure 5-1 - Flood Compensation

Figure provided in Appendix 8.1B at the end of this document.

5.4.44. It was concluded that whilst some groundwater inflow into the flood storage area is likely, that the flow rate would be significantly less than the capacity of the outlet and thus would not lead to any pre-filling or dead storage. Conversely, the groundwater inflow would help sustain the intended wetland feature, enabling a turnover of water and maintenance of its level, which would be excavated below that required for flood storage (i.e. below the invert level of the Piffs Elm outlet).

5.4.45. Further flood compensation land is required downstream of the B4634 highway, where the realignment of the highway to accommodate the new Link Road junction, and new culverts underneath, change the mechanism of flooding. This requires no capital works with additional floodwater accommodated by the farmland, and is included in the Order limits.

River Chelt bridge

5.4.46. The Scheme requires the addition of a new bridge over the River Chelt, carrying the Link Road.

5.4.47. Advice from the Environment Agency indicates that a 4 m easement on the south bank and a 2 m easement on the north bank would be acceptable for their regulatory requirements. It is recognised by the Environment Agency that this is a reduction of easement width to below 8 m to help reduce the span, although it would need to be supported by a small layby to allow operatives to pull off the road to safely access.

5.4.48. The current proposals are for a 24 m wide span with the deck soffit set at least 600 mm above the predicted design flood level of 27.7 m AOD. The abutments will be set back from the river banks by 4 m on the north and 8 m on the south, permitting access under the bridge on both banks if required.

5.4.49. Maintaining a bankside strip will additionally act as a mammal easement below the Link Road in most river level conditions. As part of any additional design measures higher level mammal passage may be required below the roadway. This will be assessed following the completion of the flood modelling work.

Chelt floodplain structure

5.4.50. From an early stage of design it was recognised that the Link Road would need to cross the wide floodplain of the River Chelt. The early design concept was for a viaduct, being a tall slender structure (see example in Figure 5-2).

5.4.51. The results of the hydraulic modelling demonstrate that a viaduct type crossing would be a costly and inefficient solution, with the floodplain housing only shallow flooding moving at relatively slow velocities.

Figure 5-2 - Example viaduct structure

5.4.52. A more efficient solution has been developed to use multiple openings or culvert barrels (see example in Figure 5-3). The number and sizing of culverts was iteratively reduced from the 49 units that would be required to collect the entire width of the design flood extent, proving the design with the Scheme hydraulic model. The testing applies a series of 3 m wide box culverts. The depth of flow across the floodplain is 200 mm on average, with a maximum depth of 600 mm in an existing field ditch. This shallow flooding could readily be conveyed in low height culverts, for example comprising 3 m wide by 1 m high box units. Based on the hydraulic modelling, and accounting for construction sizing (wall thickness etc) some 37 separate culverts are required.

Figure 5-3 - Example multi-span bridge/culverts

5.4.53. The current set up is as follows:

- 18 nr 3 m wide × 1 m high box culverts, split into two groups of 9 culverts either side of the existing field ditch. All culverts were modelled at around ground level with a constant upstream invert level of 27.1 m AOD and downstream invert level of 27 m AOD.
- A single 6 m wide × 1.35 m high box culvert carrying the existing field ditch, placed on the bed of the existing ditch with an upstream invert level of 26.75 m AOD and a downstream invert level of 26.45 m AOD.
- 18 nr 3 m wide × 1 m high box culverts, split into two groups of 9 culverts, with the northernmost culvert approximately 200 m north of the River Chelt. All culverts in this group were modelled at ground level with a constant upstream invert level of 27.1 m AOD and downstream invert level of 27 m AOD.

5.4.54. Design development was undertaken to optimise this solution, concentrating on areas of high flow across the floodplain. A consistent invert level of each culvert was assumed to improve constructability, but varied as part of the testing. The results indicated there was a balance between the number and location of culverts and the predicted changes (small increases and decreases in flood risk) either side of the Link Road.

5.4.55. There remain small areas of land, outside the ownership of GCC, predicted to incur increased flood depth (although no increase in flood risk, as there will be no increase in the frequency or consequence of flooding). The greatest increase in flood depth by the

Link Road is intended, being within the compensatory floodplain where ground levels are being reduced to accommodate more floodwater. The Scheme balances the sustainability of further culverts (or different configurations) to provide extra flood conveyance with the magnitude of detriment and vulnerability of the receptors: the permanent scale, cost and impact of an alternative configuration would be significant when compared the temporary impact of the additional floodwater. The small areas of farmland predicted to incur increased flooding will have a right to increase flood levels through the DCO and are included in the Order limits. Consultation with the landowners is being undertaken.

5.4.56. Whilst is was recognised that there are lengths of Link Road embankments inside the functional floodplain (3.3% annual exceedance probability event (1 in 30-year return period) being equivalent to Flood Zone 3b), this is addressed though the provision of the associated Link Road compensatory floodplain in the fields to the east (upstream) of the Link Road. The location of the functional floodplain in relation to the Scheme is shown in Figure 5-4.

Figure 5-4 - Flood extent for 3.3% AEP (functional floodplain) in relation to Scheme

Figure provided in Appendix 8.1B at the end of this document.

Existing Culverts

5.4.57. Four separate culverts carry the floodway under the existing M5 motorway: the River Chelt culvert, the Leigh Brook culvert at Barn Farm, the Piffs Elm culvert collecting overland flow near Withybridge Gardens; and the Staverton culvert carrying the Staverton Stream.

5.4.58. The Scheme requires extension of two of these to maintain their hydraulic connectivity. The culverts will be maintained at their existing sizing. The current design requires for culvert extensions as follows:

- Piffs Elm culvert to be extended from ~47 m long to ~147 m long (100 m extension).
- Leigh Brook culvert to be extended from ~54 m long to ~70 m long (16 m extension).
- The River Chelt culvert remains at ~43 m long with no extension.
- The Staverton culvert remains at ~50 m long with no extension.

5.4.59. The existing culverts under the A4019 are to be removed as part of Scheme with the local drainage instead discharging into a new drainage attenuation pond and then the flood storage wetland. This will help keep a feed of water through the wetland area. The volume of water that would have passed under the A4019 is accounted for in the calculations to size the required flood storage area.

5.4.60. The existing Withybridge Lane twin culverts, running parallel to the A4019, are being retained and will need to be realigned to suit the widened highway embankment and their length extended from 10 m to 27.5 m to maintain drainage flows under Withybridge Lane.

B4634 culverts

5.4.61. Three 2100 mm × 800 mm box culverts are proposed under the B4634 highway to convey the minor watercourse northwards. These will be 2100 mm × 800 mm, each embedded by a depth of 300 mm.

5.4.62. The topographic survey of the watercourse suggests that the channel invert will need a minor amount of localised regrading to achieve a positive gradient on the channel culvert, with the downstream levels to reduce by some 20 mm. The additional two culverts will be located to the west to receive and convey flood flows under the road.

Resilience and resistance

5.4.63. The best practice advice recommends a strategy for keeping floodwater out of the construction/development. This could be through the use of low permeability construction materials or local landscaping for residential property, or raising threshold levels. However, such is not relevant for this Scheme.

5.4.64. The Scheme design does take account of the risk of flooding in the selection of materials and design parameters. The geotechnical aspects account for saturated conditions in the new highway embankments, as well as a draw down effect during recession of a flood. Such measures ensure that there is flood resistant construction and resilient design. Similarly, the Scheme has engaged an All Reservoirs Panel Engineer to advise on the design of the embankments as they fall under the remit of the Reservoirs Act 1975.

5.4.65. Minor works are also included to the roadside verge at Piffs Elm. Raising the verge by 30-50 mm over a 50 m length is sufficient to prevent the existing flooding of the highway and property inundation at Elmstone business park.

Predicted with-Scheme flood risk: fluvial/ surface water

5.4.66. Hydraulic modelling was used to predict the with-Scheme flood risk in the study area (and hence change from the Baseline). The description below includes the flood risk during the design flood, being the 1% annual exceedance probability event (1 in 100-year return period) with +53% increase in peak flow to account for future climate change.

5.4.67. The results indicate that the Scheme can sufficiently maintain the hydraulic connectivity, floodplain conveyance and volumetric storage.

5.4.68. The results mapping, shown in Figure 5-5 to Figure 5-8, indicates that the Scheme will affect the existing overland surface water flow routes (principally the A4019 overspill): but that the Scheme will not increase flood risk - it does not divert overland flows towards receptors or generate any significant areas of increased flood level. The results of the hydraulic modelling demonstrate the predicted flood risk with the Scheme in place, across the study area (and hence change from the Baseline). This is described in more detail below.

5.4.69. Where a change in risk to properties or infrastructure was predicted, the impact was assessed further and the design adapted. A change in water level of less than +/-10 mm was considered insignificant[25] and within the model tolerance, and therefore only where the change was greater than 10 mm was it considered further.

5.4.70. Where any properties/infrastructure were predicted to have an overall increased flood risk (>10 mm) the Scheme (including the embedded mitigation i.e, the flood storage and conveyance features) was modified to mitigate the impact (local protection, compensatory floodplain/storage or additional conveyance).

5.4.71. Where an increase in flood level (>10 mm) was predicted that did not impact on properties or infrastructure (i.e. on farmland or similar), the frequency and consequence of flooding was considered, to establish whether that would constitute a material change in flood risk. The impact was then either mitigated (similar as above) or for non-material impacts, acceptance sought through the DCO. This is described from paragraph 5.4.98.

5.4.72. Selected point results are tabulated on the pages below to give an indication of the impacts, showing both the Baseline With-Scheme flood depths and flood flows. The location of these points are shown in Figure 4-5. The results mapping is included to show the flood risk depth maps and the level difference maps. The results are shown for the:

- 1% annual exceedance probability event (1 in 100-year return period) present day.
- 1% annual exceedance probability event (1 in 100-year return period) with climate change over the next 100-years.

[25] LA113 describes a change in water level of less than 10 mm as being negligible in EIA terms. Furthermore, Natural Resources Wales' Guidance Note 028 reflects a 10 mm tolerance when defining model predicted change. A 10 mm tolerance was agreed with the Environment Agency for this project on 29 April 2021.

- 0.1% annual exceedance probability event (1 in 1000-year return period).

5.4.73. All results are tabulated and mapped for a 100-hour simulation, allowing flood levels to rise and fall in the wetland storage area.

5.4.74. The separate ICM modelling for the minor watercourses at the B4634 is described in a separate technical note[Error! Bookmark not defined.] which contains the full results. Of note was t he predicted impact in the smaller events (20% annual exceedance probability event (1 in 5-year return period) and 10% annual exceedance probability event (1 in 10-year return period)) with up to 20 mm increase in peak flood level anticipated in the farmland downstream of the road. This minor impact was not predicted in the larger events – e.g. 1% annual exceedance probability event (1 in 100-year return period) or the design flood where a reduction in flood level was predicted, although some increases in flood level were predicted along the watercourse. The implications of these results are discussed further in the subsequent sections of this FRA.

1% annual exceedance probability event (1 in 100-year return period)

5.4.75. The effect of the Scheme on the Baseline conditions for the present day 1% annual exceedance probability event (1 in 100-year return period) are detailed below. Further details are described in the Scheme Hydraulic Modelling Report (Application document TR010063/APP/9.19).

5.4.76. The Scheme results generally show no significant difference to Baseline flood extents in the Leigh Brook catchment, upstream and downstream of the motorway, for the 1% annual exceedance probability event (1 in 100-year return period).

5.4.77. At Uckington, west of the headwaters of the Leigh Brook, a new roadside drainage ditch as part of the Scheme is predicted to reduce flood levels by between 10-150 mm and thus reducing flood risk to the properties there.

5.4.78. There is a minor increase in flood levels just upstream of Leigh Brook culvert, under the M5 motorway, where peak flood levels are predicted to increase by between 10-30 mm.

