M5 Junction 10 Improvements Scheme

Preliminary Environmental Information Report (PEIR)

Climate chapter

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Document accessibility

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Glossary

Abbreviation	Definition
AADT	Annual Average Daily Traffic
AAWT	Annual Average Weekday Traffic
AEP	Annual Exceedance Probability
ALC	Agricultural Land Classification
AMP	Archaeological Management Plan
AONB	Area of Outstanding Natural Building
ARN	Affected Road Network
ASPT	Average Score Per Taxon
AQAL	Air Quality Assessment Level
AQMA	Air Quality Management Area
AQS	Air Quality Strategy
BAP	Biodiversity Action Plan
BCT	Bat Conservation Trust
BEIS	Department of Business, Energy, and Industrial Strategy
BGS	British Geological Survey
BMV	Best and Most Versatile
BoQ	Bill of Quantities
BS	British Standards
BTO	British Trust for Ornithology
CAMS	Catchment Abstraction Management Strategy
CBC	Cheltenham Borough Council
CBC	Common Birds Census
CCC	Committee on Climate Change
CD&E	construction, Demolition and Excavation
CEMP	Construction Environmental Management Plan
CEA	Cumulative Effects Assessment
CIEEM	Chartered Institute of Ecology and Environmental Management
CIRIA	Construction Industry Research and Information Association
CL:AIRE	Contaminated Land: Applications in Real Environments
CLP	Classification, Labelling and Packaging
CMS	Continuous Monitoring Station
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COP	Conference of the Parties
COSHH	Control of Substances Hazardous to Health
CPS	Connecting Places Strategies
CRoW	Countryside and Rights of Way
CRTN	Calculation of Road Traffic Noise
CSZs	Core Sustenance Zones
DCO	Development Consent Order
DfT	Department for Transport
DM	Do Minimum
DMOY	Do Minimum Scenario in the Opening Year
DMFY	Do Minimum Scenario in the Future Assessment Year
DMRB	Design Manual for Roads and Bridges
DoE	Department of the Environment
DoWCoP	Definition of Waste: Development Industry Code of Practice
DS	Do Something
DSFY	Do Something in the Future Assessment Year
DSOY	Do Something Scenario in the Opening Year
EC	European Commission
ECoW	Ecological Clerk of Works
eDNA	environmental DNA

Abbreviation	Definition
EEA	European Economic Area
EFT	Emissions Factors Toolkit
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
END	Environmental Noise Directive
EPA	Environmental Protection Act
EPS	European Protected Species
EPUK	Environmental Protection UK
EQS	Environmental Quality Standards
EU	European Union
ES	Environmental Statement
FRA	Flood Risk Assessment
ES	Environmental Statement
GCC	Gloucester City Council
GCER	Gloucestershire Centre for Environmental Records
GCN	Great Crested Newt
GFirst LEP	Gloucestershire Local Enterprise Partnership
GHER	Gloucestershire Historic Environment Record
GHGs	Greenhouse Gases
GLNP	Gloucestershire Local Nature Partnership
GLVIA3	Guidelines for Landscape and Visual Impact Assessment
GLTA	Ground Level Tree Assessment
GPLC	Guiding Principles for Land Contamination
GWDTE	Groundwater Dependant Terrestrial Ecosystems
GWT	Gloucestershire Wildlife Trust
HDV	Heavy Duty Vehicles
HER	Historic Environment Record
HEWRAT	Highways England Water Risk Assessment Tool
HGVs	High Good Vehicles
HIF	Housing Infrastructure Fund
HLC	Historic Landscape Characterisation
HMC	Habitat Modification Class
HMS	Habitat Modification Score
HRA	Habitat Regulations Assessments
HSI	Habitat Suitability Index
IAQM	Institute of Air Quality Management
IDB	International Drainage Board
IPCC	International Panel on Climate Change
JCS	Joint Core Strategy
JNCC	Joint Nature Conservation Committee
LAQM	Local Air Quality Management
LCAs	Landscape Character Assessments
LCRM	Land Contamination: Risk Management
LCT	Landscape Character Type
LDV	Light Duty Vehicles
LLFA	Lead Local Flood Authority
LNR	Local Nature Reserves
LOAEL	Lowest observed adverse effect level
LTP	Local Transport Plans
LVIA	Landscape and Visual Impact Assessment
MAFF	Ministry of Agriculture, Fisheries and Food
MCHW	Manual of Contract Documents for Highway Works
MHCLG	Ministry of Housing, Communities and Local Government
MMP	Materials Management Plan
MSA	Mineral Safeguarding Areas
MW	Minor Watercourse

Abbreviation	Definition
NCA	National Character Area
NERC	Natural Environment and Rural Communities
NHLE	National Heritage List for England
NIAs	Noise Important Areas
NMP	National Mapping Programme
NMU	Non- Motorised User
NNR	National Nature Reserves
NPS NN	National Policy Statement for National Networks
NOEL	No Observed Effect Level
NPPF	National Planning Policy Framework
NPPG	National Planning Practice Guidance
NPSE	Noise Policy Statement for England
NSIP	Nationally Significant Infrastructure Projects
NSR	Noise Sensitive Receptors
NVC	National Vegetation Classification
OS	Ordnance Survey
PAH	Polyaromatic Hydrocarbons
PAS	Portable Antiquities Scheme
PCBs	Polychlorinated Biphenyls
PCF	Project Control Framework
PCL	Potential Contaminant Linkage
PCM	Pollution Climate Mapping
PCSM	Preliminary Conceptual Site Model
PEAOR	Preliminary Environmental Assessment of Options Report
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PPE	Personal Protective Equipment
PPGs	Pollution Prevention Guidelines
PPG	Planning Practice Guidance
PPS10	Planning Policy Statement 10
PPGN	Planning Practice Guidance: Noise
PRA	Preliminary Roost Assessment
PRoW	Public Right of Way
Q_{95}	The 5 percentile flow
RAMS	Risk Assessments, Method Statements
RBD	River Basin Districts
RBMP	River Basin Management Plans
RCP	Relative Concentration Pathway
RCS	River Corridor Survey
RFFPs	Reasonably Foreseeable Future Projects
RHS	River Habitat Survey
RNAG	Reason for not Achieving Good
RoWIP	Rights of Way Improvement Plan
SAC	Special Area of Conservation
SHMP	Soil Handling Management Plan
SM	Scheduled Monument
SOAEL	Significant Observed Adverse Effect Level
SoCC	Statement of Community Consultation
SPD	Supplementary Planning Document
SPA	Special Protection Area
SPZ	Source Protection Zones
SSSI	Site of Special Scientific Interest
SuDS	Sustainable Drainage Systems
SWMP	Site Waste Management Plan
TAMP	Transport Asset Management Plan
TBC	Tewkesbury Borough Council

Abbreviation	Definition
TAR	Technical Appraisal Report
TSCS	Thin Surface Course System
UKCP18	United Kingdom Climate Projections 2018
UNFCCC	United Nations Framework Convention on Climate Change
UXO	Unexploded Ordnance
VfM	Value for Money
WCH	Walkers, Cyclists and Horse Riders
WEEE	Waste Electrical and Electronic Equipment
WER	Water Environment Regulations
WFD	Water Framework Directive
WHTP	Whalley, Hawkes, Paisley & Trigg
WSI	Written Scheme of Investigation
ZTV	Zone of Theoretical Visibility

The Chapters 1-4 of this PEIR have been produced as a separate document.

