A417 Missing Link
TR010056

6.4 Environmental Statement
Appendix 13.3 Flood Risk Assessment

Planning Act 2008

APFP Regulation 5(2)(a)
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

A417 Missing Link

Development Consent Order 202[x]

6.4 Environmental Statement
Appendix 13.3 Flood Risk Assessment

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Table of Contents

Table of Photographs

Table of Tables

1 Introduction

1.1 Purpose of this document

1.1.1 This Flood Risk Assessment (FRA) is required to identify the sources of flood risk to and from the scheme. The scheme is described in Environmental Statement (ES) Chapter 2 The project (Document Ref 6.2).

1.1.2 A FRA is required in England for any development or change of use in Flood Zones 2 or 3[1], as identified from the Environment Agency (EA) flood maps[2], any development more than 1 hectare (ha) in size in Flood Zone 1[3] or any development which may be susceptible to flooding from sources other than rivers and the sea.

1.1.3 A review of the online EA flood maps[2] indicates that the site is within Flood Zone 1; however, as the overall development is greater than 1 ha a FRA is required in accordance with the current legislation.

1.1.4 Elements of the scheme which could potentially impact on flood risk include:

- The widening of the A417 up Crickley Hill and the adjacent earth bunding provided along the southern side of the alignment which introduces earthworks into the bottom of the existing valley on the southern toe which covers the existing watercourse. This necessitates a realignment of the stream on the south side of the new A417 embankment between Grove Farm and the existing culvert near Crickley Hill Farm (Flyup 417 Bike Park).
- The wider A417 up Crickley Hill also requires the existing culvert beneath the A417 to be replaced and extended under the raised and widened road and earth bunding.
- The scheme includes a large cutting through the limestone escarpment and a significant increase in paved areas. The size of the cuttings will result in some redistribution of existing catchments within the drainage system. These elements of the scheme could have an impact on flood risk from groundwater, artificial drainage and surface water sources.

1.2 Flood risk assessment methodology

1.2.1 This report has been prepared with reference to the National Policy Statement for National Networks (NPSNN), which sets out policies to guide how DCO applications will be decided and how the effects of national networks infrastructure should be considered. This report also considers the National Planning Policy Framework (NPPF)[4], the NPPF Technical Guidance[5] and follows the methodology prescribed in CIRIA document C624: Development and Flood Risk, Guidance for the Construction Industry[6].

1.2.2 The assessment process has proceeded as follows:

- **policy context:** a review of relevant national, regional and local policies
- **site and development description:** establishment of the nature of the existing site and of the scheme, so that relevant details can be described
- **baseline:** identification of all existing potential sources of flood risk
- **risk assessment:** assessment of the risks associated with relevant flood sources, mechanisms and impacts, so that the need for mitigation can be identified
- **mitigation:** identification of any flood risk management measures required

- **conclusions:** based on our assessment, whether flood risk to the development and surrounding areas will or will not increase over its lifetime

1.2.3 This FRA has been prepared using surveys and readily available information and has been informed by hydraulic modelling.

2 Flooding legislation and policy framework

2.1 Legislation

Flood Risk Regulations 2009

2.1.1 The Flood Risk Regulations 2009 require the assessment and management of flood risk in England and Wales. The regulations designate a Local Lead Flood Authority (LLFA) and impose duties on the EA and LLFAs to prepare a number of documents including:

- preliminary flood risk assessments
- flood risk and flood hazard maps
- flood risk management plans

Flood and Water Management Act 2010

2.1.2 The Flood and Water Management Act gives the EA a strategic overview of the management of flood and coastal erosion risk in England. In accordance with the Government's Response to the Pitt Review[7], it also gives upper tier local authorities in England responsibility for preparing and putting in place strategies for managing flood risk from groundwater, surface water and ordinary watercourses in their areas.

2.1.3 It provides for better, more comprehensive management of flood risk for people, homes and businesses, helps safeguard community groups from unaffordable rises in surface water drainage charges and protects water supplies to the consumer.

2.2 National policy

National Policy Statement for National Networks (NPSNN)

2.2.1 NPSNN paragraph reference 5.90 to 5.115 sets out how flood risk impacts should be considered. A NPSNN compliant FRA should include the following:

- Consideration of the risks of all forms of flooding arising from the project (including adjacent parts of the United Kingdom), in addition to the risks of flooding to the project, and demonstrate how these risks will be managed and, where relevant, mitigated, so that the development remains safe throughout its lifetime[8].
- The impacts of climate change should be taken into account, clearly stating the development lifetime over which the assessment has been made.
- Consideration of the vulnerability of those using the infrastructure including arrangements for safe access and exit.
- Inclusion of an assessment of the remaining (known as 'residual') risk after risk reduction measures have been taken into account and demonstrate that this is acceptable for the project.

- Consideration of whether there is a need to remain operational during a worst-case flood event of the development's lifetime.
- Evidence for the Secretary of State to apply the Sequential Test and Exception Test, as appropriate.

National Planning Policy Framework (NPPF)

2.2.2 The Department for Communities and Local Government (DCLG) published the NPPF on the 27 March 2012. This was a wholesale reform of the planning system and replaced all existing Planning Policy Guidance (PPGs) and Statements (PPSs) to make the planning system less complex and more accessible. It transfers more responsibility onto individual planning authorities and states that there should normally be a practice in favour of 'sustainable development'. The NPPF has subsequently been updated by the Ministry of Housing, Communities and Local Government (MHCLG) in July 2018 and again in February 2019.

2.2.3 The aim of the NPPF, particularly relating to flooding[9], is to ensure that flood risk is considered at all stages in the planning process, to avoid inappropriate development in areas at risk of flooding and to direct development away from areas at highest risk. It does this by formulating a risk-based approach towards flooding to be adopted at all levels of planning.

2.2.4 The NPPF requires that the "Sequential Test" is applied during the planning process. The Sequential Test aims to ensure that preference for developable land is given to land that has the lowest risk of flooding, based on the data available. The starting point for the 'Sequential Test' is the system of 'Flood Zoning'. This is a system that assesses the risk posed by rivers and in coastal areas estuaries and the sea. This information is collected and made available by the EA and the Local Planning Authority (LPA).

2.2.5 The Sequential Test requires that development should only be considered within Flood Zone 2 if there are no appropriate development sites in Flood Zone 1. Development in Flood Zone 3 should only be considered if development is not possible in Flood Zone 2; assuming development in Flood Zone 1 has also been ruled out.