5.4.79. Baseline flows through Leigh Brook culvert, which carries the Leigh Brook under the M5 motorway, are unaffected by the Scheme during the 1 in 100 year event. Peak flow predictions through this culvert, for both Baseline and Scheme, are 2.2 m^3/s.

5.4.80. In the Chelt catchment, there are some changes to flood extents upstream and downstream of the M5 motorway. Existing flooding has been removed within the Scheme footprint; at the motorway junction, the A4019 widening and the Link Road (by virtue of the raised ground levels).

5.4.81. There is a reduction in flood levels upstream of the M5 motorway embankment, south of the A4019, resulting from excavated (reduced) ground levels where the flood storage area is proposed. However, the associated flood levels have increased by between 10-100 mm in some minor areas upstream and downstream of Withybridge Lane. There is no impact on peak flows through the River Chelt culvert during the 1 in 100 year event; peak flow through this structure is 18.3 m^3/s in both the Baseline and with Scheme.

5.4.82. The Scheme results show a widespread reduction in flood levels downstream of the motorway embankment, south of the A4019. Less extensive flooding is predicted downstream of the Piffs Elm culvert, extending west to Boddington Road. Flood levels immediately downstream of the Piffs Elm culvert are reduced from the Baseline by around 100 mm, and flood levels west of this are also reduced. No flooding of the A4019 at Piffs Elm is predicted. There is also a reduction in flood levels upstream of Boddington House, where flood levels are reduced by around 10-20 mm.

5.4.83. There is a modification in flood extents immediately upstream and downstream of the Link Road, which comprises of a mix of increases and decreases in flooding associated with the proposed Link Road culverts.

5.4.84. The ICM modelling for the minor watercourses at the B4634 (southern end of the Link Road) predicted up to 240 mm reduction in peak flood levels upstream of the road (as the additional culvert conveyance passed flow earlier in the event), with a negligible change

on the downstream farmland (as the overtopping surge was prevented). A small area of increased flood level was predicted on the banks of the watercourse, of up to 20 mm. The Scheme prevents flooding of the B4634 during this event.

Table 5-2 - 1% AEP event (1 in 100-year return period) Baseline and Scheme depths

Location	Baseline depth (m)	Scheme depth (m)
1 Leigh Brook nr Leigh Brook culvert	0.00	0.00
2 Leigh Brook existing slip road	0.00	0.00
3 Leigh Brook nr A4019	0.00	0.00
4 A4019	0.00	0.00
5 Withybridge Gardens	0.81	1.00
6 north of Butlers court	0.14	0.71
7 Eastern end of River Chelt floodplain	0.18	0.18
8 nr Staverton culvert	0.30	0.30
9 Boddington Lane	0.43	0.41

Table 5-3 - 1% AEP event (1 in 100-year return period) Baseline and Scheme flows (m^3/s)

Location	Baseline flow (m^3/s)	Scheme flow (m^3/s)
A Leigh Brook culvert	2.2	2.2
B Piffs elm culvert	3.0	1.7
C River Chelt culvert	18.3	18.3
D Staverton culvert	2.7	2.7
E A4019 culvert	0.0	0.0
F A4019 overtopping	0.0	0.0
G Withybridge Lane	8.2	8.2
H Boddington Lane (nr downstream boundary)	3.0	1.6

Figure 5-5 - 1% AEP Scheme flood risk depth map – present day

Figure provided in Appendix 8.1B at the end of this document.

Figure 5-6 - 1% AEP level difference map – present day
Scheme flood levels minus Baseline flood levels. A + change is an increase in flood risk.
A – change is a reduction in flood risk

Figure provided in Appendix 8.1B at the end of this document.

Design flood

5.4.85. The effect of the Scheme on the Baseline conditions 1% annual exceedance probability event (1 in 100-year return period) with allowance for climate change (the design flood) are detailed below. Further details are described in the Scheme Hydraulic Modelling Report (Application document TR010063/APP/9.19).

5.4.86. The results for this event show that the Scheme severs the overland flow across the A4019 into the Leigh Brook floodplain and thus there is a significant reduction in Baseline flood extents in the catchment. The most significant reduction in Baseline flood extents is alongside the motorway embankment north of the A4019, where areas with existing flood depths of more than 1 m no longer flood. There is a widespread reduction in Baseline flood levels across the Leigh Brook floodplain; flood levels have reduced by an average of 0.5 m, both upstream and downstream of the motorway.

5.4.87. There is consequently a reduction in peak flow through Leigh Brook Culvert, under the M5 motorway, the predictions reducing from 9.4 m^3/s to 3.2 m^3/s with-Scheme. This results in decreased flood levels downstream of the M5 motorway and a reduction in out of bank flooding which continues west to the model's downstream boundary.

5.4.88. The raising of the A4019 in the with-Scheme model retains more water in the Chelt floodplain (which would have previously entered the Leigh Brook catchment). As intended, water enters the flood storage area adjacent to the M5 motorway and results in deeper flooding as a result of excavated (reduced) ground levels. Flood depths in the storage area south of Withybridge Gardens increase from 1.15 m in the Baseline to 2.41 m with Scheme, and at the southern end of the storage area, north of Butlers Court, from 0.35 m in the Baseline to 2.08 m with Scheme. Note that the peak flood level reduces slightly across this area, demonstrating that the flood storage area provides an excess volume.

5.4.89. No water overtops or passes under the A4019 with the Scheme. However, there are small increases in flood levels in the vicinity: in the field ditch north of the A4019 (just east of the existing A4019 culvert outfall); and south of the A4019, near the Withybridge Lane culverts.

5.4.90. New flooding is predicted on the compensatory floodplain, upstream of the Link Road, with up to 230 mm depth of floodwater predicted to inundate this area. Increases and decreases in flood levels are predicted both upstream and downstream of the proposed Link Road culverts.

5.4.91. The Scheme prevents overtopping of the A4019 of Piffs Elm (near Elmstone Business Park), downstream of the M5 motorway embankment, and removes the Baseline flooding around Stanboro Cottage. This is a result of the Scheme nominally raising ground levels alongside the A4019 to create an active travel route and the minor verge reprofiling on the south side of the highway.

5.4.92. The ICM modelling for the minor watercourses at the B4634 (southern end of the Link Road) predicted up to 20 mm reduction in peak flood levels in the farmland upstream (as the additional culvert conveyance passes flow earlier in the event). Similarly, a reduction in peak flood level was predicted in the downstream farmland, albeit smaller at around 10 mm although with some reductions over 20 mm (as the overtopping surge is prevented). A 30 - 40 mm increase in the depth of flooding was predicted alongside the watercourse immediately downstream of the B4634, where the new culverts convey water downstream. Flooding on the B4634 is reduced during this event with the Scheme in place, with overtopping now prevented.

Table 5-4 - 1% AEP event (1 in 100-year return period) with climate change Scheme depths

Location	Baseline depth (m)	Scheme depth (m)
1 Leigh Brook nr Leigh Brook culvert	0.71	0.00
2 Leigh Brook existing slip road	0.75	0.00
3 Leigh Brook nr A4019	0.23	0.00
4 A4019	0.25	0.00
5 Withybridge Gardens	1.43	2.45
6 north of Butlers court	0.72	2.16
7 Eastern end of River Chelt floodplain	0.26	0.26

Location	Baseline depth (m)	Scheme depth (m)
8 nr Staverton culvert	0.43	0.43
9 Boddington Lane	0.47	0.46

Table 5-5 - 1% AEP event (1 in 100-year return period) with climate change Scheme flows

Location	Baseline flow (m^3/s)	Scheme flow (m^3/s)
A Leigh Brook culvert	9.4	3.2
B Piffs elm culvert	3.7	3.3
C River Chelt culvert	21.5	21.5
D Staverton culvert	2.8	2.8
E A4019 culvert	1.6	0.0
F A4019 overtopping	10.3	0.0
G Withybridge Lane	20.6	20.6
H Boddington Lane (nr downstream boundary)	5.9	5.3

Figure 5-7 - 1% AEP Scheme flood risk depth map – future with 53% climate change

Figure provided in Appendix 8.1B at the end of this document.

Figure 5-8 - 1% AEP level difference map – future with 53% climate change
Scheme flood levels minus Baseline flood levels. A + change is an increase in flood risk.
A – change is a reduction in flood risk

Figure provided in Appendix 8.1B at the end of this document.

0.1% annual exceedance probability event (1 in 1000-year return period)

5.4.93. The effect of the Scheme on the Baseline conditions for the present day 0.1% annual exceedance probability event (1 in 1000-year return period) are detailed below. Further details are described in the Scheme Hydraulic Modelling Report (Application document TR010063/APP/9.19).

5.4.94. The results for this event show that the Scheme are similar to the design event, albeit with slightly higher flows and flood levels. The Scheme severs the overland flow across the A4019 into the Leigh Brook floodplain and thus there is a significant reduction compared to the Baseline flood extents in this catchment. There is a reduction in peak flow through Leigh Brook Culvert, under the M5 motorway, the predictions reducing from 10.2 m^3/s to 3.4 m^3/s with-Scheme. This results in decreased flood levels downstream of the M5 motorway and a reduction in out of bank flooding which continues west to the model's downstream boundary.

5.4.95. At Piffs Elm (near Elmstone Business Park), downstream of the M5 motorway embankment, the reduction in flow in the Piffs Elm ditch along with the minor raising the highway verge is sufficient to prevent flooding of the A4019, Stanboro Cottage and Elmstone Business Park.

Table 5-6 - 0.1% AEP event (1 in 1,000 year return period) Baseline and Scheme depths

Location	Baseline depth (m)	Scheme depth (m)

1 Leigh Brook nr Leigh Brook culvert	1.04	0.00
2 Leigh Brook existing slip road	1.08	0.01
3 Leigh Brook nr A4019	0.43	0.00
4 A4019	0.29	0.00
5 Withybridge Gardens	1.47	2.86
6 north of Butlers court	0.77	2.57
7 Eastern end of River Chelt floodplain	0.27	0.26
8 nr Staverton culvert	0.45	0.45
9 Boddington Lane	0.47	0.47

Table 5-7 - 0.1% AEP event (1 in 1,000-year return period) Baseline and Scheme flows

Location	Baseline flow (m^3/s)	Scheme flow (m^3/s)
A Leigh Brook culvert	10.2	3.4
B Piffs elm culvert	3.7	3.3
C River Chelt culvert	21.7	21.7
D Staverton culvert	2.8	2.8
E A4019 culvert	1.6	0.0
F A4019 overtopping	13.3	0.0
G Withybridge Lane	22.4	22.4
H Boddington Lane (nr downstream boundary)	6.4	5.9

Figure 5-9 - 0.1% AEP Scheme flood risk depth map – present day

Figure provided in Appendix 8.1B at the end of this document.

Figure 5-10 - 0.1% AEP level difference map

Figure provided in Appendix 8.1B at the end of this document.

Flood event of July 2007

5.4.96. The effect of the Scheme on the flooding that occurred in July 2007 was determined by applying the recorded rainfall and flows to the with-Scheme hydraulic model. Initially this was undertaken to validate the Baseline model, comparing the predicted flood levels with observations and recorded wrack marks provided by the Environment Agency. The same flows were then applied to the with-Scheme model.

5.4.97. The modelling of the 2007 flood event using the with-Scheme hydraulic model demonstrates that the Scheme would have had little adverse impact on flooding in the catchment, except where intended through the various mitigations. This includes at the B4634 with a reduction in upstream flooding, and up to 10 mm increase on the downstream fields, albeit with a localised 20 mm increase beside the watercourse. The Scheme was predicted to prevent the B4634 from flooding during this event.

Summary of Impacts on flood risk

5.4.98. For the vast majority of land described in the flood model the Scheme reduces flood risk

with a reduction in flood depth and extent.