1. Introduction

2. The Scheme

3. Assessment of Alternatives

4. Environmental Assessment Methodology

Table 4-1 - Significance Matrix

Sensitivity of receptor	Magnitude of impact				
	Major	Moderate	Minor	Negligible	No change
Very high	Very large	Large or very large	Moderate or large	Slight	Neutral
High	Large or very large	Moderate or large	Slight or moderate	Slight	Neutral
Medium	Moderate or large	Moderate	Slight	Neutral or slight	Neutral
Low	Slight or moderate	Slight	Neutral or slight	Neutral or slight	Neutral
Negligible	Slight	Neutral or slight	Neutral or slight	Neutral	Neutral

Table Source: DMRB LA 104 Environmental assessment and monitoring Table 3.8.1

Table 4-2 - Significance categories and typical descriptions

Value	Typical descriptors
Very Large	Effects at this level are material in the decision-making process.
Large	Effects at this level are likely to be material in the decision-making process.
Moderate	Effects at this level can be considered to be material decision-making factors.
Slight	Effects at this level are not material in the decision-making process.
Negligible	No effects or those that are beneath levels of perception, within normal bounds of variation or within the margin of forecasting error.

Table Source: DMRB LA 104 Environmental assessment and monitoring Table 3.7

The discipline specific chapters of this PEIR have been produced as separate documents.

5. Air Quality

6. Noise and Vibration

7. Biodiversity

8. Road Drainage and the Water Environment

9. Landscape and Visual

10. Geology and Soils

11. Cultural Heritage

12. Materials and Waste

13. Population and Human Health

14. Climate

14.1. General introduction

14.1.1. This chapter presents the preliminary environmental assessment of the M5 Junction 10 Improvements Scheme (the Scheme) for Climate based on the Scheme as it is described in Chapter 2 (and detailed in the Design Fix 2 drawings in Appendix 2.1). This chapter identifies the study area, describes the methodology, presents baseline conditions, identifies potential impacts and presents suggested mitigation measures.

14.1.2. This chapter has been divided into two sub-sections in order to address the climate change requirements outlined in The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (SI 2008/301), which state that the assessment should consider both:

- The potential effects of the Scheme on climate, in particular the magnitude of greenhouse gases (GHGs) emissions emitted during both construction and operation; and
- The vulnerability of the Scheme to climate change, in particular the impacts of extreme weather (caused by climate change) during operation and construction and adaptation to mitigate the effects of these impacts.

EFFECTS ON CLIMATE

14.2. Planning policy and topic legislative context

14.2.1. Human activities contribute to the emission of GHG such as carbon dioxide (CO_2) to the atmosphere, primarily by the combustion of fossil fuels. GHG trap heat in the atmosphere, with higher concentrations leading to increased global temperatures. Atmospheric CO_2 concentrations now exceed 400 parts per million for the first time in around 3 million years[1], and increased emissions have led to global average surface temperatures of 1°C higher than pre-industrial levels. There is a global consensus that emissions must be reduced dramatically. Relevant international, national and local policies are cited below in Table 14-1.

Table 14-1 - Policy Review

Scale	Policy Document	Policy Summary
International	Kyoto Protocol (1997)	The first international agreement to mandate GHG emission reductions. Under the United Nations Framework Convention on Climate Change (UNFCCC) treaty, industrialised nations pledged to cut their annual emissions by 5% on a 1990 baseline by 2012. Although the target was met successfully, it was insufficient to offset the increase in emissions from industrialising countries. Total global emissions continued to grow over the period, by 40% between 1990 and 2009.
	Paris Agreement (2015)	Strengthened negotiations at Conference of the Parties (COP) 21 led to the 2015 Paris Agreement, the aim of which is to maintain the increase in global average temperature at 'well below' 2°*C* and 'pursue efforts' to limit the temperature increase even further to 1.5°*C*. By April 2016, 190 parties, including the UK, had made voluntary pledges to reduce emissions[2], however the cumulative effect of these would still lead to an estimated 3°*C* of warming or greater.

[1] Atmospheric CO2 concentrations in 2020
[2] Intended Nationally Determined Contributions

Scale	Policy Document	Policy Summary
		In 2018, the International Panel on Climate Change (IPCC) published a special report in response to the Paris Agreement, to present the impacts of the targeted 1.5°*C* temperature rise. The report highlighted that to achieve this, global emissions must decrease by 45% by 2030 (against a 1990 baseline), and that net zero global emissions (where emissions and removals from the atmosphere are balanced) must be achieved by 2050. This is noted to require rapid and far-reaching transitions of every sector on an unprecedented scale.
National	Climate Change Act (2008)	To support international efforts, the UK Climate Change Act (2008) set a legal reduction target of 80% against 1990 levels by 2050. It also introduced a series of carbon 'budgets' for five-year periods, to act as stepping-stones to the overall reduction. There are budgets currently set up to 2032. In response to the ambitions of the Paris Agreement, in 2019 the Climate Change Act was amended to set the overall reduction target by 2050 to at least 100% in net emissions against 1990 levels. The UK has so far outperformed its budgets, but progress is slowing, and the country is not on track to meet its future budgets or the overall reduction target, according to the most Recent Progress to Parliament by the Committee on Climate Change (CCC)[3] .
	National Planning Policy Framework (NPPF) (2021)	Paragraph 152 outlines its support for transitioning to a low carbon future, by way of reducing GHG emissions and supporting renewable and low carbon energy and associated infrastructure. Building on the NPPF, planning practice guidance published in June 2014 advises on how to identify suitable measures in the planning process to mitigate for and adapt to climate change.
	National Policy Statement for National Networks (NPS NN) (2014)	The NPS NN paragraph 5.17 states that 'it is very unlikely that the impact of a road project will, in isolation, affect the ability of Government to meet its carbon reduction plan targets.' However, the paragraph goes on to say that applicants should provide evidence of the carbon impact of the project and an assessment against the Government's carbon budgets. Paragraph 5.18 states that any increase in carbon emissions is not a reason to refuse development consent, unless the increase in carbon emissions resulting from the Scheme are so significant that it would have a material impact on the ability of Government to meet its carbon reduction targets. Paragraph 5.19 outlines the need for appropriate mitigation measures to be implemented in both design and construction. The effectiveness of such mitigation will be considered by the Secretary of State in order to ensure the carbon footprint is not 'unnecessarily high', with the adequacy of the measures constituting a material factor in the decision-making process.
	Construction 2025	Construction 2025 sets out how efficiency improvements will be created in construction covering sustainability and carbon and including a target to reduce emissions by 50%.