2.2.6 The Flood Zoning system adopted in England is described in Table 2-1, as defined in NPPF technical guidance[3].

Table 2-1 Flood zoning system used across England as defined in NPPF

Flood zone	Definition
Zone 1 low probability	This zone comprises land assessed as having a less than 1 in 1,000 annual probability of river or sea flooding in any year (<0.1% Annual Exceedance Probability (AEP)).
Zone 2 medium probability	This zone comprises land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% - 0.1% AEP) or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% - 0.1% AEP) in any year.
Zone 3a high Probability	This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1% AEP) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5% AEP) in any year.
Zone 3b Functional Floodplain	This zone comprises land where water has to flow or be stored in times of flood. Strategic flood risk assessments (SFRAs) should identify this flood zone as land which would flood with an annual probability of 1 in 20 (5% AEP) or greater in any year or is designed to flood in an extreme (0.1% AEP) flood, or at another probability to be agreed between the LPA and the EA, including water conveyance routes.

2.2.7 The application of the Sequential Test relies on Regional Planning Bodies (RPBs) Regional Flood Risk Appraisals (RFRAs) which informs the Regional Spatial Strategies (RSS) and the LPA's Strategic Flood Risk Assessments (SFRAs) which informs the Local Development Framework (LDF) by identifying areas suitable for development. Therefore, the Sequential Test must be undertaken at an early stage of the development process (in some cases before land is purchased) and should involve close consultation with the LPA.

2.2.8 The NPPF encourages those involved in development to consider the flood vulnerability of the scheme to the impact of flooding. The vulnerability of different types of development is listed in the NPPF. This is relevant for considering what type of development is appropriate for a site (based on its Flood Zone) and how a development site should be laid out if there are different Flood Zones encountered within a wider site. The compatibility of a development in terms of its vulnerability and Flood Zoning is also described in the NPPF; as shown in Table 2-2. This illustrates how higher vulnerability land uses should be directed to lower flood risk locations sites and vice versa.

Table 2-2 Flood risk vulnerability and compatibility

Flood zone	Essential infrastructure	Water compatible	Highly vulnerable	More vulnerable	Less vulnerable
Flood Zone 1	✓	✓	✓	✓	✓
Flood Zone 2	✓	✓	Exception test	✓	✓
Flood Zone 3a	Exception test	✓	×	Exception test	✓
Flood Zone 3b "Functional Floodplain"	Exception test	✓	×	×	×

Key: ✓ Development is appropriate, × Development should not be permitted, 'Exception Test' will be required.

2.2.9 Should the sequential approach show it is not possible for the development to be located in zones of lower flood risk it may be possible to, using the 'Exception Test' demonstrate that development is still feasible by the management of flood risk. The 'Exception Test' within NPPF requires the demonstration that both:

- the development provides wider sustainability benefits that outweigh the flood risk.
- an FRA must be able to demonstrate that the proposed development is safe considering its expected lifetime and the vulnerability of the proposed land uses without increasing flood risk elsewhere and where possible reducing overall flood risk.

2.2.10 In April 2015 changes to the NPPF saw the Lead Local Flood Authority (LLFA) made a statutory planning consultee for development and flood risk issues except those concerning Main Rivers. Responsibility for the latter still resides with the EA. Furthermore, the LPA, through the planning system, were given the role of ensuring sustainable drainage is incorporated into schemes.

Strategic flood risk assessment

2.2.11 The Level 1 Strategic Flood Risk Assessment (SFRA)[9] contains an assessment of all forms of flood risk: fluvial, tidal, surface water, groundwater, sewers and impounded water bodies within Gloucestershire. The SFRA informs decision making processes in terms of new and existing developments and identifies the level required for site specific FRAs. The document also highlights sites at significant risk of flooding and guides developments to areas that lie within Flood Zone 1. Areas with a high likelihood of flooding from a combination of sources have been assessed further in the Level 2 SFRA[10] but as the scheme lies within Flood Zone 1 it is not included.

Joint Core Strategy 2011-2031

2.2.12 The Joint Core Strategy[11] is a partnership between Gloucester City Council (GCC), Cheltenham Borough Council (CBC) and Tewkesbury Borough Council (TBC) and is a strategic document that sets out how the area will develop between 2011 and 2031 and was adopted in December 2017. The relevant policies within the strategy include: INF1 – Transport Network and INF2 – Flood Risk Management. INF1 mentions the A417 as part of the strategic road network that Highways England (HE) is responsible for maintaining and improving. In INF2 the councils align themselves with the NPPF and commit to incorporating SuDS where possible.

3 Consultation

3.1 Introduction

3.1.1 There are several key local stakeholders and/or approving authorities associated with the development of the scheme, including the Environment Agency (EA), the LLFA (in this case GCC), water companies and Internal Drainage Boards (IDB), where applicable. The project teams have been in discussion with stakeholders since 2003.

3.1.2 Consultation with the EA and GCC is recorded in the respective Statement of Common Ground, see Statement of Commonality (Document Reference 7.3). A summary of the stakeholder consultations undertaken is presented in the following sections.

3.2 Environment Agency

3.2.1 The EA have wide ranging powers for Main Rivers and groundwater bodies under the Water Resources Act (1991)[12] and the Environment Act (1995)[13]. Under the

Flood and Water Management Act (2010)[14] they have a responsibility to produce a national strategy towards managing flood risk and are a statutory planning consultee for development and flood risk issues.

3.2.2 As a statutory consultee on flood risk matters the EA routinely inspect and assess development proposals. They can impose design criteria and requirements upon the design to ensure that the development itself is not at an unsatisfactory risk of flooding from any source, nor that the development will cause an increase in flood risk elsewhere.

3.2.3 The EA is responsible for managing the risk of flooding from main rivers, reservoirs, estuaries and the sea. They have been involved in various discussions with HE with regards to previous design phases and consultation will continue as the scheme progresses.

3.2.4 Initial feedback from the EA includes the following points:

- Data are available online for generating flood maps for planning[15], including fluvial and surface water flood extents, reservoir breach risks, flood warning areas (flood warnings are provided for Horsbere Brook which is to the west of the study area) and historic flood extents. These data sets have all been reviewed in the preparation of this FRA.
- Data from the EA's online flood mapping[2] indicates that the scheme lies completely within Flood Zone 1 which corresponds to a less than 1 in 1,000 annual probability of river or sea flooding in any year. This is confirmed by the GCC online public flood maps[16].
- The EA have listed their key concerns in terms of flood risk for the development[17]. These include risks to the watercourse adjacent to Crickley Hill and concerns around the current drainage system.
- The EA have confirmed that modelling a 70% fluvial allowance for climate change must be applied to fluvial flows if fluvial modelling is undertaken in accordance with the new FRA guidance[18].
- For drainage design, a peak rainfall climate change allowance of 40% is to be applied. This was suggested by the EA and agreed on with GCC[19].

3.2.5 Further feedback was provided by the EA in response to the 'A417 Missing Link Environmental Impact Assessment (EIA) Scoping Report'. Appendix 4.2 Responses to Scoping Opinion (Document Reference 6.4) documents the EA's response and Highways England's actions. Points of relevance included:

- The EA reiterated their concerns associated with flood risk and encouraged the planned site investigations to determine reliable baseline conditions.
- The EA stated it may be necessary to model Ordinary Watercourses where their catchment is below 3km² as these have not been included on the Flood Map for Planning[2]. This is only necessary for watercourses in close proximity to the scheme; a tributary of Norman's Brook adjacent to Crickley Hill.