5.4.99. Increases in peak flood level are predicted at two locations comprising small changes in the depth of existing flooding, as opposed to creating new flooding (except the compensatory floodplain). The Order limits are set to encompass such areas of land where the sustainability or environmental impact of mitigation would outweigh the impact on 3rd parties. These locations are:

- 6 fields of existing farmland either side of the Link Road (whilst there are increases in flood level of up to 230 mm inside the compensatory floodplain, the increase is less than 60 mm outside of it); and
- 4 fields of existing farmland alongside the Staverton Stream, downstream (north) of the B4634. At the 20% AEP a 10 - 30 mm increase in flood level is predicted over this land. At the design flood this reduces with a widespread reduction in level of 20-30 mm, leaving only a small area next to the watercourse experiencing up to 40 mm increase in level.

5.4.100. The effect on flood risk has been considered using the industry accepted definition of flood risk, being a combination of the **probability** (likelihood or chance) of an event happening and the **consequences** (impact) if it occurred. The consequence of flooding was considered as whether it: causes new flooding; put lives at risk; increases the flood extent; increases the duration of flooding; increases the rate of rise; increases the flood hazard (a function of flow velocity, depth and debris factor); affects access or egress; affects how the land can be used; or causes a reduction in land value. In this context flood risk is developed from the frequency of occurrence and the impact it would have: this could be on the wider environment or the owner/occupant and their ability to go about their daily lives. Depth of flooding is only one part of this equation.

5.4.101. A summary of the assessment is described below in Table 5-8.

5.4.102. It is concluded that the unmitigated adverse effects do not change the flood risk to those areas.

Table 5-8 - Impact on flood risk

Location	Probability of flooding	Consequences of flooding	Change in flood risk
Link Road	No change – the frequency of flow on the floodplain is unaffected by the Scheme. Some land is being intentionally lowered to create compensatory floodplain area, which will then flood once the floodplain inundates.	No change, except where new flooding is created by virtue of the compensatory floodplain	No change
Staverton Stream	With the floodplain in hydraulic connectivity with the watercourse, the 10 mm to 30 mm increases in flood level will cause an indiscernible (non-material) increase in flood frequency. Area floods from a 20% AEP in the Baseline.	An indiscernible increase in flood extent on the fields The rate of rise of floodwater is imperceptibly increased. The onset of out-of-bank flooding will occur earlier in an event. However, the scale of changes are a non-material consequence.	A non-material increase

WFD Enhancements

5.4.103. To mitigate for the impacts to ecology and hydromorphology on the River Chelt, and to align with the Water Framework Directive (WFD) objectives, watercourse enhancement measures are proposed for a stretch approximately 160 m upstream and 100 m downstream of the new River Chelt crossing as part of the Link Road. In addition, similar measures will be implemented for a 100 m stretch upstream of the existing River Chelt M5 culvert. The measures will comprise:

- enhanced riparian and marginal planting to enhance biodiversity, allowing for dappled lighting.
- bank reprofiling with the creation of berms and two stage channels to enhance flood plain connectivity (see Appendix 8.2A - WFD Surface Water Impact Assessment, Application document TR010063/APP/6.15).
- installation of in channel morphological enhancements for example: riffle pool sequences and/or large wood.

5.4.104. Hydraulic modelling of the proposed berms was undertaken separately from the large flood risk model and tested in a standalone HEC RAS software model. This was undertaken to confirm the installation of localised berms in the river banks would have no adverse impact on water levels in the reach. The modelling demonstrated that a localised increase in conveyance would arise but would not adversely impact flood levels upstream or downstream of the enhancements – with the existing channels forming the hydraulic control.

Predicted with-Scheme flood risk: groundwater

5.4.105. A groundwater assesment has been completed to understand the impact that the Scheme's below ground elements will have on the groundwater regime. This is described in Chapter 8 of the Environmental Statement (Application document TR010063/APP/6.6) and with the detail in the Appendix 8.2B - WFD Groundwater Impact Assessment (Application document TR010063/APP/6.15). In summary, the Scheme was found to have no significant effect on groundwater.

5.5. Mitigate

5.5.1. Where required, essential (additional) measures will be required to manage/mitigate any unacceptable consequences that appear through the detailed design. Essential mitigation

on this Scheme might include for additional compensatory floodplain to offset any new hydraulic impacts (afflux) of the crossing, or extra conveyance culverts underneath the Link Road. These elements were tested in the hydraulic model to evaluate their performance in offsetting the Scheme impacts described above. Neither was found to be ideal, with the storage option requiring a lot more land to reduce the small areas of detriment.

5.5.2. Whilst the Scheme is not predicted to increase flood risk elsewhere, albeit with a non-material increase in the flood compensation alongside the Staverton Stream and within the compensatory floodplain besides the Link Road, consultation with the affected landowners is being undertaken to ensure that they are fully aware of the small increases in peak flood level and find them acceptable.

5.5.3. At the same time, a right is also being sought through the DCO process to permit some increased depth of flood:

- on farmland both upstream and downstream of the Link Road; and
- on farmland between the B4634 and Withybridge Lane.

5.6. Management of flood risk

5.6.1. The construction works have the potential to temporarily increase flood risk. Temporary works to enable the construction of the River Chelt bridge and its floodplain crossing may require a narrowing of the channel or floodplain for a short period. The increase flood risk caused by this activity could be managed by undertaking the work during normal flow conditions when inclement weather is not forecast, or having the appropriate measures in place to deal with flows.

5.6.2. It is recommended that the Contractor monitors weather conditions and river flows and makes due allowance for materials and plant storage should high rainfall be predicted. As described above for mitigation, advice from the Environment Agency should be sought and where possible the site manager register the works for Floodline Warnings Direct: by calling Floodline on 0345 988 1188 or Textphone 0345 602 6340 or on the internet at https://www.fws.environment-agency.gov.uk/app/olr/register.

5.6.3. The contractor should also ensure that emergency plans are in place to maintain the de facto flood defences (raised river banks) during the works.

5.6.4. During operation of the Scheme it is likely that river borne debris will be deposited at the culvert inlets and bridge abutments as it is washed along the River Chelt or Leigh Brook. This will need to be cleared as part of a routine, and event specific, maintenance plan for the Scheme to reduce the risk of culvert blockage.

5.7. Off site impacts

5.7.1. The Scheme has been tested in the hydraulic model to evaluate any impact on flood risk elsewhere, remote from the Scheme. The Scheme with the embedded mitigation typically reduces the impact on flood risk to that of a beneficial or neutral effect. There are large areas where a betterment is predicted, significantly in the Leigh Brook catchment upstream of the M5 motorway.

5.7.2. There are areas inside the Order limits that are affected by small increases in flood level, although these areas (except the compensatory floodplain) are already flooded in the Baseline (see paragraph 5.4.99). The impact assessment is described in the Environmental Statement (Chapter 8 Road Drainage and Water Environment, Application document TR010063/APP/6.6). Where the magnitude of adverse impacts on 3rd party land was considered Minor[26] (10 mm to 50 mm) or worse (> 50 mm), and/or it was considered economically or environmentally unsustainable to provide additional mitigation measures, the probability and consequences of flooding were considered to establish whether that would constitute a change in flood risk. This analysis found that the Scheme

[26] As defined in National Highways et al (2020) Design Manual for Roads and Bridges - LA 113 Road drainage and the water environment. Vol 1, s.l.: s.n.

is not predicted to cause a material increase in flood risk elsewhere.

5.7.3. Despite having no material increase on flood risk elsewhere, the project is consulting with the affected landowners to demonstrate that they are fully aware of, and accept, the small increases in peak flood level. At the same time rights are also being sought through the DCO for the increased flooding on the farmland:

- on farmland both upstream and downstream of the Link Road; and
- on farmland between the B4634 and Withybridge Lane.

5.7.4. Downstream of the flood storage area (which heavily attenuates flows) peak flood stage is reduced, resulting in a much smaller floodplain west of the M5 motorway. However, as the flood storage draws down relatively slowly, the overall duration of the residual flooding is increased in some discrete locations, by up to 48-hours in places. This is not considered to be an increase in flood risk. However, consultation with the landowner is being undertaken in this area too.

6. Residual risks

There are always residual risks, caused by failure or over-design events. This section describes these in relation to the M5 Junction 10 Improvements Scheme.

6.1. Extreme event

6.1.1. The residual risks of the extreme event (0.1% annual exceedance probability event (1 in 1,000-year return period) as defined in the NPPF) are of deeper flooding and higher velocities in the river and on the floodplain. This event has been simulated in the hydraulic model and described in both the Baseline Hydraulic Modelling Report (Application document TR010063/APP/9.18) and Scheme Hydraulic Modelling Report (Application document TR010063/APP/9.19), and from paragraph 5.4.93 above.

6.1.2. The hydraulic modelling demonstrates that neither the carriageway of the A4019, new Junction 10, nor the Link Road become flooded from the watercourse or overland flow during this extreme event. The 0.1% annual exceedance probability event (1 in 1,000-year return period) is larger than the 1% annual exceedance probability event (1 in 100-year return period) with 53% allowance for climate change. The Scheme functions similarly in the extreme event although does increase peak flood levels in the designated flood storage area besides the M5 motorway and A4019 at Junction 10. Peak levels here are predicted to increase by 230 mm in the extreme event compared to the Baseline.

6.1.3. It is recognised that the highway drainage system will not cope with such intense rainfall and that water will be spilling off the carriageways onto the surrounding land. This water will be unattenuated. However, in such an extreme event, the paved areas are likely to respond in a similar way to the surrounding farmland, with no infiltration and all rainfall being held on the ground surface. In such a situation, this will be no change from the Baseline condition.

6.1.4. The Scheme and other surrounding areas will remain at flood risk in the extreme event. Surrounding areas are predicted to flood in the current situation. This frequency will increase with the impacts of climate change – although it is not currently UK best practice to apply climate change allowances on the 0.1% annual exceedance probability event (1 in 1,000-year return period) given the uncertainty on both estimates.

The Credible Maximum climate scenario

6.1.5. The NNPS asks for demonstration that there are no critical features of the design of new national networks infrastructure which may be seriously affected by more radical changes to the climate beyond that projected in the latest set of UK climate projections.

6.1.6. Use was made of the Environment Agency guidance on assessing credible maximum scenarios for NSIPs using the Upper End climate change allowance. As a sensitivity test it assesses how susceptible the Scheme is to changes in the climate for a worst case future scenario, and can help to ensure that the development can be adapted to large-scale climate change over its lifetime.

6.1.7. The Impact of the Scheme, compared to the Baseline, was evaluated for the Upper End (+94% flow) climate change scenario on top of the present day 1% annual exceedance probability event (1 in 100-year return period).

6.1.8. The modelling identified that the credible maximum scenario would not affect the Scheme, with the highways remaining operational should more radical changes to the climate occur.

6.1.9. The sensitivity test did predict additional detriment with the Scheme in place, with this affecting the farmland around the flood storage area and the Link Road. The flood extent south of the storage area is increased compared to Baseline, however the flood extent east of the storage area is reduced as floodwater is held back by the Link Road. Additional flooding was also predicted west of Uckington, although not impacting on the property there.

6.1.10. As expected, the higher flood levels arising from higher credible maximum flows means that the Scheme displaces additional floodwater that is not accommodated in the flood storage area or compensatory floodplain. As the 36 culverts included under the Link Road were sized and numbered to account for the design flow, a greater overland flow, would require additional culverts.

6.1.11. It should be noted that despite the higher flood levels in the credible maximum event, the floodwater was not predicted to reach the soffit of the Link Road culverts.

6.1.12. Adaptation measures are available to the Scheme should the future climate risk become greater than those being applied to the design event. These might include:

- Adding extra culverts under the link road to collect the larger overland flow;
- Enlarging the flood storage area and/or enlarging the Piffs Elm culvert under the M5 motorway; and
- Enlarging the Uckington roadside ditch to collect the increased flows into this drainage channel.