[3] Recent Progress to Parliament by the Committee on Climate Change

Scale	Policy Document	Policy Summary
		The emissions reduction target of 50% is not scheme specific, and the efficiency improvements are broad. In terms of the Scheme and emissions reduction, the reduction target should be taken into account when developing Scheme specific mitigation measures, where relevant.
	Infrastructure Carbon Review	HM Treasury produced the Infrastructure Carbon Review (2013) to set out carbon reduction actions required by infrastructure organisations. In terms of the Scheme and emissions reduction, the reduction actions should be taken into account when developing Scheme specific mitigation measures, where relevant.
Local	Gloucestershire Joint Core Strategy (JCS) 2011-2031 (2017)[4]	Policy INF6: Infrastructure Delivery is particularly relevant to the Scheme as it makes reference to the need for additional infrastructure and services and the relevance to climate change. The policy states that the local authority should *'seek to secure appropriate infrastructure, which is necessary, directly related, and fairly and reasonably related to the scale and kind of the development proposal',* including climate change mitigation and adaptation.'
	Gloucestershire's Climate Change Strategy (2019)	All Gloucestershire councils have declared a Climate Emergency. GCC's vision is stated as*: 'By 2050 we will create a carbon neutral county that provides quality of life now and for future generations, having improved the quality of our natural environment. By 2030 we will have reduced our carbon emissions by 80%.'* Following the declaration, a climate change strategy was produced to outline the actions needed to reach this target. One of eight 'themes for action' within the strategy is 'Transport – carbon busting options for all': *'As the lead highways authority (with connections to public transport) we will help to improve air quality in the six districts, encouraging a significant shift in travel behaviour, reducing car emissions in the county. We will reflect our new commitments in our Local Transport Plan[5], clearly identifying strategies to reduce carbon emissions. We will take the lead on co-ordinating the growth of electric vehicles and other low carbon transport, and the associated charging infrastructure.'* Another theme within the Strategy is 'Putting climate change at the heart of decision making'.
Guidance	PAS 2080:2016 Carbon Management in infrastructure	Acts as a global standard for managing infrastructure carbon. The framework looks at the whole value chain, aiming to reduce carbon and reduce cost through more intelligent design, construction and use. The principles of PAS 2080:2016 are used to inform the assessment of projects on climate and supplement the guidance provided in LA 114.

Table 14-2 - UK carbon reduction targets

UK Carbon budget period	UK Carbon budget level
1st carbon budget (2008 to 2012)	3,108 $MtCO_2e$

[4] Gloucestershire Joint Core Strategy Adopted Version 2017
[5] The Local Transport Plan is currently being revised.

UK Carbon budget period	UK Carbon budget level
2nd carbon budget (2013 to 2017)	2,782 $MtCO_2e$
3rd carbon budget (2018 to 2022)	2,544 $MtCO_2e$
4th carbon budget (2023 to 2027)	1,950 $MtCO_2e$
5th carbon budget (2028 to 2032)	1,725 $MtCO_2e$
6th carbon budget (2033 to 2037)	965 $MtCO_2e$

Table Source: Adapted from UK Government Carbon Reduction Targets 2008 (Committee on Climate Change, 2017)Methodology

14.2.2. The approach taken aligns with the guidance set out in Design Manual for Roads and Bridges (DMRB) LA 114[6], DMRB LA 105 Air quality[7] and TAG Unit A3 Environmental Impact Appraisal, Chapter 4 Greenhouse Gases[8]

14.2.3. It is key to note that whilst Effects on Climate is a wide-ranging topic in terms of potential sources, it is simple in terms of its receptors and impacts because:

- There is only one receptor, the atmosphere;
- There is only one direct impact, global warming; and
- All units of CO_2e can be considered to have the same impact no matter where they are emitted.

14.2.4. Therefore, assessment of the effects of the Scheme on climate is limited to quantification of the magnitude of emissions, from individual sources and in total, and comparison of these to the baseline. Different GHGs have different global warming potentials, and to account for this they will be reported throughout this assessment as their carbon dioxide equivalent (CO_2e) value.

14.2.5. The goal of the assessment is to calculate the emissions anticipated to be generated by the Scheme to:

- Determine the magnitude of the Scheme's effect on climate, in comparison with the Do Minimum Scenario;
- Assess the significance of the effect on climate by considering it in context with UK carbon reduction targets; and
- Enable identification of emissions hot spots within the 'Do Something' scenario to inform identification of appropriate mitigation measures.

14.2.6. Emissions calculations are carried out by multiplying activity data by an emission factor associated with the activity being measured. Activity data is a quantitative measure of an activity that results in emissions during a given period of time, (e.g. kilometres driven, kWh electricity consumed, tonnes waste sent to landfill). An emission factor is a measure of the mass of emissions relative to a unit of activity.

14.2.7. There is currently insufficient design information available to conduct a fully quantitative assessment at this stage. The assessment presented in this PEIR uses a precautionary approach that has been applied to the assumptions made in this chapter and still provides a reasonable assessment of the emissions that will result from the Scheme. A further, more detailed assessment will be provided in the ES.

[6] LA 114 - Climate - DMRB (standardsforhighways.co.uk)
[7] https://www.standardsforhighways.co.uk/prod/attachments/10191621-07df-44a3-892e-c1d5c7a28d90?inline=true
[8] TAG UNIT A3 Environmental Impact Appraisal (publishing.service.gov.uk)

Calculating Construction Emissions

14.2.8. The data for the assessment has been provided by the designer and is up-to-date for this stage of the design.

14.2.9. A quantification of construction phase emissions has been calculated using Highways England's Carbon Tool. This uses pre-populated carbon conversion factors from the ICE database to calculate emissions from various material and non-material sources as detailed in Table 14-3.

Table 14-3 - Sources and lifecycle stages for project GHG emissions

Main stage of project lifecycle	Sub-stage of life cycle	Potential sources of GHG emissions (not exhaustive)	Included within assessment?
Construction Stage	Product stage; including raw material supply, transport and infrastructure	Embodied GHG emissions associated with the required raw materials	Yes
	Construction processes stage; including transport to and from works site and construction processes	Activities for organisations conducting construction work.	Yes – Transportation of materials No – All other construction processes as data was not available.
	Land Use Change	GHG emissions mobilised from vegetation or soil loss during construction	No – no data for Land Use Change was available.
Operation stage	Use of infrastructure by the end-user (road user)	Vehicles using highways infrastructure	Yes
	Operation and maintenance	Energy consumption for infrastructure operation and activities of organisations conducting routine maintenance.	Yes – Assumed as 0.29% of road-user emissions as a worst-case scenario.
	Land use and forestry	Ongoing land use GHG emissions/sequestration each year	No – no data for Land Use and Forestry is available yet.