3.2.6 The EA have been contacted regarding the FRA to request Product 4[20] data for the development area. As the scheme is located in Flood Zone 1, there were no recorded flood outlines and therefore a Product 4 response was not provided.

3.2.7 The information provided by the EA has been used to assess the baseline conditions and identify key flood risks.

3.3 Lead local flood authority

3.3.1 The LLFA is responsible for developing, maintaining, applying and monitoring a flood risk management strategy for Gloucestershire. For this project this LLFA is GCC, and will be referred to as GCC for the remainder of this document. GCC has made a number of strategic documents available via their website, including:

- a Level 1 and Level 2 SFRA published in September 2008[9,10], which assess all sources of flood risk within its geographic area of responsibility and aligns future development plans with low flood risk areas;
- a Preliminary Flood Risk Assessment (PFRA) published in November 2011[21], which compiles datasets containing historical flooding events from Ordinary Watercourses, surface water, sewers and groundwater; and
- a Local Flood Risk Management Strategy (LFRMS) published in summer 2014[22], which outlines the Council's role and implementation strategy. This strategy document has been produced in consultation with local partners and focuses on local sources of flooding from surface runoff, groundwater and Ordinary Watercourses.

3.3.2 GCC have been consulted with regards to the assessment of flood risk. A detailed record of consultation is documented in the respective Statement of Common Ground, see Statement of Commonality (Document Reference 7.3). Water company

3.4 Water companies

3.4.1 Severn Trent Water Ltd. (STW) and Thames Water Utilities Ltd. (TWU) are the potable water suppliers and sewerage undertakers with powers under The Water Industry Act 1991[23].

3.4.2 Under the Flood and Water Management Act, Water and Sewerage Companies are responsible for managing the risks of flooding from surface water and foul or combined sewer systems providing drainage from buildings and yards.

3.4.3 Consultation with STW has identified some of their assets which are being impacted by the scheme. These will result in STW assets being relocated, replaced or upgraded to maintain supply.

3.4.4 There were no TWU utilities identified as being impacted as a result of the scheme.

4 Baseline conditions

4.1 Sources of information

4.1.1 This assessment is based on the sources of information presented in Table 4-1 and initial consultation with key stakeholders (section 3). Whilst some of these documents have been written from a regional perspective, they are able to offer an indication of the wider flood risks that could be of concern to the scheme.

Table 4-1 Main sources of information used in preparing this document

Source/report title	Author	Year
Level 1 SFRA	GCC	2008
Level 2 SFRA	Gloucester, Cheltenham and Tewkesbury Joint Core Strategy	2011
PFRA	GCC	2011
LFRMS	GCC	2014
Level 1 FRA	Highways England	2019
Scoping Opinion	PINS	2019
EA Consultation Minutes	Correspondence between Highways England and EA	2018-19
A417 Missing Link Ground Investigation, Factual Report on Ground Investigation	Geotechnical Engineering Ltd	2019
Government Open Data[24]	Data.gov.uk	Accessed 2019
ES Appendix 13.7: Hydrogeological Impact Assessment (Document Reference 6.4)	Highways England	2021
Highways Agency Drainage Data Management System (HADDMS)	Highways England	Accessed 2019-2020
Received drainage records and maintenance information from RMS Ltd. (DBFO)	Several: WSP Civils Ltd, RMS (Gloucester) Ltd, Frank Graham Consulting Engineers	1993-2002 (received May 2020)
Topographical Survey	Conducted by Malcolm Hughes on behalf of HE	2019

4.2 Site description

4.2.1 The existing A417 is a strategic route between Gloucester and Swindon and is located in the Cotswolds AONB, further details are included ES Chapter 2 The project (Document Reference 6.2).

4.3 Topography

4.3.1 Topographical data has been obtained from the Ordnance Survey Open Data[25], topographical surveys, Open Government LiDAR and Geostore datasets. The development is located within the Cotswolds AONB and therefore the topography varies significantly across in the area due to the presence of several hills and valleys. The northwest-southeast trending Cotswold escarpment dominates the regional landscape, formed by the Jurassic limestones of the Inferior Oolite Group overlying the weaker, more easily eroded mudstones of the Lias Group. The scheme includes an asymmetrical valley adjacent to Crickley Hill, where the northern slopes are steeper than the southern slopes. The existing A417 runs along the axis of this valley. As detailed in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2), above the escarpment the landscape comprises an extensive plateau that follows the dip of the underlying limestone (2-5° to the east or southeast).

4.4 Fluvial flood risk

4.4.1 Flooding from rivers, streams and other natural inland watercourses is usually caused by prolonged or intense rainfall generating high rates of surface water runoff throughout the catchment. This overwhelms the capacity of the fluvial

system as a flood flow and as a result, spills into available floodplain storage areas.

4.4.2 From a review of the main documents presented in Table 4-1 and the water features survey completed between April 2018 and March 2019 (ES Appendix 13.11 Water features survey (Document Reference 6.4)), the general surface water features and catchments of interest have been summarised as follows:

- The scheme is located between the River Severn catchment and the River Thames catchment. To the west of the divide, the land drains to the River Severn and its tributaries, including Norman's Brook (via the tributary of Norman's Brook), Horsbere Brook and the River Frome. To the east and south-east, the land drains to the River Churn, a tributary of the Thames, via unnamed tributaries.
- A tributary of Norman's Brook lies within the study area, running parallel to and crossing under the existing A417 on Crickley Hill. This will be realigned as part of the scheme. A tracer test was conducted using tracer dye on 6 March 2019 to confirm the tributary is hydraulically connected to Norman's Brook and not Horsbere Brook as indicated in WFD waterbody delineation and online mapping. However, should the tributary of Norman's Brook culvert beneath the A417 become blocked, flow could cross the catchment boundary and flow towards Horsbere Brook[26]. A number of springs and areas of marshy ground have been identified on the slopes below the escarpment which drain into this watercourse. As the watercourse is not a Main River, flood management responsibilities lie with GCC and not the EA.
- The watercourses and springs identified are small, ephemeral and have catchment areas less than 3km², and have not been included in the EA fluvial flood modelling. Therefore, even though the EA fluvial flood map[2] does not show flood extents in this area, there is still a potential flood risk.
- The water features survey (ES Appendix 13.11 Water features survey (Document Reference 6.4)) conducted identified a number of ponds within close proximity, within 35m, to the scheme.

4.5 Surface water (pluvial flood risk)

4.5.1 A potential source of flooding is posed by rainwater that flows across the ground and inundates property or infrastructure before it can reach artificial or natural drainage features. This is a function of ground topography, the nature of the ground surface (permeability, vegetation etc.) and intensity of rainfall.