6.2. Risk of breach

6.2.1. There are no formal existing raised defences in the study area that may breach in the future and impact on the Scheme. Those river banks along the River Chelt that are elevated are not at risk of breach, being natural features or non-continuous structures that are already outflanked by floodwaters. Risk of breach or defence failure is not an issue for this FRA.

6.2.2. As a result of raising the A4019, and the subsequent excavation for compensatory storage south of the A4019, the resulting floodplain of the River Chelt will become designated a large raised reservoir under the Reservoirs Act 1975, as amended by the Flood and Water Management Act 2010. Accordingly, flood modelling has been undertaken to understand the impact of both a 0.01% annual exceedance probability event (1 in 10,000-year return period) and the Probable Maximum Flood (PMF). The results of that modelling have, amongst other activities, have been used to direct landscape planting on the raised embankment.

6.2.3. As the works meet the definition of a ‘large raised reservoir’, the Environment Agency will need to be informed. In England the Environment Agency monitors compliance with the amended Reservoirs Act 1975 and take the role of Regulatory Authority. Dams in England are regulated by the Reservoirs Act 1975, which sets out stringent conditions for the operation of reservoirs to ensure high levels of safety. They are designed and operated in a way to ensure the likelihood of failure (breach) is incredibly low.

6.2.4. A Construction Engineer has been appointed under Section 6 of the Reservoirs Act 1975 to design and supervise the construction of the works: the Reservoirs Act 1975 requires those who wish to construct a reservoir to commission the services of a reservoir Construction Engineer from the panel of All Reservoirs Panel Engineers held by Defra.

6.3. Access and egress conditions

6.3.1. The Scheme, particularly the Link Road, will provide a link between developing urban areas. The design is intended to provide safe access, and will be designed to be flood free from fluvial sources during the design event (1% annual exceedance probability event (1 in 100-year return period) over the lifetime of the development).

6.3.2. The road is likely be flooded by overload of its own drainage system during an extreme event. The NPPF Planning Practice Guidance acknowledges this and states that “…where this [dry access] is not possible, limited depths of flooding may be acceptable…”.

6.4. Management over development lifetime

6.4.1. There are lifetime management issues for the Scheme related to the management and maintenance of the watercourses and its related infrastructure. It appears that the River

Chelt channel through the M5 motorway culvert has suffered from accumulations of sediments and debris over the years. Any trash/debris deposited at or in the culvert will need to be removed from the site to maintain the hydraulic capacity, reducing the risk of blockage, which would otherwise raise flood level on the eastern side of the M5 motorway. It is a similar need for the Leigh Brook, Piffs Elm and Staverton culverts.

6.4.2. The new hydraulic structures for the Link Road will need regular inspection and maintenance. Accumulations of sediments and debris at these will increase flood risk on the surrounding land, and could cause property flooding. It should be noted that flood flows will increase with time in line with climate change. This will increase the frequency for channel and structure maintenance.

6.4.3. The risk of blockage of the existing river and floodplain crossings has been considered. Blockage runs were completed for the Baseline conditions as described in the Baseline Hydraulic Modelling Report (Application document TR010063/APP/9.18). The risk of blockage of the Scheme river and floodplain crossings was considered separately for the 1% annual exceedance probability event (1 in 100-year return period) to isolate the impacts of each and advise any operation and maintenance manual for the Scheme. This is described in the Scheme Hydraulic Modelling Report (Application document TR010063/APP/9.19). Blockage runs were completed based on the Environment Agency's Blockage management guide[27], which indicates that, for culverts, up to a 100% blockage should be considered. Completion of 100% blockage runs in the hydraulic model are not possible: it results in zero flow in the downstream channel, which is likely to cause the hydraulic model to fail. Model runs were therefore completed with a degree of blockage as close to 100% as possible without destabilising the model.

6.4.4. If GCC plans any alterations to the flood storage reservoir, which increase or decrease its capacity, it will need to appoint a Construction Engineer under the Reservoirs Act 1975. If GCC or Highways England plan any works that might affect the safety of the reservoir, GCC will need to ensure that the works are supervised by a qualified civil engineer (as defined under the Act).

6.5. Flood warning and evacuation

6.5.1. At this stage of the project no specific flood warning systems are considered necessary for the Scheme, nor are any flood-focussed emergency evacuation plans except during the construction period. The contractor should allow for evacuation of the works and safe storage of all plant and materials out of the river and floodplain.

[27] Environment Agency, 2019. Blockage management guide, Guide – SC110005/R1.

7. Summary and conclusions

7.1.1. This ES FRA has presented a final detailed assessment of flood risk to the M5 Junction 10 Improvements Scheme, and the potential flood effects on external receptors arising from it.

7.1.2. This FRA concludes that:

- The Scheme crosses Environment Agency Flood Zone 2 and 3.
- The vulnerability classification of the Scheme is Essential Infrastructure.
- The Scheme vulnerability is compatible with the envisaged flood risk.
- The Scheme satisfies the Sequential Test.
- The Scheme satisfies the Exception Test (in accordance with the NPPF) as it will aid in unlocking economic potential and encourage growth, and job creation; and has been demonstrated to manage flood risk satisfactorily over the lifetime of the development, with no material increase in flood risk elsewhere.

7.1.3. The Scheme is at risk from flood sources as summarised below, with the risk based on the published Environment Agency data and supported by the hydraulic modelling undertaken for the project.

Table 7-1 - Summary of flood risk

Flood risk Source	Relevant Source of flooding	Risk	Requires further assessment?
Fluvial	Yes	High	Construction phase assessment required
Surface water	Yes	High	Construction phase assessment required
Groundwater	Yes	Medium	No
Coastal/tidal	No	None	No
Sewers	No	Low	No
Other sources	No	Low	No

7.1.4. The Sequential Test is passed for the Scheme, through demonstration of the site selection process that took flood risk into account alongside other constraints.

7.1.5. Increases in rainfall and river flow arising from future climate change will increase flood risk from all sources. The increase in flood risk off site, due to climate change, will not be exacerbated by the Scheme.

Fluvial flooding

7.1.6. Parts of the Scheme are located inside the predicted flood extents, which requires mitigation (embedded or additional) to alleviate the predicted significant effects. The fluvial assessment demonstrates that the Scheme is appropriate in terms of flood risk, having passed Part B of the Exception Test, by demonstrating no material increase in flood risk elsewhere as a result of those measures. The Scheme is appropriate on the basis of development vulnerability and Flood Zone compatibility.

7.1.7. On the basis of this information it is concluded for the Environmental Statement that the Scheme will be appropriate in that all applicable fluvial flood risks and effects are acceptable. The Scheme's embedded mitigation (including compensatory floodplain and storage areas) ensures that any fluvial flood effects are acceptable in the context of flood risk and the receptor vulnerability. Where adverse flood (environmental) effects are predicted, the Scheme presents no material increase in flood risk. The Scheme is seeking landowner acceptance of the increases in peak flood level wherever possible, and has included these areas inside the Order limits identifying them for temporary possession with a permanent right.

Surface water flooding

7.1.8. The assessment of surface water flood risk has shown that the Scheme is not at significant risk from this source of flooding. While there are parts that intersect areas at pluvial flood risk any flood risks associated with this can readily be mitigated through incorporating appropriate landform and drainage measures and sequentially siting site specific components in areas of least pluvial flood risk. At the B4634, additional culverts are included in the design to alleviate the encroachment of the southern junction of the Link Road into the floodplain of the minor watercourse: this has a non-material impact on flood risk which is contained in the Scheme's flood compensation assigned in that area. Consultation with the affected landowners is being undertaken for the farmland adjacent to Withybridge Lane where a 10 – 30 mm increase in flood level is predicted in that area at the 20% AEP. At the design event, this impact becomes a 20 – 30 mm reduction in flood level, leaving only a small area experiencing up to 40 mm increase in level. This area is included in the Order limits.

7.1.9. It is concluded that the Scheme is appropriate in terms of all applicable pluvial flood risks being acceptable. This conclusion is subject to due consideration being given in the detailed design process to ensuring that design will not affect the Baseline pluvial flood risk (it being smaller than the fluvial flood risk for which impacts are being mitigated) and that the principles of designing for exceedance are adhered to, as guided by the outputs of this FRA.

Groundwater flooding

7.1.10. The appraisal of available information and subsequent groundwater assessment of groundwater flood risk has shown that, in general, there is the potential for groundwater emergence at the surface due to the permeable geology and relatively flat topography. Based on the groundwater assessment, it is expected that land reprofiling and drainage measures will sufficiently mitigate the risks to the Scheme. it has been demonstrated that the flood storage area will not accumulate groundwater, leaving the excavated volume for flood storage. As such, the groundwater flood risk is acceptable.

7.1.11. The groundwater assessment has also concluded that groundwater flood risk to subsurface structures can be acceptably managed with the proposed form of piling permitting passage of groundwater, and the worst case embankment type being similarly acceptable.

Highway drainage

7.1.12. The Scheme development of a new motorway junction, highway widening and link road, including new bridges and road embankments will increase the impermeable area across a partly greenfield environment. The increase in runoff rates, will be managed through the application of a drainage (SuDS) strategy.

Flooding from other sources

7.1.13. The residual risk associated with all sources of artificial flooding is evaluated to be very low and does not place any constraints or requirements for additional environmental measures on the Scheme. The flood risk associated with existing infrastructure was considered including the Dowdeswell reservoir, canals, sewers. These features have been deemed to pose a very low residual risk based on the very low probabilities of any of the infrastructure failing. This in many cases is due to the requirements of the asset owners to inspect and maintain their assets.

7.1.14. Based on the assessment summarised above, the residual risk associated with all sources of artificial flooding is evaluated to be very low and does not place any constraints or requirements for environmental measures on the Scheme.

7.2. Answers to the key questions

7.2.1. The FRA can now address the questions defined by the scope in Section 1.5.

Is the site likely to be at risk of flooding from: a watercourse, the sea, an estuary, groundwater, overland flow, an artificial drainage system, infrastructure failure?

Yes, there is a risk of flooding from the River Chelt, the Leigh Brook and the Staverton Stream.

Is the Scheme likely to obstruct the maintenance access requirements or affect the integrity of an existing flood defence?

No, the Scheme will provide maintenance access to the River Chelt from the Link Road for maintenance of the crossings and river in general. Similarly, the maintenance access to the Leigh Brook culvert will be replaced. There are no existing flood defences that will be affected by the Scheme.

Is the Scheme likely to increase flood risk elsewhere due to increased runoff rates and volumes from the site?

No, whilst the Scheme could increase runoff and flood risk, controls on peak discharge rates and volumes are included in the design. The predicted increases in flood risk to farmland is considered non-material and is being consulted upon with the landowners. The land affected is included in the DCO Order limits. There are no increases in flood risk to property.

Given the above, and the nature of the development, is continued promotion of a possible development at the site appropriate?

Yes – the Scheme satisfies the requirements of the NPPF with regards flood risk.

7.2.2. As a Scheme crosses the floodplains of the River Chelt and Leigh Brook the specific requirements for Flood Zone 3b should be designed and constructed to, hence:

Will it remain operational and safe for users in times of flood?

Yes, the Scheme is designed for the 1% annual exceedance probability event (1 in 100-year return period) with allowance for climate change on peak flow over the lifetime of the development. The design and assessment are based on the current peak flow allowance of +53% as per the July 2021 guidance.

Will it result in no net loss of floodplain storage?

The Scheme will present a footprint in the floodplain to carry the road/s over the watercourses and hence displace floodwater. The design includes compensatory floodplain, and flood storage, to replace this.

Will it not impede water flows, and not increase flood risk, elsewhere?

The Scheme will impede water flows in the River Chelt preventing them from overtopping the A4019 into the Leigh Brook. The compensatory flood storage and other embedded mitigation ensures there is no material increase in flood risk elsewhere.