14.2.10. At the time of writing this report, the data for construction processes mainly related to fuel, electricity and water use and business and employee transport are not available. Once available, this data would need to be modelled in the Highways England carbon tool and findings to be updated in this report during preliminary design stage.

Study Area

14.2.11. The study area has been defined according to National Highways guidance and covers the emission of GHG resulting from the Scheme in its construction and operational phases, as well as opportunities for emissions reduction. The study area is not limited to the geographic extent of the Scheme itself, as many emissions will result from upstream and off-site activities such as material production.

Calculating Operational Emissions

14.2.12. Operational emissions are calculated separately from Highway England's Carbon Tool, which is focused specifically on construction-phase emissions. Road user carbon emissions have been calculated in accordance with DMRB LA114. Emissions are calculated using DEFRA's Emissions Factors Toolkit (v10), which takes account of Department for Transport (DfT) fleet projections including conventional vehicles (petrol and diesel) as well as hybrid and electric vehicles.

14.2.13. There is no operational energy use or maintenance and repair data available for the Scheme. Published data from other highway schemes[9] shows that, proportionally, emissions from operational energy use and maintenance works equate to between 0.05 and 0.29% of in-use traffic emissions. 0.29% of road user emissions has been applied as a reasonable worst-case operation and maintenance figure, based on this limited data set.

Emissions Analysis and Significance Assessment

14.2.14. The emissions calculated for the Do Something scenario of the Scheme will be compared against the Do Minimum scenario baseline for the assessment years. The difference between these emissions can be considered to be the impact of the Scheme.

14.2.15. There is no accepted technical or policy guidance on how to determine the significance of a project's effects on climate. However, the NPS NN acknowledges that the emissions from the construction and operation of a road scheme are likely to be negligible compared to total UK emissions, and are unlikely to materially impact the UK Government's ability to meet its carbon reduction targets: 'it is very unlikely that the impact of a road project will, in isolation, affect the ability of Government to meet its carbon reduction plan targets'.

14.2.16. For this reason, it is considered unlikely that Scheme emissions will be of a quantity great enough to cause a significant effect on climate.

14.2.17. However, due to the global scale, long-term duration and cumulative and irreversible nature of the impact, the effects on climate of the Scheme are still considered important. Gloucestershire County Council is committed to reducing emissions where practicable, and therefore emissions have been quantified and presented as part of the ES.

14.2.18. Following the determination of emissions, mitigation measures to reduce emissions will be suggested.

14.3. Consultation

14.3.1. No specific consultation is proposed.

14.4. Baseline conditions

14.4.1. Baseline conditions are defined by the:

- Total background emissions from all sources, i.e. all UK emissions, at all scales; and
- Predicted total emissions occurring for both the Opening Year (2025), and the Design Year (2041), assuming the Scheme is not constructed, i.e. the 'Do Minimum' scenarios.

National Emissions Baseline

14.4.2. It is estimated that total global GHG emissions from all sources currently amount to approximately 50 billion tonnes of CO_2e[10]. However, it is not considered representative to compare any UK scheme against this, as any scheme will always be negligible. Instead,

[9] Welsh Government (2016). M4 Corridor around Newport, Environmental Statement: Volume 3, Appendix 2.4 Carbon Report
[10] http://themasites.pbl.nl/publications/pbl-2017-summary-trends-in-global-co2-and-total-greenhouse-gas-emissions-2983.pdf

it is considered most appropriate to use the national baseline for comparison as its magnitude is more relevant and UK specific.

14.4.3. At the time of writing (August 2021) the UK is the world's eighth largest emitter of CO_2e. The total UK emissions for 2019 (the last reported year) were 454.8 million tonnes of CO_2e[11]. The transport sector was the largest emitting sector of UK GHG emissions in 2019, contributing 27% of emissions. There has been little overall change (4.6% reduction) in emissions from the transport sector between 1990 and 2019. Improvements in fuel efficiency are approximately balanced by increasing vehicle numbers.

14.4.4. The UK is currently in the third carbon budgetary period (2018-2022), the budget for which is 2,544 $MtCO_2e$. The UK cannot legally emit more GHG than this within the budgetary period. The fourth carbon budget is 1,950 $MtCO_2e$ (over the period 2023–27), the fifth budget is 1,725 $MtCO_2e$ (2028-32), and the sixth carbon budget is 965 $MtCO_2e$ (2033-37). Whilst budgets are not set beyond this, there is a legal requirement for the UK to reach 'net zero' emissions $MtCO_2e$ by 2050. The construction (2025) and Opening Year (2028) of the Scheme fall within the fourth and fifth carbon budgets respectively.

Scheme Emission Baseline

14.4.5. The calculated emissions for the Do Minimum scenario cover the following life cycle modules:

- Road user carbon emissions;
- Maintenance and refurbishment of the Scheme; and
- Operational energy use for the Scheme.

14.4.6. Only these life cycle modules are included as they are the only stages relevant to an operational highway. There are no construction emissions associated with the Do-Minimum scenario.

Road user carbon

14.4.7. The user carbon emissions for the Do minimum scenarios have been calculated in accordance with DMRB LA114. They are as follows:

2025 Opening Year:	206,102 tCO_2e
2041 Design Year:	208,677 tCO_2e
60-year operational period:	12,498,733 tCO_2e

14.4.8. The data show an expected 1.01% increase in emissions between the Opening and Design Years.

Operational Energy Use and Maintenance

14.4.9. Applying 0.29% of road user emissions as a reasonable worst-case value, the Scheme's Do-Minimum scenario emissions for operational energy use and maintenance of the existing roads in the study area can be estimated as:

2025 Opening Year:	206,102 x 0.29% = 598 tCO_2e
2041 Design Year:	208,677 x 0.29% = 605 tCO_2e

Total Baseline Emissions

14.4.10. Based on the addition of the above, the total Scheme baseline emissions for the Do-Minimum scenarios are estimated to be as follows:

2025 Opening Year:	206,700 tCO_2e

[11] 2019 UK Greenhouse Gas Emissions, Final Figures (publishing.service.gov.uk)

2041 Design Year: 209,282 tCO_2e

Scheme Baseline Summary

14.4.11. Table 14-3 provides a summary of the emissions for the Do-minimum scenarios.

Table 14-4 - Emissions for Do-minimum scenario in 2025 and 2041

Design Year	Emissions (tCO_2e)		
	Road-user Carbon	Operational Energy Use and Maintenance	Total
2025	206,102	598	206,700
2041	208,677	605	209,282

14.5. Potential impacts

Construction Impacts

14.5.1. The calculated construction phase emissions for the Do Something scenario, compared with the Do Minimum, are shown in Table 14-5.

14.5.2. The construction phase of the Scheme will generate 76,648 tCO_2e. As emissions from construction do not occur in the Do Minimum scenario, it can be considered that the construction stage of the Scheme would have the impact of releasing an additional 76,648 tCO2e into the atmosphere in the Do Something scenario.