4.5.2 According to the EA's online Risk of Flooding from Surface Water (RoFSW) maps[2] there is some risk to the scheme in terms of surface water flooding from the tributary of Norman's Brook, which is the scheme's most prominent surface water feature. Ponding is also identified at the disused Crickley Hill Farm access bridge; considered to be due to insufficient culvert capacity[27].

4.5.3 The RoFSW maps[2] indicate a risk of surface water flooding between the Air Balloon roundabout and Cowley roundabout near Shab Hill; which drains towards the River Churn. Surface water flooding is also shown around Watercombe Farm, Castle Hill Cottage and Stockwell Farms, which drains towards the River Frome. These surface water flow paths correspond to headwaters of the tributaries to the River Churn.

4.5.4 The PFRA[21] indicates that there are no properties vulnerable to surface water flooding during an extreme rainfall event within the area of the scheme.

Hydraulic Modelling

4.5.5 A pair of integrated catchment models have been created in MicroDrainage to represent the existing baseline and the scheme to allow for comparison. These models consider both overland flows and those routed through drainage systems.

4.5.6 The principle features included in the baseline 1D model are the main tributary of Norman's Brook watercourse including culverts, highway and land drainage networks on A417 Crickley Hill and soakaways at A417 Birdlip Hill. The tributary of Norman's Brook culvert, which runs under the A417, has been represented using the best available data; a combination of as-built drawings, surveys and site visits. From the water feature survey (ES Appendix 13.11 Water features survey (Document Reference 6.4)) it has been determined that the existing watercourse features irregular meanders, a cascade, small ponds and several culverts. The watercourse has been represented in the model as a 600mm deep trapezoidal open channel, with the soffit set at existing ground level. The irregular nature of the channel is accounted for by utilising a high Manning's co-efficient.

4.5.7 As the catchment of the tributary of Norman's Brook is less than 3km^2 it has not been modelled by the EA to inform the fluvial flood maps[2]. The baseline catchment model therefore provides an updated overview of flooding of the area surrounding Crickley Hill.

4.5.8 The baseline flood outputs from the MicroDrainage model show similar surface water flood extents to the RoFSW maps[2]. The integrated model identifies the main flood routes west along Dog Lane and south west across the neighbouring field which corresponds with historical flooding evidence. This area of flooding is linked to the catchment draining through tributary of Norman's Brook culvert which passes under the existing A417 and along Dog Lane. Further details are provided in section 6.3 and the mapped flood extent is shown in ES Figure 13.20 Crickley Hill Surface Water Flooding - Baseline (Document Reference 6.3).

4.6 Groundwater flood risk

4.6.1 Flooding can occur in locations where groundwater is present at shallow depths. Prolonged periods of rainfall can result in elevated groundwater levels that can lead to the groundwater level reaching the surface as flooding. This can pose a flood risk to developments, particularly basements and cellars. In addition, the emergence of groundwater will prevent infiltration occurring and so will promote the occurrence of overland flow. Groundwater may also exfiltrate to existing surface water drainage systems of poor integrity, reducing their ability to accommodate surface water runoff.

4.6.2 Several watercourses in the study area, such as the tributary of Norman's Brook, are fed by springs meaning they are ephemeral and do not always have flow in their upper reaches. As a result, these surface watercourses are dependent on groundwater and sensitive to changes in groundwater levels and flows.

4.6.3 The British Geological Survey (BGS) Groundwater Susceptibility dataset indicates there is the potential for groundwater flooding to occur at the surface to the west of Crickley Hill. At Nettleton, in the River Frome headwater valley, there is a potential for groundwater flooding to occur at the surface or below ground. Along Crickley Hill and up to the Severn/Thames catchment divide, and in the southern extent of study area there is a limited potential for groundwater flooding to occur.

4.6.4 The geological characteristics of the study area are detailed in ES Chapter 9 Geology and soils (Document Reference 6.2).

4.6.5 The hydrogeological characteristics of the study area and groundwater monitoring data is presented in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).

4.6.6 The ground investigation data has been considered in the development of the groundwater conceptual models. These models primarily focus on the assessment of groundwater quality but also help inform the groundwater flow paths present. The conceptual models are described in detail in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).

4.6.7 The SFRA[9] does not identify the scheme to be at risk from groundwater flooding.

4.7 Artificial drainage systems

4.7.1 Artificial drainage systems designed to manage surface water runoff can pose a flood risk if the system is overwhelmed. This may occur if the amount of surface water runoff exceeds the system capacity or if the system becomes blocked or surcharged by the receiving watercourse. Artificial drainage systems designed to manage foul water (and combined effluent) can pose a flood risk and public health risk if the system is overwhelmed. This may occur if the amount of foul water allowed to discharge exceeds the system capacity.

4.7.2 Existing artificial drainage systems (foul, combined and surface) could pose a flood risk to the site in the event of failure. This would result in water (possibly contaminated) exploiting the overland flow routes.

4.7.3 For the scheme, the Highways Agency Drainage Data Management System (HADDMS) was used to understand current drainage. This database does not indicate conclusively what is connected and where the surface water discharges. The information available indicates that the drainage for this section of the road has been developed extensively over the time along with highway improvements resulting in several different approaches. These consist of gullies, concrete surface water channels, filter drains, carrier drains, ditches and soakaways. The network also appears to operate under free-flow conditions, with unconstrained discharges and limited attenuation.

4.7.4 The HADMMS database does not identify any flooding hotspots within the scheme area.

4.7.5 The topographic survey identified surface drainage elements such as gullies and manhole covers but did not include the survey of any below ground buried structures and services. The culverted section of the tributary of Norman’s Brook was initially omitted which was required to better understand artificial drainage flood risk. Given the importance of this culvert to the scheme, a topographic survey was commissioned to identify the route, size and levels of the culverted section of the watercourse located along the southern toe of Crickley Hill. The findings of this survey were reported in January 2020 but again did not provide complete line and levels for the culvert. Through several site-visits and as-built records, sufficient information of the culvert has since been obtained to allow it to be adequately represented in the hydraulic modelling undertaken for this scheme.

4.7.6 Based on available records it is considered that the existing A417 between Parsons Pitch and the current Air Balloon roundabout drains predominantly to groundwater via soakaways. Elsewhere the existing A417 within the study area drains to watercourses.

4.7.7 The tributary of Norman's Brook runs adjacent to the existing A417 between Crickley Hill Farm and Air Balloon roundabout and it is assumed that the runoff from the adjacent highway is discharged to this watercourse before passing beneath the A417 in culvert. This assumption was confirmed by the records received by the DBFO[28].

4.8 Infrastructure flooding

4.8.1 Where infrastructure exists that retains, transmits or controls the flow of water, flooding may result if there is a structural, hydraulic, geotechnical, mechanical or operational failure. This may be infrastructure that has been specifically designed and implemented as a water controlling structure, such as a water main or a dam. It may also be a structure such as a road or rail embankment. No such infrastructure was identified.