7.3. Concluding remarks

7.3.1. In conclusion, on the basis of the information provided in this Environmental Statement FRA, it is concluded that the Scheme will not be at significant risk of flooding, subject to the implementation of site specific fluvial flood mitigation measures. Furthermore, the Scheme will not result in a material increase in flood risk to third parties.

7.3.2. On this basis, it is concluded that sufficient evidence is provided in the DCO application to demonstrate that there will be no material increase in flood risk as a result of fluvial, surface or ground water arising from the Scheme during its construction and operational phases.

7.4. Recommendations

7.4.1. It is recommended that the Scheme at detailed design is tested in the flood model to ensure that it remains consistent with the findings.

Appendices

Appendix 8.1 A. Planning policy tests

Appendix 8.1A i. Sequential Test

Please refer to document:

Atkins, February 2021, West Cheltenham Link Road Route Corridor Assessment.

Appendix 8.1A ii. Exception Test

The Exception Test should only be applied after the application of the Sequential Test. For this site and the M5 Junction 10 Improvements Scheme, the Exception Test is required.

Following the steps set out in the NPPF, paragraph 027, Table 3 and Diagram 3, for the Exception Test (set out in NPPF paragraph 102) to be passed the development must pass both parts of the Exception Test.

Source: NPPF, Paragraph 067

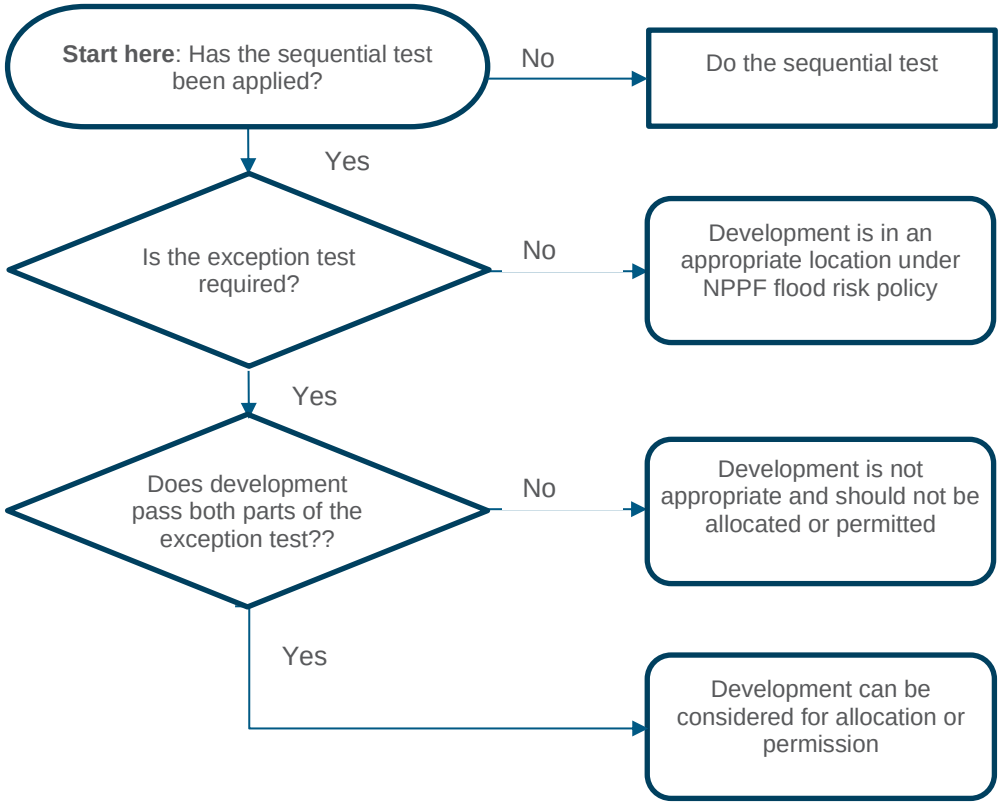
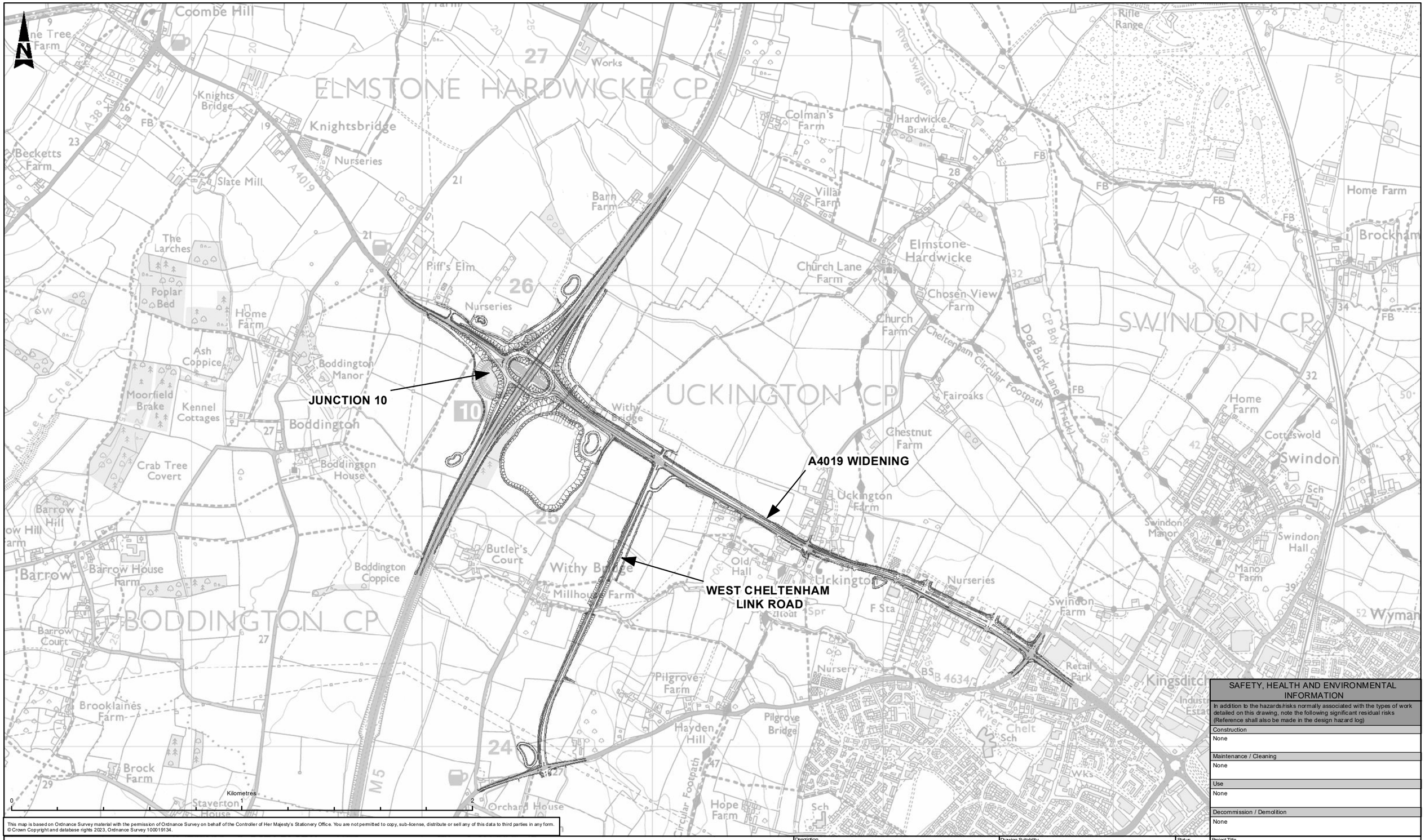


Figure A- 1 - NPPF Sequential Test application on the Scheme

Appendix 8.1 B. FRA Figures

Figure reference	Document title	Sheet	Document number	Revision
1-2	The M5 Junction 10 Improvements Scheme	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000017	0
3-1	Environment Agency's historical flood mapping	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000018	0
3-2	Environment Agency's flood map for planning	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000020	0
3-3	Environment Agency's flood risk from rivers or the sea	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000022	0
3-4	Environment Agency's flood risk from surface water	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000024	0
3-7	Environment Agency's flood risk from reservoirs	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000026	0
4-1	Study Area and indicative Scheme	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000028	0
4-2	Site topography	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000029	0
4-3	Main hydraulic features	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000030	0
4.4	Flood extent for 3.3% AEP (functional floodplain)	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-400003	0
4-5	Location of points for result reporting	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000031	0
4-6	1% AEP Baseline flood risk depth map - present day	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000034	0
4-7	1% AEP Baseline flood risk depth map - future with 53% climate change	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000035	0
5-1	Flood Compensation	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000032	0
5.4	Flood extent for 3.3% AEP (functional floodplain) in relation to Scheme	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-400002	0

Figure reference	Document title	Sheet	Document number	Revision
5-5	1% AEP Scheme flood risk depth map - present day	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000038	0
5-6	1% AEP level difference map – present day	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000036	0
5-7	1% AEP Scheme flood risk depth map – future with 53% climate change	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000039	0
5-8	1% AEP level difference map – future with 53% climate change	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000037	0
5-9	0.1% AEP Scheme flood risk depth map - present day	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000042	0
5-10	0.1% AEP level difference map	1 of 1	GCCM5J10-ATK-EWE-ZZ-GS-GI-000044	0



LEGEND

SCHEME ALIGNMENT

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction
None

Maintenance / Cleaning
None

Use
None

Decommission / Demolition
None

Description	Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
PUBLISHED	A1	P02	JM	NJ	CC	LJ	12/09/23

Drawing Suitability: **PUBLISHED**

Status: **A1**

Project Title: M5 Junction 10 Improvements Scheme

Drawing Title: FIGURE 1-2 THE M5 JUNCTION 10 IMPROVEMENTS SCHEME

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Shire Hall
Bearland
Gloucester
GL1 2TH
Tel: 08000 514 514
www.atkinsglobal.com

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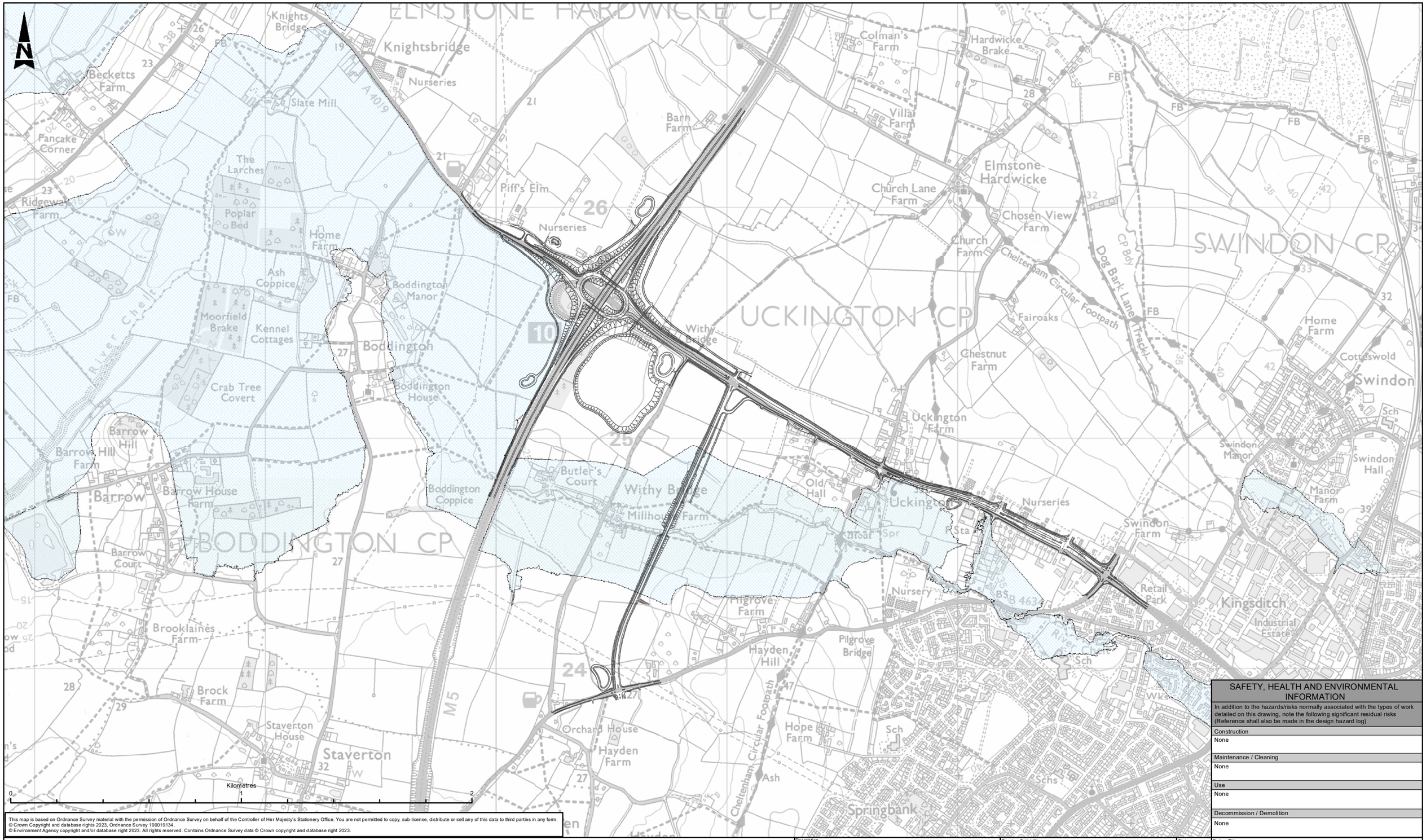