Table 14-5 - Construction Stage Emissions

Category	Emissions (tCO_2e)		
	Materials	Transportation	Total
Bulk Materials	31,695	14,087	45,782
Earthworks	10,753	8,703	19,456
Fencing, barriers & road restraints systems	814	6	819
Road pavements	145	18	163
Civil structures & walls	2,068	229	2,296
Waste	3,259	4,873	8,132
Total Emissions	**48,733**	**27,915**	**76,648**

Table source: HE Carbon Tool v2.3 output

Operation Impacts

14.5.3. The calculated operation phase emissions for the Do Something scenario, compared with the Do Minimum, are shown in Table 14-6.

14.5.4. The Do Something scenario of the Scheme will generate 5,127 tCO_2e in the Opening Year, and 14,882 tCO_2e in the Design Year compared with the Do Minimum. This is an increase in annual operational emissions of 2.42% and 6.66% for the Opening and Design years respectively and corresponds to an increase in vehicle kilometres travelled.

Table 14-6 - Operation Stage Emissions for 2025 and 2041

Life Cycle	Emissions (tCO_2e)								
	2025 Do-Minimum	2025 Do-Something	Difference	2041 Do-Minimum	2041 Do-Something	Difference	Total over 60-year operation* (Do-Minimum)	Total over 60-year operation* (Do-Something)	Difference
Road User Carbon	206,102	211,229	5,127	208,677	223,559	14,882	12,498,733	13,308,735	810,003
Maintenance and Operation	598	613	15	605	648	43	36,246	38,595	2,349
Total Emissions	206,700	211,842	5,142	209,282	224,207	14,925	12,534,979	13,347,330	812,352

*Cumulative over the period 2025-2085

Comparison to UK Carbon Budgets

14.5.5. Gloucestershire County Council is committed to reducing GHG emissions wherever practicable and to supporting the UK Government in meeting its carbon reduction targets. Table 14-7 shows the proportion of the relevant carbon budgets that the Scheme would contribute, multiplied over the 5-year budget period.

Table 14-7 - Comparison of Scheme to UK Government Carbon Budgets

Project Stage	Estimated total carbon over carbon budget (tCO_2e)	Net CO_2 project GHG emissions (tCO_2e)	Relevant carbon budget			
			3rd carbon budget (2018-22)	4th carbon budget (2023-27)	5th carbon budget (2028-32)	6th carbon budget (2033-37)
Construction	76,648	-	-	76,648	-	-
Operation	2,806,086	114,207	-	17,260	40,996	56,282
Total	2,882,734	114,207	-	93,908	40,996	56,282
Percentage of carbon budget			-	0.0048%	0.0024%	0.0058%

Source: Adapted from DMRB LA 114, populated with own calculations

Significant Effects

14.5.6. Emissions have been calculated to contribute 114,207 tCO_2e net emissions towards the UK Carbon Budgets as far as 2037. It is considered that this magnitude of emissions from the Scheme will not have a significant effect on climate, in line with the position set out in the NPS NN.

14.5.7. However, although the emissions are shown as negligible against the UK national budgets, any increase in emissions will contribute to the UK's ability to meet its targets. Mitigation measures to further reduce the Scheme's impact are therefore proposed in section 14.7.

14.6. Potential mitigation measures

14.6.1. Emissions will be mitigated by applying the carbon reduction hierarchy as detailed in DMRB LA 114:

- Avoid / prevent:
  - Maximise potential for re-using and / or refurbishing existing assets to reduce the extent of new construction required; and
  - Explore alternative lower carbon options to deliver the project objectives (i.e., shorter route options with smaller construction footprints).
- Reduce:
  - Apply low carbon solutions (including technologies, materials, and products) to minimise resource consumption during the construction, operation, user's use of the project, and at end-of-life; and
  - Construct efficiently, using techniques (e.g. during construction and operation) that reduce resource consumption over the life cycle of the project.
- Remediate:
  - After addressing steps 1 and 2 projects will identify, assess and integrate measures to further reduce carbon through on or off-site offsetting or sequestration.
  - Potential mitigation measures relevant to the construction and operation stages of the Scheme are suggested below.

Table 14-8 - Construction emissions mitigation measures

Life cycle module		Mitigation measures
Materials		Reduction of materials consumption should be carried out in accordance with the mitigation measures outlined in the Materials and Waste Chapter (Chapter 12). In addition, consideration should be given to alternative low carbon materials e.g. recycled aggregates, cement substitution etc.
Transport		Materials transportation should be reduced and/or avoided by minimising the quantity of materials required. Additionally, where possible detailed design and procurement measures should be specified to minimise the necessity to source materials from long distances.
Construction Processes	Construction plant use	Construction plant emissions should be minimised by designing for efficient construction processes as part of design development. During construction plant emissions should be managed via the CEMP, which should specify plant operator efficiency requirements.

Life cycle module		Mitigation measures
	Construction water use	Construction water consumption should be minimised by designing for efficient construction processes as part of design development. During construction mains water consumption should be managed via the CEMP, which should specify reduction and reuse measures.
	Construction waste transportation	Reduction of waste generation should be carried out in accordance with the mitigation measures outlined in the Materials and Waste Chapter (Chapter 12).
	Construction waste off-site processing	Waste treatment/disposal should be carried out in accordance with the mitigation measures outlined in the Materials and Waste Chapter (Chapter 12).
	Employee commuting	Local contractors should be used where possible, reducing the distance driven by employees.

14.6.2. Operational emissions can be mitigated by designing a Scheme which minimises emissions from traffic and operational energy use. Potential mitigation measures for reducing in-use emissions are shown in Table 14-9.

Table 14-9 - Operation emissions mitigation measures

Life Cycle Module	Mitigation Measures
Road user carbon	Mitigation of in-use emissions should be explored based on examination of traffic management scenarios over the network. Inclusion of NMU routes would encourage the utilisation of alternative means of transport and help achieve the goal of creating a more integrated and sustainable transport network, whilst reducing emissions.
Maintenance and repair	The mitigation measures detailed in Table 14-6 for the construction stage are also applicable to ongoing maintenance and repair.
Operational energy use	Operational energy use should be minimised by designing for use of low energy lighting and traffic management systems, specification of controls that minimise on-time, and use of low carbon energy sources, where practicable.

14.7. Residual impacts

14.7.1. Due to the embedded nature of the mitigation measures proposed, some of which have already been incorporated into the design (for example, selection of route length) and some of which are yet to be incorporated, it is not practicable to complete a quantitative assessment of ‘before’ and ‘after’ mitigation. Rather, the assessment shows a snapshot of the current design.

14.8. Cumulative effects

14.8.1. The effects of GHG emissions are essentially cumulative; it is their concentration in the atmosphere, not the actual level of emissions, that determines the warming effect (i.e. it is the ‘stock’ rather than the ‘flow’ which is important). In addition, it is the global excess of emissions from human activities all over the world that contributes to the overall effect on climate, not only local emissions. For this reason, the impact of the Scheme should be considered in the context of overall emissions from the UK and globally. Compared with global emissions the scale of the impact of the Scheme is negligible. However, the overall effect on climate of GHG emissions is made up of many small emissions sources, of which this project would contribute.