4.9 Historic flooding

4.9.1 Historic flooding is often a good indicator for future flooding. According to the EA's Historic Flood Map there are no recorded incidents of fluvial flooding within the site however this dataset is not definitive and may not capture the whole extents of all historic flooding. The PFRA does not mention flooding in the specific area of the site, but there have been significant flood events in the past associated with high levels of rainfall such as summer 2007 where culverted watercourses and drainage systems were overwhelmed[21].

4.9.2 Historical evidence of flooding along Dog Lane revealed that the culverted length of the tributary of Norman's Brook which passes beneath Dog Lane, regularly exceeds capacity and lifts the manhole cover off in front of the property associated with Witcombe Supplies. Surface water flooding from heavy rainfall events frequently flows down Dog Lane, before bearing left along Bentham Lane towards Little Witcombe. This takes water from the Norman's Brook catchment across to the Horsbere Brook catchment.

4.9.3 Evidence around the A417 Flyup highlighted the issue of the tributary of Norman's Brook culvert becoming blocked, with flow passing out of bank and flowing alongside the existing A417 to the south and flowing onto Bentham Lane towards Little Witcombe and the Horsbere Brook catchment.

5 Sequential and exception test

5.1 Sequential test

5.1.1 Data from the EA's online flood mapping[2] indicates that the scheme lies within Flood Zone 1 but as the site is greater than 1ha in area a Sequential Test is still required. The development can be classed as 'essential infrastructure'[9] due to the necessity of the development to improve regional transport routes.

5.1.2 This FRA details the flood risk associated with the proposed A417 Missing Link scheme outlined in Chapter 2 The Project (Document Ref 6.2).

5.1.3 As the development is classed as 'essential infrastructure' and is in Flood Zone 1, it passes the Sequential Test in accordance with Table 3 in the NPPF Technical Guidance[5].

5.2 Exception test

5.2.1 The Exception Test, as set out in the NPPF and outlined in Section 3.2 is a method used to demonstrate and help ensure that flood risk to people and

property will be managed satisfactorily, while allowing necessary development to go ahead in situations where suitable sites at lower risk of flooding are not available. It is comprised of two parts:

- demonstration that the site will provide wider sustainability benefits to the community that outweigh flood risks; and
- that it will be safe for its lifetime, without increasing flood risk elsewhere and where possible reduce flood risk overall.

5.2.2 As the scheme lies within Flood Zone 1 and is classified as 'essential infrastructure' an Exception Test is not required in accordance with Table 3 in the NPPF Technical Guidance[5] .

6 Flood risk assessment

6.1 Flooding sources

6.1.1 In line with best practice this section of the FRA considers flood risk from a range of possible sources. Based on a review of relevant policies, the nature of the development and the baseline information in Section 4 the following sources of flooding have been considered in detail:

- **Fluvial**: floodwater originating from watercourse when the amount of water exceeds the channel capacity of that watercourse.
- **Surface Water**: flooding caused by intense rainfall exceeding the available infiltration and/or drainage network capacity.
- **Groundwater**: flooding caused when groundwater levels rise above ground level following prolonged rainfall, obstructions to groundwater flow or rebound of previously depressed groundwater levels.
- **Artificial Drainage Systems**: flooding originating from surface water, foul or combined drainage systems, typically caused by limited capacity or blockages.

6.2 Fluvial flood risk

6.2.1 As the site is within Flood Zone 1, there is a limited risk of fluvial flooding. There is only one significant Ordinary Watercourse within the scheme footprint (the tributary of Norman's Brook located along the southern toe of Crickley Hill) and no specific recorded events of historic flooding. The lack of fluvial flood extents shown on EA flood mapping[2] is due to the watercourses in the study area being too small to be modelled by the EA.

6.2.2 The tributary of Norman's Brook which flows adjacent to the existing A417 approximately midway between the Brockworth bypass and Air Balloon roundabout needs to be realigned as part of the scheme. This is due to the widening of the highway to the south of the existing alignment where the tributary is located. The watercourse lies in a valley and existing constrictions and topography provide online attenuation.

6.2.3 A change in the flow pathway may impact on properties and aquatic environments close to flood zones. In particular, culverting or the realignment of the tributary of Norman's Brook may result in flooding further upstream and downstream without appropriate mitigation to attenuate flows.

6.2.4 Within the current design of the scheme, the channel will be realigned further up the valley side. It is anticipated that as the design becomes more detailed, the specific design details of the realigned channel, including its precise location, will

be informed by detailed hydraulic modelling to ensure that flood risk to the site and elsewhere is not increased, and where possible reduced.

6.2.5 This assessment indicates there is **low** risk of fluvial flooding to, or from the site.

6.3 Surface water (pluvial) flood risk

6.3.1 The additional lanes associated with the scheme could result in increased rates and volumes of surface water runoff, resulting from an increase in impermeable area or changes to the existing drainage regime. The scheme also results in a greater catchment area draining to the watercourse adjacent to Crickley Hill arising from the significant cutting between Shab Hill and the Air Balloon roundabout. This could lead to a potential increase in surface water flood risk. For this assessment the scheme has been considered in two sections; Cowley to the Air Balloon roundabout and Air Balloon roundabout to Brockworth bypass.

6.3.2 An assessment of the surface water flood risk has been undertaken based on the EA's RoFSW map data set[2], analysing the topography of the site and from a site walkover. This was further supported by hydraulic modelling (detailed in Sections 4.5 and 6.3) of the Crickley Hill section to improve the understanding of flood risk from the tributary of Norman's Brook. This baseline understanding has been used to inform the scheme's drainage design and surface water management.

6.3.3 There is a very low to low risk of flooding from surface water along the section of the existing A417 highway that lies between the Cowley and Air Balloon roundabouts.

6.3.4 Surface water flooding has been identified to the east of the scheme at Stockwell Farm Barn, between Cowley roundabout and Shab Hill. This forms a flow path which becomes the headwaters of the River Frome. A second surface water flow path is shown passing through Shab Hill Farm which forms the headwaters of the River Churn.

6.3.5 These surface water flow paths are not associated with a permanent watercourse but most likely arises due to the topography and the presence of a dry valley. This assessment indicates here is a **medium** risk of surface water flooding to, or from the scheme at this location.

6.3.6 Along the section between Air Balloon roundabout and the Brockworth bypass there is a high surface water flood risk following the channel of the tributary of Norman's Brook. The EA RoFSW maps[2] indicate that the surface water flow path passes up onto, then along the A417; it is not clear whether the EA modelling has taken account of the culvert beneath the A417. The site visit indicated that the A417 is raised slightly above the natural ground levels, so would likely intercept flow, and divert at least some of it south towards Bentham Lane should the culvert capacity be reached or become blocked. This is corroborated against historical evidence of flooding in the area.