LEGEND

SCHEME

HISTORIC FLOOD MAP

Note: All Historical Flood mapping data has been obtained from the Environment Agency

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION
In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)
Construction
None
Maintenance / Cleaning
None
Use
None
Decommission / Demolition
None

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PUBLISHED	A1	P02	JM	NJ	CC	LJ	30/06/23

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Shire Hall
Bearland
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Drawing Title: FIGURE 3-1
THE ENVIRONMENT AGENCY'S
HISTORICAL FLOOD MAPPING

Client: Gloucestershire County Council

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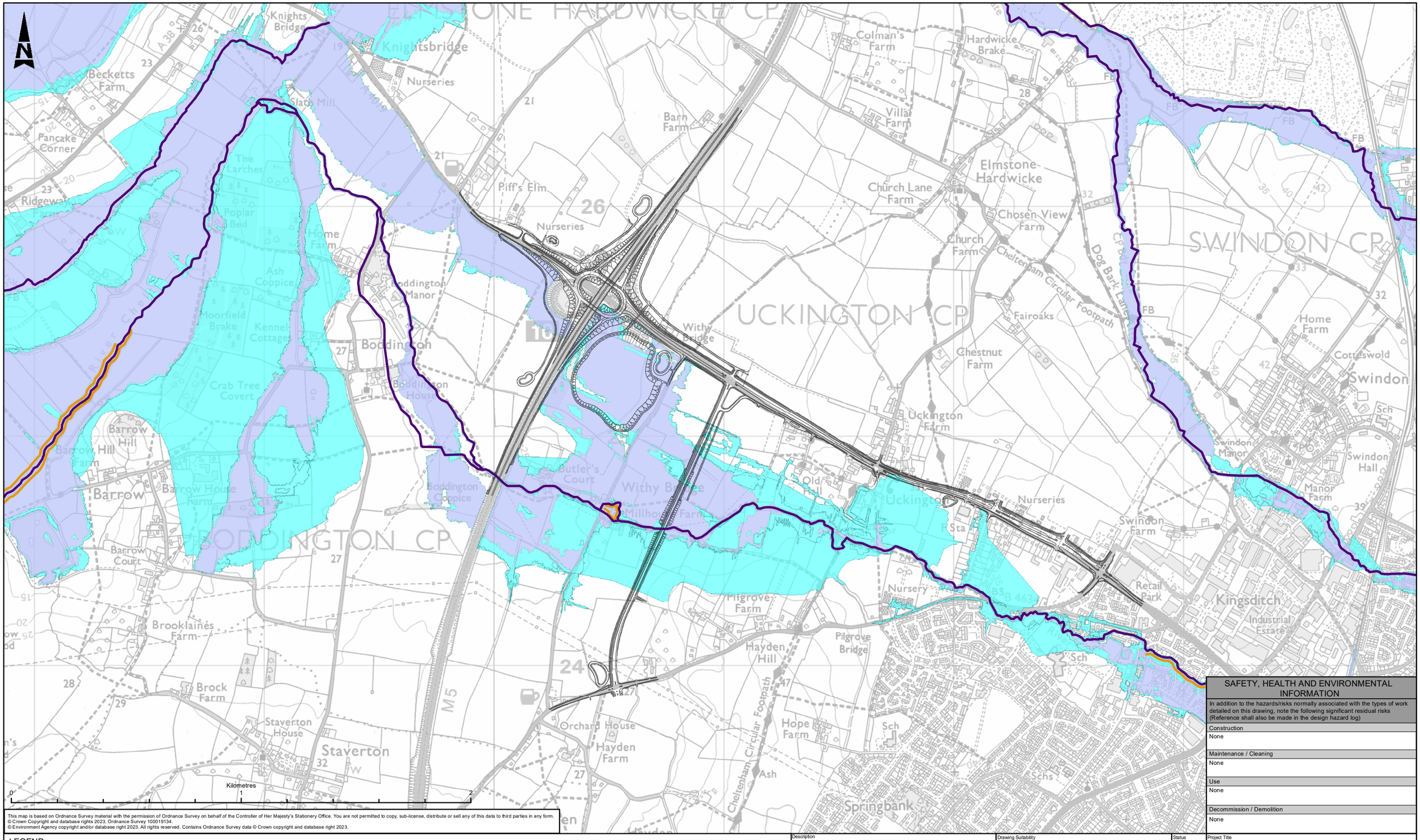

LEGEND

- MAIN RIVER
- FLOOD DEFENCE
- SCHEME ALIGNMENT
- FLOOD ZONE 3
- FLOOD ZONE 2

Note: All Flood Zone, Main River and Flood Defence data has been obtained from the Environment Agency

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction
None

Maintenance / Cleaning
None

Use
None

Decommission / Demolition
None

Description	Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
PUBLISHED	A1	P02	JM	NJ	CC	LJ	30/06/23

Drawing Suitability: **PUBLISHED**
Status: **A1**

Project Title: M5 Junction 10 Improvements Scheme

Drawing Title: FIGURE 3-2
THE ENVIRONMENT AGENCY'S
FLOOD MAP FOR PLANNING

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Shire Hall
Bearland
Gloucester
GL1 2TH
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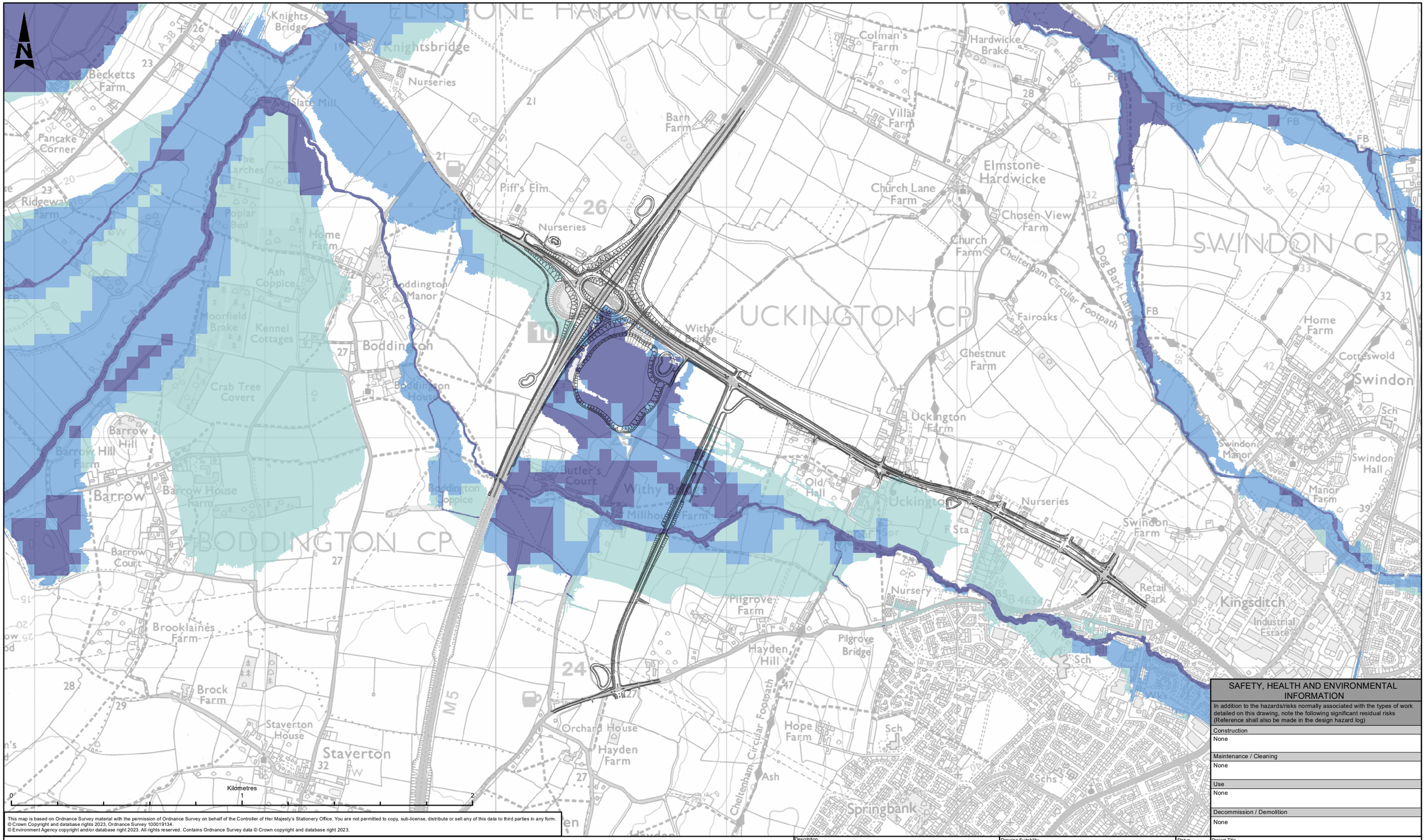

LEGEND

SCHEME ALIGNMENT

RISK CATEGORY

- HIGH
- MEDIUM
- LOW

Note: All Flood Risk data has been obtained from the Environment Agency

Description	Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
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Drawing Suitability: **PUBLISHED** — Status: **A1**

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Bearland
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Construction
None

Maintenance / Cleaning
None

Use
None

Decommission / Demolition
None

Project Title: M5 Junction 10 Improvements Scheme

Drawing Title: FIGURE 3-3
THE ENVIRONMENT AGENCY'S
FLOOD RISK FROM RIVERS
OR THE SEA

Drawing Number: Project | Originator | Volume
GCCM5J10-ATK-EWE-ZZ-GS-GI-000022
Location | Type | Role | Number