14.9. NPS compliance

14.9.1. The NPS NN acknowledges that the emissions from the construction and operation of a road scheme are likely to be negligible compared to total UK emissions, and are unlikely to materially impact the UK Government's ability to meet its carbon reduction targets. However, the NPS NN requires evidence of the emissions impact of a scheme, an assessment of the emissions against the Government's carbon budgets, and evidence of mitigation measures. The assessment presented in this chapter provides the required evidence and assessment against targets.

14.10. Assumptions and limitations

14.10.1. The key limitation of the assessment is the availability and accuracy of design and construction information to enable calculations. This may require assumptions to be made, and some industry standard data to be used as a proxy. The data and associated assumptions considered for the carbon emissions assessment are detailed below.

14.10.2. The following assumptions have been made during the carbon assessment:

- For all major structures (M5 J10 northbound interchange bridge, M5 J10 southbound interchange bridge, River Chelt bridge) no preferred option has yet been declared. The assessment has captured all available materials data for each option currently being considered and reported the worst-case carbon emissions for each option into the final construction emissions total;
- All concrete (other than pre-cast concrete) used in construction is modelled as 'ready-mix concrete';
- Aggregates are assumed to make up 75% of the total weight of the concrete used in construction;
- All cement and binder are assumed to be Portland Cement;
- Asphalt volumes were calculated based on the minimum surfacing depth required for construction and the unit weight of 23kN/m^3;
- All earthwork materials used in construction are assumed to be soil unless explicitly mentioned as otherwise in the bill of quantities;
- As the cut-fill balance is unknown, all earthworks soil is assumed to be imported to site unless explicitly marked a site-won in the bill of quantities. All excavated materials are assumed to be waste, unless otherwise stated in the bill of quantities;
- All materials are assumed to be nationally manufactured and transported to site from an average distance of 100km (as detailed in the default transport scenarios in RICS[12]);
- Carbon factors are drawn from the Highway England Carbon Tool (v2.3) which are sourced from the Inventory of Carbon and Energy database;
- Road User Carbon is drawn from the Defra's Emissions Factor Toolkit (v10). Within the toolkit, account is not taken for the increase of electric vehicles beyond 2030. It is consistent with the TAG methodology defined by the DfT and assesses emissions over a 60-year period; and
- The scenario 'R' has been used in the assessment of Road User Carbon, which includes expected emissions from scheme-enabled developments.

14.11. Chapter summary

14.11.1. In terms of construction phase emissions, the Scheme will generate an additional 76,648 tCO_2e. This would contribute 0.004% to the fourth carbon budget. In line with the conclusions drawn in the NPS NN, it is not deemed that the construction phase of the Scheme would have a significant effect on climate.

[12] whole-life-carbon-assessment-for-the-built-environment-1st-edition-rics.pdf

14.11.2. In terms of operation phase emissions, the Do Something scenario of the Scheme will generate an additional 5,127 tCO_2e in the Opening Year, and 14,882 tCO_2e in the Design Year compared with the Do Minimum due in large part to an increase in vehicle kilometres travelled, taking into account the added emissions from scheme-enabled developments. Cumulatively over a 60-year period, the net emissions due to the Scheme would be 886,651 tCO_2e.

14.11.3. It should be noted that this assessment is conservative, representing a worst case. Given current policy commitments made by the UK Government, it is considered to be an overestimate as the uptake of new electric vehicles in future years would be expected to be higher than the proportions used in the national projections included in Defra's Emissions Factor Toolkit (v10) used for the Scheme assessment (see 14.2.12 above). This is shown through the 77,072 Ultra Low Emissions Vehicles registered in Q2 2021, a 422% increase on Q2 2019[13]. ULEVs accounted for 11.8% of all new car registrations in Q2 2021, compared to 7.8% in Q2 2020. Within the Emissions Factor Toolkit, account is not taken for the increase of electric vehicles beyond 2030.

14.11.4. Due to the status of published and legislated Carbon Budgets according to the Climate Change Act, not all cumulative emissions can be compared directly to Carbon Budgets, which only run to 2037. The total lifecycle emissions due to the Scheme would represent 0.0048% of the fourth Carbon Budget (2023-27), 0.0024% of the fifth Carbon Budget (2028-33) and 0.0058% of the sixth Carbon Budget (2033-37).

14.11.5. In line with the conclusions drawn in the NPS NN, it is not deemed that the Scheme would have a significant effect on climate.

VULNERABILITY TO CLIMATE CHANGE

14.12. Introduction

14.12.1. The main objective of the climate vulnerability assessment is to ensure that climate change, and impacts associated with extreme weather, are considered during planning so that they can be avoided and, if that is not possible, mitigated during the construction and operation of the Scheme. To achieve this objective this chapter presents:

- An examination of the current climate baseline using the Met Offices latest regional dataset of 30-year averages and data from nearby long running meteorological stations;
- A consideration of the projected future climate baseline for the period 2071-89;
- An assessment of how the Scheme may be vulnerable to the impacts of climate change during its construction and operation;
- Identification of specific mitigation to adapt the design and operational processes to reduce the Scheme's potential adverse climate vulnerabilities; and
- An assessment of the residual climate change vulnerability of the Scheme that considers both adverse and beneficial vulnerability impacts by quantifying their likelihood and consequence of each potential vulnerability.

14.12.2. The adopted assessment approach reviews how climate change could affect the Scheme's assets, as well as how it could affect the potential environmental impacts identified in the other chapters of this assessment, i.e. how it could impact environmental receptors. The methodology follows guidance set out in DMRB LA 114 and is informed by best practice climate assessment approaches and literature, as well as professional judgement.

14.12.3. This chapter should be read in conjunction with the description of the development presented in Chapter 2 The Scheme. It is also noted that the scope of the climate vulnerability assessment has overlaps with aspects of other chapters in this report, in particular:

[13] Vehicle Licensing Statistics: April to June 2021 (publishing.service.gov.uk)

- Chapter 8 Water Environment - which includes consideration of the impact of future climate change on the water environment through, for example, increased high intensity short duration rainfall events.

14.12.4. The examination of climate projections has confirmed that the study areas climate (see section 14.17) is expected to change in the future. This assessment finds that the Scheme could be vulnerable to impacts linked to these changes in the climate. Mitigation measures built into the design (i.e. embedded mitigation) that either avoids these impacts, minimises them or reduces their consequences to an acceptable level are presented. After consideration of this mitigation none of the potential climate vulnerability impacts are found to be significant adverse.

14.13. Glossary of terms

14.13.1. In this environmental assessment climate vulnerability is the degree to which receptors in the study area are susceptible to the impacts of climate change (beneficial and adverse). These effects include slow onset trends in climate as well as projected changes to extreme weather. An explanation of key climate related terms used in this environmental assessment is included in the table below.