6.3.7 As discussed previously, the scheme encroaches on the land where this watercourse flows, and provides attenuation, necessitating the realignment of the channel.

6.3.8 A site visit identified that the channel and car park area, upstream of NGR SO922157 backs up due to the limited capacity of the culvert. This has resulted in significant ponding and subsequent attenuation of flows and resulted in the car park being under approximately 300mm of water. Photographs and video footage (taken on 9 January 2020) also show water flowing from the site and following the

access track, located to the south of the existing A417, and joining with flood waters along Bentham Lane, heading towards Witcombe.

6.3.9 Evidence of historical flooding obtained on a site visit near Holly Brae Farm (Witcombe Supplies), north of the existing A417 and adjacent to Dog Lane, highlighted the fact that the culverted tributary of Norman's Brook often exceeds the culvert capacity and forces the manhole off in front of the property (Photograph 6-1). The resulting surface water then flows along Dog Lane and down Bentham Lane towards Witcombe and the Horsbere Brook catchment, rather than continuing to the Norman's Brook catchment.

Photograph 6-1 Manhole located along Dog Lane which lifts under high flow conditions

Hydraulic Modelling

6.3.10 It is recognised that the impacts of the scheme on the catchment of the tributary of Norman's Brook are more complex than in other areas. To improve the understanding of flood risk around Crickley Hill and allow impacts from the scheme to be assessed, integrated catchment models have been built using MicroDrainage hydraulic analysis software along with the FloodFlow module combining overland flows, watercourses, and highway collection systems.

6.3.11 The models allow the impact of the scheme to be compared against the baseline scenario taking in to account overland flows (2D) and through buried (and open) drainage systems (1D). The model has been verified against peak flows estimated using the Revitalised Flood Hydrograph (ReFH2) Rainfall-Runoff software. Given the size of the catchment an uplift of 40% to account for climate change was applied to the 100-year rainfall event in accordance with national planning guidance.

6.3.12 The catchment models give an improved understanding of baseline flood risk. As discussed in Section 4.5, the baseline maps demonstrate similar flood extents to the RoFSW maps[2] with the exception of additional flooding visible on Dog Lane. This additional flooding is a result of the more accurate representation of the tributary of Norman's Brook culvert and corroborates recorded evidence of flow paths in this area.

6.3.13 A hydraulic capacity assessment of the culvert running alongside Dog Lane was undertaken which found that the flooding threshold at Dog Lane corresponds approximately to the peak flow for a storm event between the 1-year and 5-year return period. In events up to the 1 in 100-year event, the upstream culvert beneath the A417 has sufficient capacity to convey the peak flows but will result in significant flooding along Dog Lane. It was also found that the 1 in 100-year

+CC (40%) event is likely to result in surcharge and flooding at the culvert headwall.

6.3.14 The scheme model incorporates new highway drainage networks, attenuation basins and land drainage ditches which constitute the drainage strategy in this location (details provided in ES Appendix 13.10 Drainage Report (Document Reference 6.4)). The topographical data is formed of a composite surface comprising the wider existing topographic survey merged with the new highway design surfaces generated from CAD earthworks and 3D road alignment models.

6.3.15 The key assumption in the proposed design is that the hydraulic performance and characteristics of the realigned watercourse will replicate the existing.

6.3.16 The initial outputs from the integrated model for the scheme indicate that the peak flows arriving at the top of the culvert lie within the envelope of the baseline hydrograph as shown in Table 6-1. This addresses GCC's request that the scheme will not increase flood risk at this location. The mapped flood extent is provided in ES Figure 13.21 Crickley Hill surface water flooding – scheme (Document Reference 6.3).

Table 6-1 Flows for the tributary of Norman's Brook for a range of return periods

Return Period (345-minute winter storm)	Peak Flow (l/s)	
	Existing	Proposed
1 in 100-year + climate change	1,365	1,315
1 in 100-year	1,100	881
1 in 50-year	1,008	771
1 in 30-year	806	619
1 in 5-year	564	387
1 in 1-year	233	187

6.3.17 The trend visible in the 1 in 100-year plus climate change allowance (40%) (Table 6-1) is maintained through other return periods and shows a reduction in both peak flow and discharge volume.

6.3.18 This assessment indicates there is a **medium** risk of surface water flooding to, and from the scheme along Crickley Hill.

6.3.19 The next iteration of the MicroDrainage model at detailed design will look at incorporating any further changes to the drainage design and to extend analysis to other key points of interest along the route as the scheme design develops.

6.4 Groundwater flood risk

6.4.1 The assessment of groundwater flood risk has been informed by the groundwater conceptual model and ongoing monitoring which are detailed in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4).

6.4.2 Within and nearby to the scheme there are several springs which could be impacted. This could have an adverse effect and cause a risk to the scheme or divert flood risk elsewhere

6.4.3 As detailed in section 13.8 of ES Chapter 13 Road drainage and the water environment (Document Reference 6.2), changes in flow paths could result from the introduction of below ground structures, excavations or embankments within the aquifers which may reduce flow to groundwater receptors, resulting in the

partial or total loss of springs and depletion of existing watercourses and conversely, the creation of new springs and/or localised groundwater flooding due to groundwater mounding up-gradient of the structure.

6.4.4 High rates of infiltration to groundwater during excessive rainfall events may result in the reactivation of springs or increased stream flow. This could lead to excess flow in cuttings, and the drainage system being overwhelmed.

6.4.5 Cuttings and deep piled foundations associated with scheme structures may cause local changes to groundwater flow and could induce groundwater flooding. These impacts are however likely to be localised.

6.4.6 This assessment indicates there is **medium to high** risk of ground water flooding to, and from the scheme. Groundwater monitoring is being undertaken as part of the ground investigations. The results of these investigations and the groundwater conceptual model will inform the need for any mitigation to be incorporated during detailed design.

6.5 Artificial drainage systems

6.5.1 The current drainage system allows free discharge and has limited attenuation and it is presumed that the surface water runoff from the existing A417 upstream of the tributary of Norman's Brook culvert discharges into the tributary of Norman's Brook. With the proposed widening of the A417 and subsequent additional impermeable area, an appropriate drainage network is required to manage runoff. Unattenuated discharge into the tributary of Norman's Brook would increase the existing level of flood risk, both to receptors along Dog Lane and Witcombe, via Bentham Lane.

6.5.2 Surface water from land south-west of the scheme's cutting between the Air Balloon roundabout and Shab Hill junction currently flows to the River Churn catchment via dry valleys at Leckhampton Hill and Ullenwood, which converge at the National Star College golf course. As a result of the scheme there would be a net increase of up to 23 ha in the catchment area to the tributary of Norman's Brook and a corresponding reduction in the catchment area to the River Churn. This would return the catchments to a situation closer to the natural delineation that existed before the A417 Birdlip Bypass scheme was constructed (1987).