Original Size:	Scale	Project Ref:	Sheet:	Rev:
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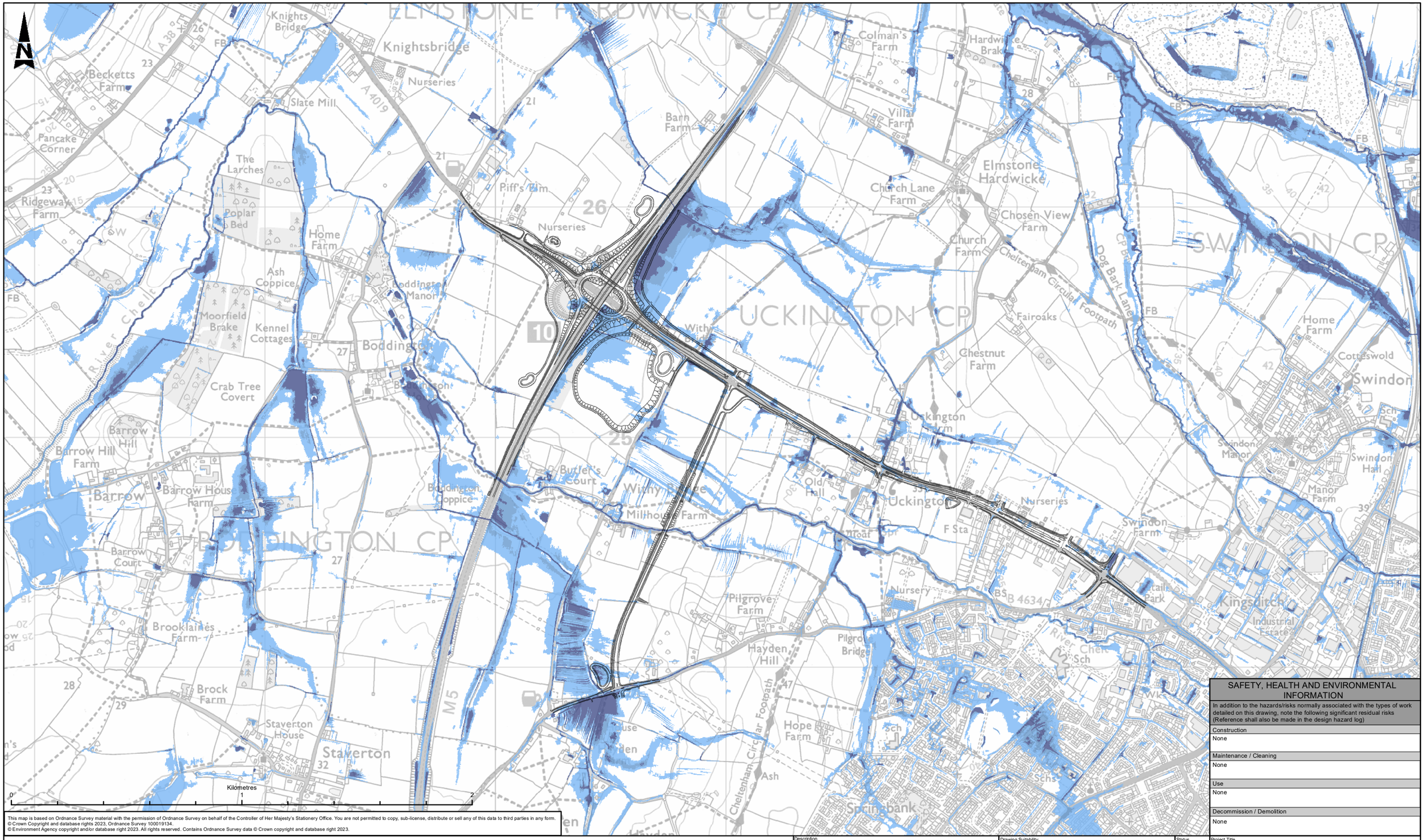

LEGEND

SCHEME ALIGNMENT

RISK CATEGORY

- HIGH
- MEDIUM
- LOW
- VERY LOW

Note: All Flood Risk data has been obtained from the Environment Agency

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction
None

Maintenance / Cleaning
None

Use
None

Decommission / Demolition
None

Description	Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
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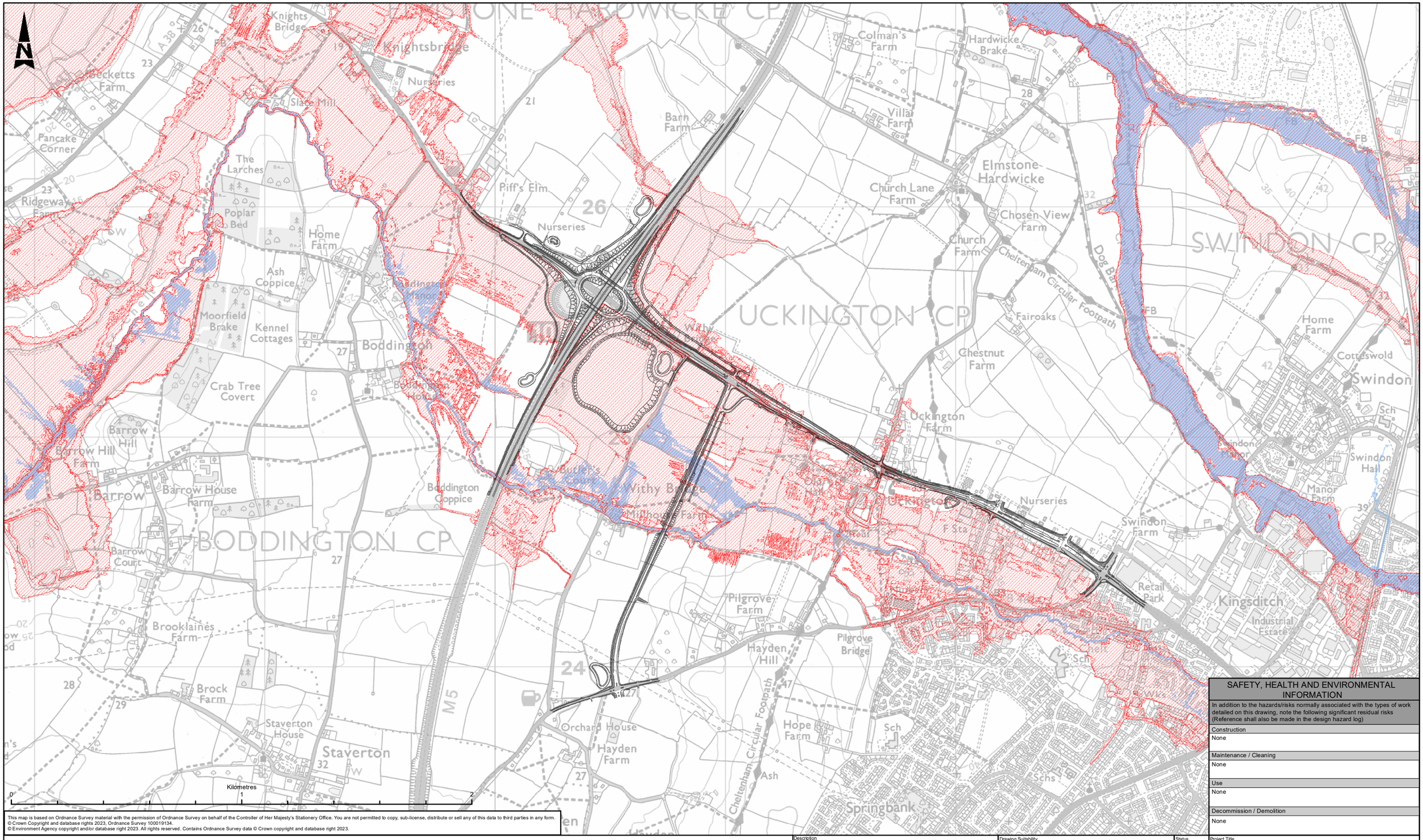
Project Title: M5 Junction 10 Improvements Scheme

Drawing Title: FIGURE 3-4
THE ENVIRONMENT AGENCY'S
FLOOD RISK FROM SURFACE WATER

Drawing Number: GCCM5J10-ATK-EWE-ZZ-GS-GI-000024
(Project | Originator | Volume | Location | Type | Role | Number)

Original Size:	Scale	Project Ref:	Sheet:	Rev:
A3	1:15,000	5214106	1 of 1	P02



LEGEND

SCHEME ALIGNMENT

MAXIMUM EXTENT OF FLOODING

WHEN RIVER LEVELS ARE NORMAL

WHEN THERE IS ALSO FLOODING FROM RIVERS

Note: All Reservoir Flood Risk data has been obtained from the Environment Agency

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction
None

Maintenance / Cleaning
None

Use
None

Decommission / Demolition
None

Description	Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
PUBLISHED	A1	P02	JM	NJ	CC	LJ	30/06/23

Drawing Suitability: **PUBLISHED** | Status: **A1**

Project Title: M5 Junction 10 Improvements Scheme

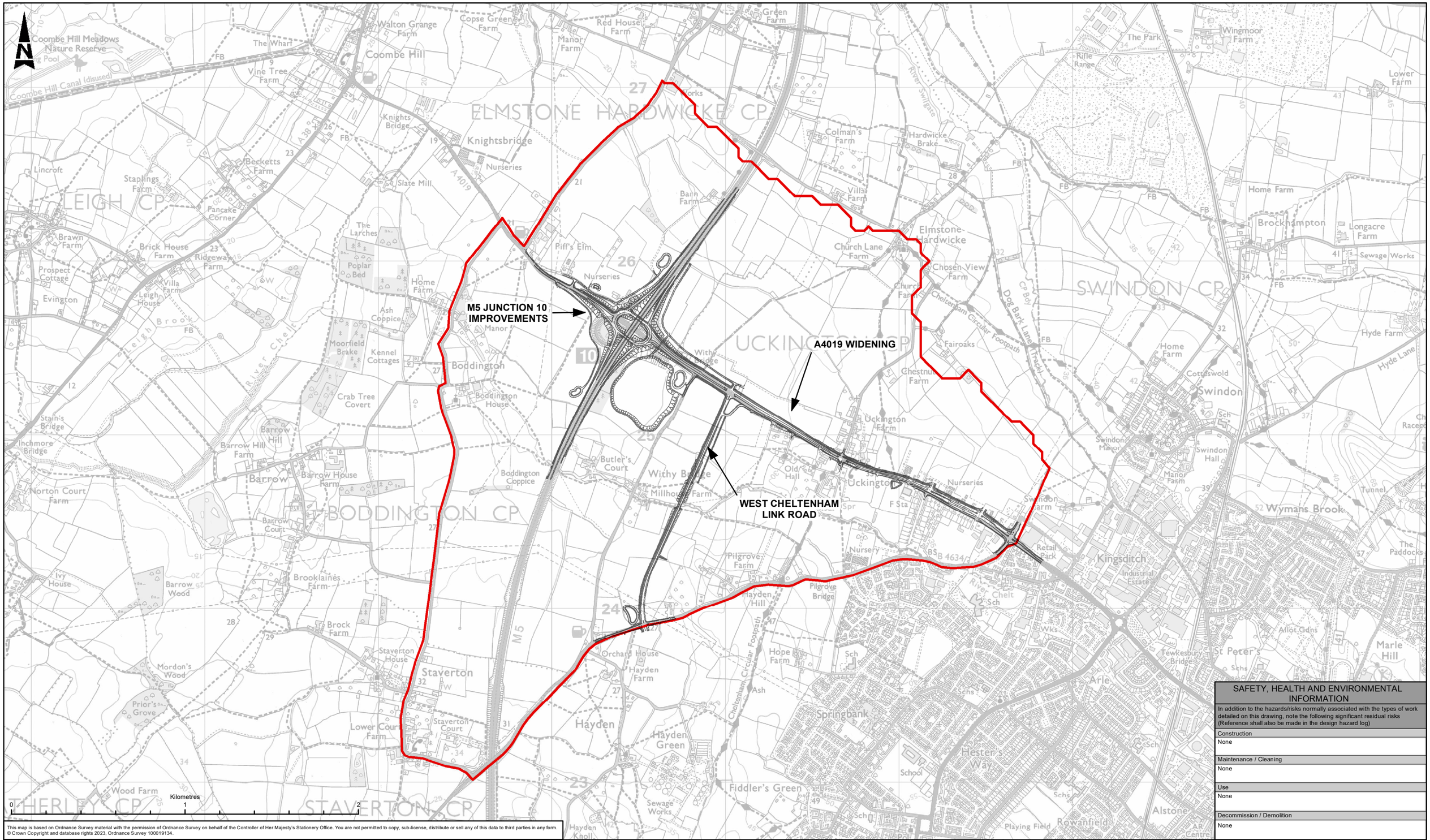
Drawing Title: FIGURE 3-7
THE ENVIRONMENT AGENCY'S
FLOOD RISK FROM RESERVOIRS