Table 14-10 - Glossary of terms

Term	Description
Adaptive management	A process of iteratively planning, implementing, and modifying strategies for managing resources in the face of uncertainty and change. Adaptive management involves adjusting approaches in response to observations of their effect and changes in the system brought on by resulting feedback effects and other variables.
Climate	Climate is the description of weather over the long-term. It is typically defined as a summary of the mean and variability of meteorological variables over a period. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization.
Climate change	Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.
Climate baseline/reference	The state against which climate change is measured. A baseline period is the historic period relative to which anomalies or future projections are compared[14].
Weather	Weather is the current state of the atmosphere. It describes, for example, its temperature, moisture content and pressure.
Extreme weather or extreme climate events	Unusual (e.g. unseasonal) or severe weather that is at the extremes of the historical distribution for that area, for example rarer than the 10th or 90th percentile of probability.
Climate impact	The impacts of climate change on metrological variables. These include warmer wetter winters, hotter drier summers, and changes in the frequency of extreme weather events.
Consequences	The effects of climate impacts on natural and human systems, for example changes in sea level or reduced water availability. In this assessment consideration of consequences is focused on any type of damage to CPS assets, the environment around them or any interference to the operation of the M25 DBFO. Secondary

[14] https://archive.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-AnnexII_FINAL.pdf

Term	Description
	consequences are also considered such as reduced performance (traffic delays) and repair costs.
Mitigation	Adaptative actions taken to remove or reduce the consequences of climate impacts.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.15 For example, some receptors have a certain level of inert adaptive capacity, i.e., the ability to absorb and recover from the consequences of climate impacts themselves.

14.14. Planning policy and topic legislative context

14.14.1. The legislation and policy framework for the Scheme's vulnerability to climate changes is set out in Table 14-11.

Table 14-11 - Policy Review

Scale	Policy Document	Key Implication for the Scheme
National	Infrastructure Planning - Environmental Impact Assessment Regulations (2017)[16]	The Regulations require: “A description of the likely significant effects of the project on climate (for example the nature and magnitude of GHG emissions) and the vulnerability of the project to climate change.”
	National Policy Statement for National Networks (NPS NN) (2014)[17]	The Scheme falls within the definition of an NSIP, making the NPS NN the primary planning policy against which an application for a DCO for the Scheme would be judged. Paragraph 4.41 states that new national networks infrastructure should typically be long-term investments which should remain operational over “many decades in the face of a changing climate”. Therefore, applications should “consider the impacts of climate change when planning location, design, build and operation”. Paragraph 5.19 outlines the need for appropriate mitigation measures to be implemented in both design and construction. The effectiveness of such mitigation will be considered by the Secretary of State in order to ensure the carbon footprint is not ‘unnecessarily high’, with the adequacy of the measures constituting a material factor in the decision-making process.
	National Planning Policy Framework (NPPF) (2021)[18]	Given that the Scheme is an NSIP, the NPPF has the status of a material consideration in planning terms. The NPPF develops a planning system that contributes to radical reductions in GHG emissions, minimises vulnerability and improves resilience. The NPPF states that “Plans should take a proactive approach to mitigating and adapting to climate change, taking into account the long-term implications for flood risk, coastal change, water supply, biodiversity and landscapes, and the risk of overheating from rising temperatures. Policies should support appropriate measures to ensure the future

[15] https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_Annexes.pdf
[16] https://www.legislation.gov.uk/uksi/2017/572/regulation/1/made
[17] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/387222/npsnn-print.pdf
[18] https://www.gov.uk/government/publications/national-planning-policy-framework--2

Scale	Policy Document	Key Implication for the Scheme
		resilience of communities and infrastructure to climate change impacts, such as providing space for physical protection measures, or making provision for the possible future relocation of vulnerable development and infrastructure" (paragraph 153).
	Climate Change Act (2008) [19]	The UK passed legislation that introduced the world's first long term legally binding framework to tackle the risks posed by climate change. The Climate Change Act (2008) created a new approach to managing and responding to climate change in the UK, by: Setting ambitious, legally binding reduction targets; Taking powers to help meet those targets; Strengthening the institutional framework; Enhancing the UK's ability to adapt to the impacts of climate change; and Establishing clear and regular accountability to the UK Parliament and to the developed legislatures. Key provisions of the Act in respect of climate change adaptation include a requirement for Government to report, at least every five years, on the risks to the UK of climate change, and to publish a programme setting out how these will be addressed. This Act also introduces powers for Government to require public bodies and statutory undertakers to carry out their own risk assessment and make plans to address those risks. The Adaptation Sub-Committee of the CCC will provide advice to, and scrutiny of, the Government's adaptation work.
	The Highways Agency Climate Change Adaptation Strategy and Framework (2009)[20]	The Climate Change Act (2008) led to modifications in existing standards on the national network. The Highways Agency has committed to assessing the potential risks that climatic changes pose to the ongoing management, maintenance, improvement, and operation of the strategic road network. This document sets out how the UK's road network may be vulnerable to climate change and how these vulnerabilities will be factored into the delivery of their business, along with the development of appropriate management and mitigation solutions to remove or reduce the vulnerabilities.
	Highways England Sustainable Development Strategy and Action Plan (2017)[21]	National Highways recognise that changes in climate may result in more frequent and severe weather events. This document sets out their commitment to ensure resilience to climate change is embedded in the activities of their business to reduce whole life costs and increase safety. To do this their ambition is to invest for the long-term – "our road network contains components that have a very long design life, such as bridges and tunnels; they will require timely and cost-effective investments to reduce the risk of increased future costs, whilst improving resilience to climate change."

[19] https://www.legislation.gov.uk/ukpga/2008/27/contents
[20] http://roads.meteo.co.me/practices/Publication_Climate%20Change%20Adaption%20Strategy%20and%20%20Framework_2009.pdf
[21] https://www.gov.uk/government/publications/highways-england-sustainable-development-strategy

Scale	Policy Document	Key Implication for the Scheme
Regional	Gloucestershire Waste Core Strategy (2012)[22]	LTP PD 4.2 – Highway network resilience makes specific reference to the importance of a 'resilient highway network that can withstand unforeseen events including extreme weather events and long-term changes to the climate.' This will be achieved through the identification of the most vulnerable parts of the transport network and developing contingency plans to ensure a functioning network during unplanned events. Importantly, as part of this policy, GCC also pledge to 'continue to deliver highway and flood alleviation schemes which reduce the risk of highway closures on class one and two routes', as well as work with the Environment Agency, National Highways and communities to 'ensure that the highway network and the communities, trade and commerce that it serves are better protected from flood impacts.'
	Gloucestershire County Council Strategy & Action Plan for Responding to Climate Change (2008)[23]	The document outlines the Council's objective to understand and manage the risks that a changing climate will have on the delivery of Council services. It also ensures that they help Gloucestershire's communities become more resilient to climate change, building on their good practice in responding to the floods in the summer of 2007. More than 15 different direct impacts of climate change are identified and discussed.
Local	Cheltenham Borough Council Climate Change Strategy (2005)[24]	CBC recognise the importance of tackling climate change on two fronts; reducing GHG emissions to minimise future climate change and planning for the unavoidable impacts of climate change. This document provides a framework for addressing both these issues. Chapter 7 outlines the expected impacts of climate change on Cheltenham and proposes a number of associated adaption measures.
	Tewkesbury Borough Council Climate Change Strategy[25]	Sets out how adaptation measures will be planned to allow TBC to continue to meet service delivery requirements, and care for the community, in the face of climate change. The Strategy identifies agriculture, biodiversity, settlements, business, and water as the sectors most vulnerable to climate change in its administrative area.
	Gloucester City Council Climate Change Strategy (2010)[26]	The strategy encourages individuals to reduce the level of transport related emissions by travelling less by car and walking, cycling, and using public transport more. Other ideas such as car share and car clubs are also promoted.