6.5.3 The mitigation for the artificial drainage flood risk is described in detail in ES Appendix 13.10 Drainage Report (Document Reference 6.4).

6.5.4 This assessment indicates that given the proposed drainage strategy there is a **low** risk of artificial drainage flooding to, or from the site.

7 Flood risk mitigation

7.1.1 The scheme has been designed and configured in a manner that takes flood risk into consideration. The following section outlines mitigation measures for dealing with the risk identified in this assessment.

7.1.2 The mitigation is documented in Table 3-2: Register of environmental actions and commitments (REAC) in ES Appendix 2.1 Environmental Management Plan (EMP) (Document Reference 6.4).

7.1.3 Given the outcomes of the FRA (section 6) the mitigation will focus on the following:

- fluvial flood risk

- surface water flood risk
- groundwater flood risk
- artificial drainage flood risk

7.2 Fluvial flood risk

7.2.1 The only watercourse that is directly impacted by the scheme is the tributary of Norman's Brook that flows along the southern toe of Crickley Hill. No fluvial flood risk has been modelled for this watercourse; given the small catchment size. Flooding of this watercourse is linked to intense rainfall events and therefore covered in the surface water flood risk (section 7.3).

7.2.2 The channel realignment would be designed to ensure that flood risk is not increased as a result of the scheme. Flood mitigation methods associated with the realignment of the tributary of Norman's Brook include maintaining the character and geomorphology of the existing stream through reintroducing cascades and meanders and identifying possible sections of the culverted watercourse that could be de-culverted and naturalised.

7.2.3 The design of the features will be developed at detailed design. The channel design will be informed by the ecological surveys (ES Appendix 8.23 River Habitat Survey and Fish Habitat Assessment (Document Reference 6.4)) and hydromorphology surveys (ES Appendix 13.5 Hydromorphological Assessment (Document Reference 6.4)), along with flow monitoring (ES Appendix 13.12 Water Environment Monitoring Data (Document Reference 6.4)). A 5-metre-wide earthworks platform along the southern edge of the widened road embankment has been developed, within which there will be a smaller channel to convey typical flows in the watercourse.

7.3 Surface water flood risk

7.3.1 In accordance with the National Standards for Sustainable Drainage[29], a surface water drainage design incorporating the use of Sustainable Drainage Systems (SuDS), where possible, is required to accompany an FRA and planning application. The hierarchy of surface water management practices is as follows, from most preferred to least preferred:

- store rainwater for later use (e.g. rainwater harvesting)
- discharge to ground (infiltration)
- discharge to a surface waterbody
- discharge to a surface water sewer, highway drain or other drainage system
- discharge to a combined sewer

7.3.2 With regards to surface water management, GCC stipulates in its SFRA[10] that:

- developments should not increase the peak discharge/volume from any existing Greenfield site
- Attenuation should be provided to a 1 in 100-year standard taking into account the impact of climate change
- space should be set aside to incorporate SuDS

7.3.3 GCC standing advice[30] states that for developments which were previously developed the peak runoff rate from the development to any drain, sewer or surface water body up to the 1 in 100 year rainfall event + 40% for climate change should reduce the surface water discharge by 40% of that existing or be as close as is reasonably practicable to the greenfield runoff rate from the development for

the same rainfall event, but in any event should never exceed the rate of discharge from the development prior to redevelopment for that event

7.3.4 For the scheme the surface water management will be partly incorporated within the drainage design.

7.3.5 The section of the scheme between Cowley and the Air Balloon roundabout that crosses surface water flow paths will incorporate appropriately sized culverts, or equivalent structure, to allow the free passage of water beneath the scheme. The hydrological estimates associated with the structure design will be made using industry standard methodologies.

7.3.6 The hydraulic modelling results indicate that the scheme will not increase flood risk at the top of the tributary of Norman's Brook culvert as the peak flows lie within the envelope of the baseline hydrograph. There are opportunities to reduce the peak flows further by providing attenuation within the upstream catchment such as debris dams and other Natural Flood Management (NFM) measures within the watercourse channel, storage within the perimeter ditch network and source control in the highway drainage system.

7.3.7 The model has scope to be expanded in area to assess the flood risk associated with other points of interest along the route.

7.4 Artificial drainage flood risk

7.4.1 The drainage design will ensure adequate protection for the scheme, and neighbouring receptors, against flooding.

7.4.2 GCC require adherence to the SuDS hierarchy; meaning that the drainage strategy should, where possible, mimic the natural hydrology of the site. In this respect soakaways would be the preferred surface water disposal technique, rather than opting to connect to a watercourse or sewer. The drainage for the scheme will be designed in accordance with the Design Manual for Roads and Bridges (DMRB).

7.4.3 The local roads will also incorporate GCC drainage requirements. As the adopting highway authority, if GCC requires variation to DMRB design, standards and specification then these will take precedence.

7.4.4 The following parameters have been used for highway drainage:

- The highway drainage will be sized to convey a 1 in 1-year return period event including a 20% uplift for climate change without surcharging in accordance with DMRB.
- The design will ensure that there is no surface water flooding on the highway for a 1 in 5-year event with an allowance for climate change.
- The highway drainage system is assessed for events up to a 1 in 100-year return period event with a 40% climate change uplift and attenuation basins are sized for a +40% climate change uplift.

7.4.5 Where reconfiguration of the existing local roads will require new drainage to connect into existing networks, the proposals will provide a like for like or reduction of impermeable area. Where there is a net increase in paved area attenuation will be provided.

7.4.6 The strategy splits the scheme into several drainage catchments, each of which has a proposed drainage solution. The following lists provisions within the overall drainage strategy:

- A range of collection systems, including gullies, concrete or grass surface water channels and filter drains to collect surface water flows from the existing A417 carriageway.
- Perimeter ditches, swales, or field drains to intercept overland runoff where external catchments drain towards the scheme.
- Filter drains or fin drains will be provided in all mainline super-elevated central reserves and alongside low side carriageway verges to ensure adequate drainage of the road pavement and foundations.
- Filter drains at toes of new earthworks and existing slopes to intercept run-off from earthwork slopes and ensure stability of cuttings and embankments.
- Several locations have been identified for basins to attenuate discharge, all of which will have flow control devices on the outfall. There are currently 12 drainage basin sites planned but these are being refined as the drainage design develops.
- Whilst soakaways are to be implemented wherever possible, their use will be limited to specific sites where they will be effective. Their use may also be restricted in locations where it is necessary to avoid undermining earthworks or existing sensitive slopes.

7.4.7 The drainage strategy will adhere to the SuDS hierarchy, but where infiltration is not possible, the surface runoff will be attenuated to Greenfield Runoff Rates (GFRR).