ATKINS
Member of the SNC-Lavalin Group
5th Floor, Block 5
Shire Hall
Bearland
Gloucester
GL1 2TH
Tel: 08000 514 514
www.atkinsglobal.com

Client: Gloucestershire County Council

Drawing Number: GCCM5J10-ATK-EWE-ZZ-GS-GI-000026
(Project | Originator | Volume | Location | Type | Role | Number)

Original Size:	Scale	Project Ref:	Sheet:	Rev:
A3	1:15,000	5214106	1 of 1	P02



LEGEND

- SCHEME ALIGNMENT
- MODEL DOMAIN

Description	Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
PUBLISHED	A1	P02	JM	NJ	CC	LJ	30/06/23

Drawing Suitability: PUBLISHED — Status: A1

ATKINS
Member of the SNC-Lavalin Group
5th Floor, Block 5
Shire Hall
Bearland
Gloucester
GL1 2TH
Tel: 08000 514 514
www.atkinsglobal.com

Client: Gloucestershire County Council

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

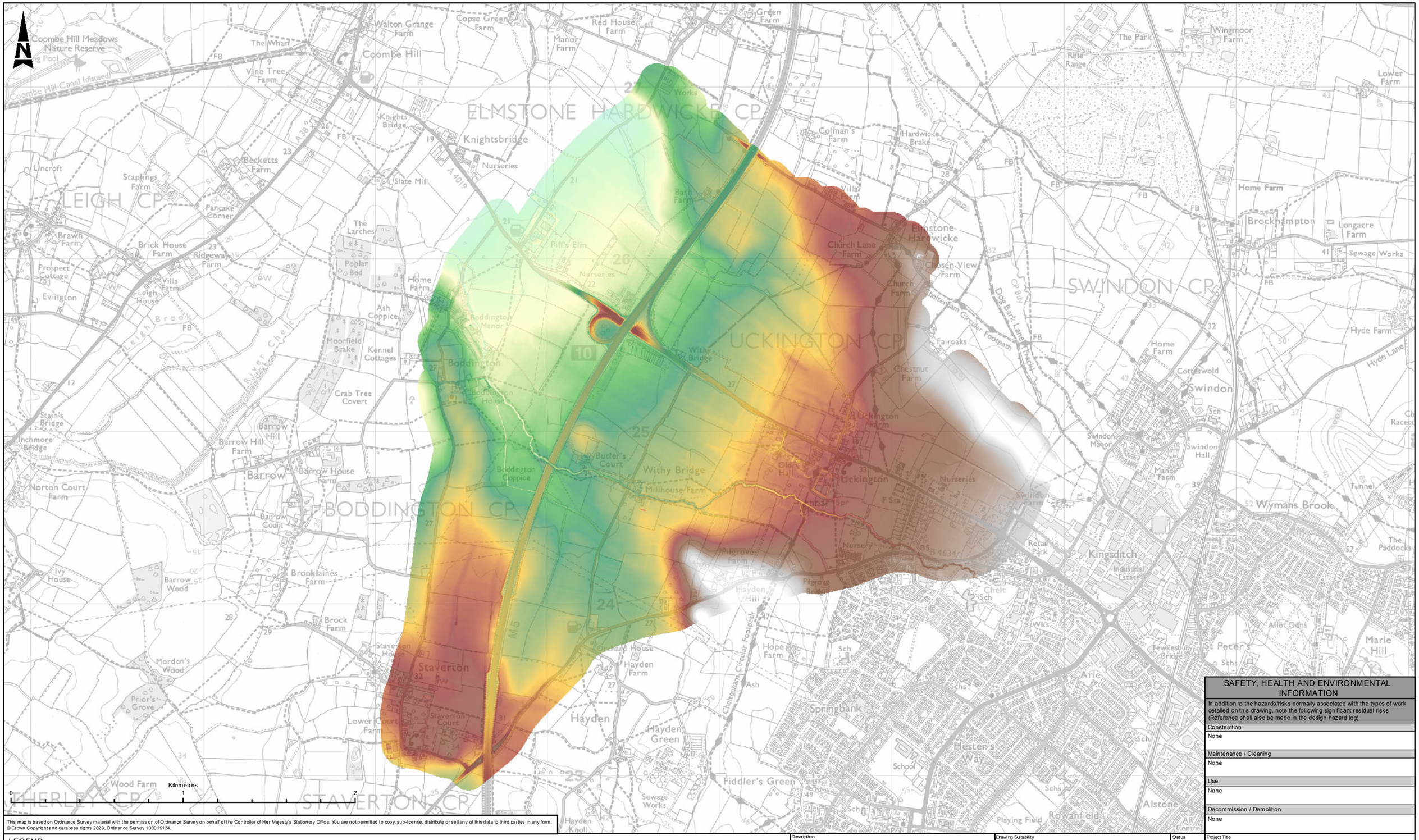
Construction	None
Maintenance / Cleaning	None
Use	None
Decommission / Demolition	None

Project Title: M5 Junction 10 Improvements Scheme

Drawing Title: FIGURE 4-1 STUDY AREA AND INDICATIVE SCHEME

Drawing Number: Project | Originator | Volume: GCCM5J10-ATK-EWE-ZZ-GS-GI-000028
Location | Type | Role | Number

Original Size:	Scale	Project Ref:	Sheet:	Rev:
A3	1:20,000	5214106	1 of 1	P02



LEGEND

EXISTING TERRAIN (mAOD)

Value

High : 46.2

Low : 18.6

Description	Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
PUBLISHED	A1	P02	JM	NJ	CC	LJ	12/09/23

Drawing Suitability: **PUBLISHED**

Status: **A1**

Project Title: M5 Junction 10 Improvements Scheme

ATKINS
Member of the SNC-Lavalin Group
5th Floor, Block 5
Shire Hall
Bearland
Gloucester
GL1 2TH
Tel: 08000 514 514
www.atkinsglobal.com

Client: Gloucestershire County Council

Drawing Title: FIGURE 4-2
SITE TOPOGRAPHY

Drawing Number: GCCM5J10-ATK-EWE-ZZ-GS-GI_000029

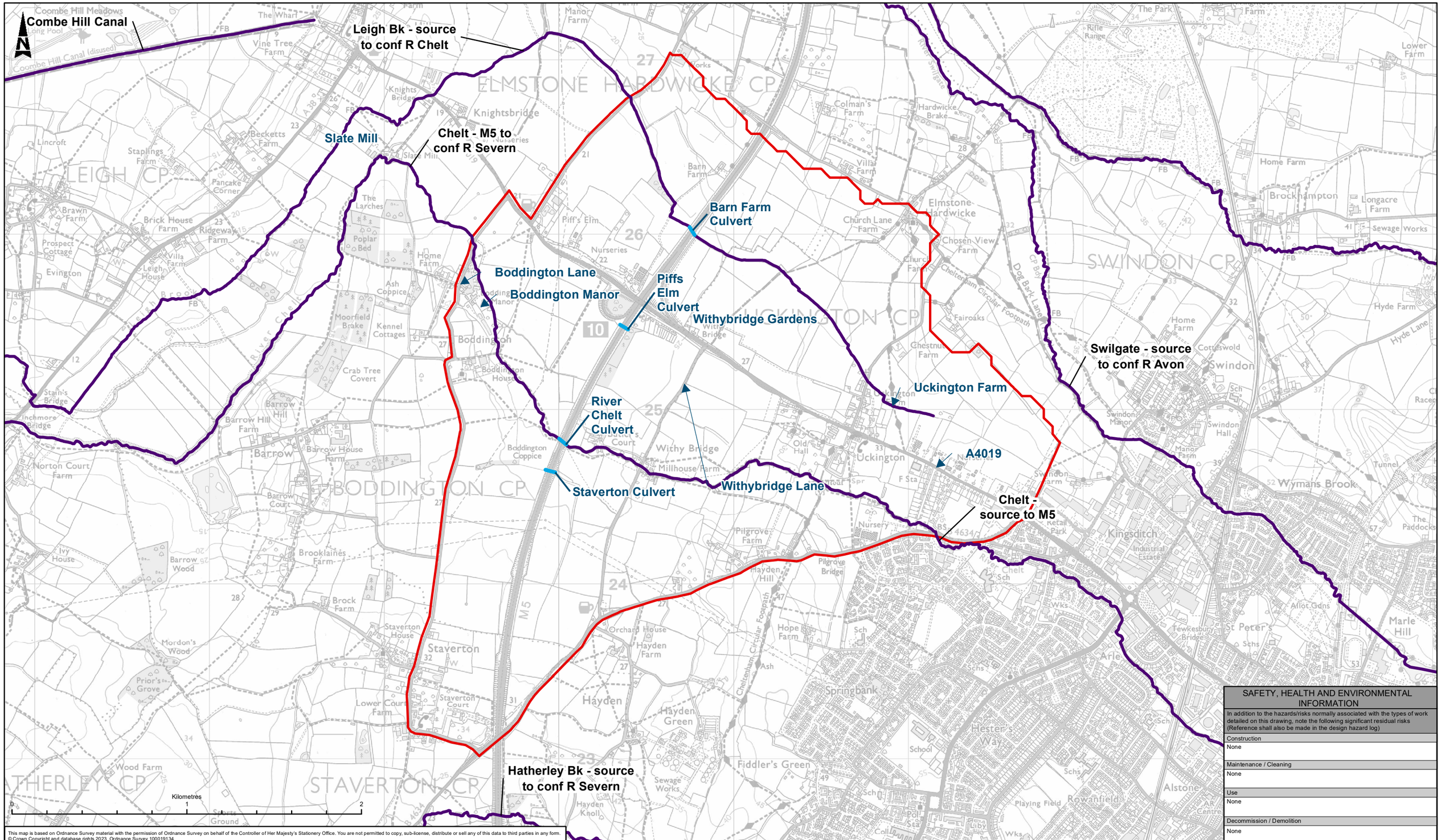
Project | Originator | Volume | Location | Type | Role | Number

Original Size:	Scale	Project Ref:	Sheet:	Rev:
A3	1:20,000	5214106	1 of 1	P02

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction	None
Maintenance / Cleaning	None
Use	None
Decommission / Demolition	None



LEGEND

- MODEL DOMAIN
- WFD WATERCOURSES
- M5 CULVERTS

Description	Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
PUBLISHED	A1	P02	JM	NJ	CC	LJ	17/07/23

Drawing Suitability: PUBLISHED

Status: A1

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction
None

Maintenance / Cleaning
None

Use
None

Decommission / Demolition
None

ATKINS
Member of the SNC-Lavalin Group
5th Floor, Block 5
Shire Hall
Bearland
Gloucester
GL1 2TH
Tel: 08000 514 514
www.atkinsglobal.com

Client: Gloucestershire County Council

Project Title: M5 Junction 10 Improvements Scheme

Drawing Title: FIGURE 4-3
MAIN HYDRAULIC FEATURES

Drawing Number: Project | Originator | Volume
GCCM5J10-ATK-EWE-ZZ-GS-GI_000030
Location | Type | Role | Number

Original Size:	Scale	Project Ref:	Sheet:	Rev:
A3	1:20,000	5214106	1 of 1	P02

AtkinsRéalis

5th Floor, Block 5
Shire Hall
Bearland
Gloucester
GL1 2TH

Tel: +44 (0) 8000 514 514