7.4.8 Further details of artificial drainage can be found in ES Appendix 13.10 Drainage Report (Document Reference 6.4).

7.5 Groundwater flood risk

7.5.1 The potential impacts from scheme upon groundwater resources and groundwater dependent features including local springs and dry valleys are assessed in ES Chapter 13 Road drainage and the water environment (Document Reference 6.2) and ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4) and mitigation outlined.

7.5.2 Cuttings and retaining structures within cuts are planned to have suitable drainage measures 1m below the adjacent finished road level.

7.5.3 The drainage design will be configured to manage inflows so that intercepted groundwater flows will remain within the catchment of the respective receiving waterbody, where possible. The intercepted groundwater will be carried from the horizontal drains to a surface water discharge point, within the same receiving water that the groundwater would naturally have discharged to.

7.5.4 The groundwater captured within the Air Balloon cutting drainage network will be carried downstream of the cutting and will feed back into the realigned tributary of Norman’s Brook.

8 Conclusions and recommendations

8.1.1 The scheme is located between Gloucester and Swindon and involves upgrading the existing single carriageway to a dual carriageway; to match the rest of the route. The scheme lies within the Cotswolds AONB and the topography varies significantly across the site.

8.1.2 This FRA has been completed based on information available online, data provided as part of the consultation exercise and from site investigations and MicroDrainage modelling.

8.1.3 The scheme intercepts surface water features such as watercourses and ponds, many of which are spring fed.

8.1.4 Consultation has been carried out with the EA and GCC.

8.1.5 Groundwater monitoring and modelling is presented in the ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4). The groundwater model which has been developed provides initial indications about the impact of the scheme on groundwater.

8.1.6 The EA previously confirmed that a 70% uplift be applied to the 100-year fluvial flows and a 40% uplift applied to the peak rainfall totals for smaller catchments (<5km²) to account for climate change. Given the size of the tributary of Norman's Brook catchment and that modelling has been based on a direct rainfall approach to evaluate surface water flooding, a 40% uplift to account for climate change was adopted.

8.1.7 A hydraulic model has been constructed for the Crickley Hill area to inform understanding of both baseline and proposed surface water flooding and to ensure flows are not being increased as a result of the scheme. A more detailed representation of the existing and proposed channels of the tributary of Norman's Brook will be included in the model at detailed design.

8.2 Summary of flood risk

8.2.1 **Fluvial flood risk**: The entirety of the scheme lies within Flood Zone 1 and therefore is at very low risk of fluvial flooding. The tributary of Norman's Brook will be realigned as part of the scheme.

8.2.2 **Surface water flood risk**: The majority of the scheme is at a very low risk of flooding from surface water but there are a few areas of high surface water flood risk shown on the EA flood maps[2] and the integrated hydraulic model.

8.2.3 Between the Cowley and Air Balloon roundabouts, the scheme crosses a surface water flow path near Shab Hill Farm. Suitably sized structures will be included in the design to ensure free passage of surface water flows.

8.2.4 The tributary of Norman's Brook flowing down Crickley Hill presents a significant surface water flood risk which might be exacerbated by the realignment of this channel and increase in drainage area as part of the scheme. The baseline modelling has improved the understanding of the current surface water flood risk.

8.2.5 The scheme around Crickley Hill has also been modelled and initial results indicate that with the proposed drainage strategy the scheme will not increase flood risk here or further downstream. However, there is still a residual risk should the tributary of Norman's Brook culvert reach capacity or become blocked.

8.2.6 Based on the current understanding of the surface water flood risk for the scheme, the risk is considered to be **medium**.

8.2.7 **Groundwater flood risk**: There are several springs and watercourses that are groundwater fed within the scheme footprint. The hydraulic link between groundwater levels and the surface water features is being determined by the ongoing ground investigation monitoring, which is assessed as part of the ES Chapter 13 Road drainage and the water environment (Document Reference 6.2) and detailed in ES Appendix 13.7 Hydrogeological Impact Assessment (Document Reference 6.4). Due to the potential impact on groundwater from elements of the scheme such as cuttings and buried structures, the groundwater flood risk at this stage is considered to be **medium**.

8.2.8 **Artificial drainage flood risk**: The existing network appears to operate under free-flow conditions with unconstrained discharges and negligible attenuation. The scheme will increase the drainage catchment areas and surface runoff rates from the increased impermeable area but has been accounted for within the scheme's drainage strategy (ES Appendix 13.10 Drainage Report (Document Reference 6.4. The flood risk associated with artificial drainage is considered **low**.

8.3 Flood mitigation

8.3.1 The mitigation outlined in this section is documented in Table 3-2: Register of environmental actions and commitments (REAC) in ES Appendix 2.1 EMP (Document Ref 6.4).

8.3.2 **Fluvial flood risk**: Fluvial flood risk has not been identified.

8.3.3 The realignment of the tributary of Norman's Brook would be designed to cater for the ecological requirements of aquatic species present in the tributary of Norman's Brook. The barriers (man-made weirs) currently present within the tributary of Norman's Brook would not be recreated in the new channel, which would be characterised by step-pool habitat, typical of higher gradient headwater streams. The new channel would improve connectivity of habitat for aquatic species.

8.3.4 **Surface water flood risk**: Surface water management will be partly incorporated within the scheme's drainage design. The hydraulic model will be used to inform the detailed design to ensure any residual surface water flood risk is mitigated.

8.3.5 Where the scheme passes over surface water flood flow paths, culverts will be designed to accommodate flow. The hydrology for the catchment draining to this point will be estimated using modelling or industry standard methods and used to size the structures to reduce ponding or flood risk.

8.3.6 Attenuation methods will also be implemented if necessary, as further mitigation and to reduce peak flows entering the drainage network such as at the tributary of Norman's Brook culvert.

8.3.7 Mitigation has been considered for construction of the scheme as well as specifically for the realignment of the tributary of Norman's Brook. The general measures include the implementation of a temporary surface water management system early on in the construction sequencing and ensuring site compounds and all plant and material used to be stored outside of the floodplain. Specifically, for the tributary of Norman's Brook, it will be ensured that the temporary works will have suitable provisions to pass high flows, and the water within the catchment

area will be monitored. Full details of the flood risk mitigation for the construction process is provided in ES Appendix 2.1 EMP (Document Ref 6.4).

8.3.8 Opportunities for SuDS considering both flood attenuation and water quality are identified where possible along the scheme.

8.3.9 **Groundwater flood risk**: The drainage design includes aspects of groundwater flood risk management such as managing inflows so that the intercepted groundwater flows would remain within the catchment of the respective receiving waterbody.

8.3.10 **Artificial drainage flood risk**: The drainage design for the scheme incorporates gullies, concrete surface water channels, filter drains, carrier drains, ditches, attenuation basins and soakaways. Highway runoff will not be allowed to discharge freely, instead attenuation basins and swales are being incorporated into the drainage design to manage this.

References

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[18] Correspondence between HE and the Environment Agency (31.08.2017)
[19] Correspondence between HE and the Environment Agency (08.03.2019)
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