14.15. Methodology

14.15.1. Where the climate change impact on project receptors is potentially significant, a risk assessment has been undertaken. The method for this assessment is set out in this

[22] https://www.gloucestershire.gov.uk/planning-and-environment/planning-policy/gloucestershire-waste-core-strategy/
[23] https://www.gloucestershire.gov.uk/media/2266/080709_corporate_climate_change_strategy___annexes__published-30432.pdf
[24] https://democracy.cheltenham.gov.uk/Data/Cabinet/20050517/Agenda/2005%2005%2017%20Cabinet%20Report%20Climate%20Change%20%20%20strategy.pdf
[25] https://www.tewkesbury.gov.uk/strategies-and-policies
[26] https://www.gloucester.gov.uk/media/1212/climatechangestrategy2009.pdf

section. It follows the guidance set out in DMRB LA 114 and is informed by best practice climate assessment approaches and literature, as well as professional judgement.

14.15.2. The study area for the climate vulnerability assessment incorporates the construction footprint of the Scheme (including compounds and temporary land take), all potential environmental receptors that could be impacted by the Scheme and the regional transport network around the Scheme that could be affected by cumulative climate vulnerability impacts.

14.15.3. There are four stages to the climate vulnerability assessment method:

- Stage 1 - Identify the receptors;
- Stage 2 - Assess the likelihood of impacts on each receptor;
- Stage 3 - Assess the consequence of impacts for each receptor; and
- Stage 4 - Determine the significance of each impact based on a combination of the likelihood of an impact occurring and the consequences of that impact.

Stage 1 - Identification of receptors

14.15.4. Receptors which may be affected by climate change have been identified with consideration of the characteristics of potential future extreme weather events as well as gradual changes to the climate that could occur in the study area over the Scheme's design life. Identification of these is based on an assessment of climate projections from United Kingdom Climate Projections 2018 (UKCP18). These projections have been developed by the Met Office Hadley Centre Climate Programme which is supported by the Department of Business, Energy and Industrial Strategy (BEIS) and the DEFRA. They provide the most up-to-date assessment of how the climate of the UK may change over the 21st century.

14.15.5. In accordance with DMRB LA 114 the assessment has considered the impacts of climate change on the following receptors:

- Construction process (including workforce, plant, machinery etc.);
- The assets and their operation, maintenance, and refurbishment (including pavements, structures, earthworks and drainage and technology assets such as signals and signs); and
- End-users (members of the public, commercial operators, nearby residential properties, road user safety and experience).

14.15.6. Where it is not already covered in the relevant topic chapters, consequential loss or damage to environmental receptors as a result of the Scheme's vulnerability to climate change will be discussed in the cumulative effects section of the chapter.

Stage 2 - Assess the likelihood of impacts

14.15.7. In accordance with DMRB LA 114, the likelihood of potential climate changes and events occurring are determined using available data (such as the known recurrence interval of extreme weather events) and professional judgement, based on knowledge and experience of other similar schemes. The likelihood categories and associated frequencies are provided in Table 14-12.

Table 14-12 - Likelihood categories

Likelihood category	Description (probability and frequency of occurrence)
Very high	The event occurs multiple times during the lifetime of the project (60 years) e.g. approximately annually, typically 60 events.
High	The event occurs several times during the lifetime of the project (60 years) e.g. approximately once every five years, typically 12 events.
Medium	The event occurs limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years, typically 4 events.

Low	The event occurs during the lifetime of the project (60 years) e.g., once in 60 years.
Very low	The event can occur once during the lifetime of the project (60 years).

Table Notes: Project lifetime is considered to include construction and operational phases; project lifetime is take to be 60 years in line with LA114 and WebTAG.

Table Source: DMRB Climate: LA114 Table 3.39a (June, 2021).

Stage 3 - Assess the consequence of impacts

14.15.8. The consequence of climate change impacts on the Scheme receptors are categorised using the criteria in Table 14-13.

Table 14-13 - Measure of consequence

Consequence of impact	Example description
Very large adverse	Operation – national level (or greater) disruption to strategic route(s) lasting more than 1 week.
Large adverse	Operation – national level disruption to strategic route(s) lasting more than 1 day but less than 1 week or regional level disruption to strategic route(s) lasting more than 1 week.
Moderate adverse	Operation – regional level disruption to strategic route(s) lasting more than 1 day but less than 1 week.
Minor adverse	Operation – regional level disruption to strategic route(s) lasting less than 1 day.
Negligible	Operation – disruption to an isolated section of a strategic route lasting less than 1 day.

Table Source: DMRB Climate: LA114 Table 3.39b (June, 2021).

Stage 4 - Determine significance of impacts

14.15.9. The results of the likelihood and consequence assessments are combined to derive a significance classification as outlined in Table 14-14.

Table 14-14 - Significance matrix

Impact consequence	Impact likelihood				
	Very low	Low	Medium	High	Very high
Very large	NS	S	S	S	S
Large	NS	NS	S	S	S
Moderate	NS	NS	S	S	S
Minor	NS	NS	NS	NS	NS
Negligible	NS	NS	NS	NS	NS

Table notes: NS = Not Significant, S = Significant

Impacts can be adverse or beneficial.

Table Source: DMRB LA114 Table 3.41 (June, 2021).

14.15.10. The assessment is undertaken with consideration of the Scheme design and mitigation.

14.16. Consultation

14.16.1. No specific consultation has been undertaken for climate vulnerability.

14.16.2. In relation to flood risk and drainage design, requirements in the NPPF and Environment Agency design guidance relating to climate change apply. A detailed FRA was completed in September 2021 (Appendix 8.1). The FRA uses the latest climate change allowances published by the relevant authority. The purpose of consultation on the FRA has been to agree it's scope and specific approaches regarding:

- Assessment of the baseline flood risk - determining the required return periods for modelling;
- Upfront flood modelling informing design of any river crossings and associated flood defence schemes; and
- Assessment of the with-scheme impacts to determine the required return periods for modelling.

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

14.16.4. Consultation with the Environment Agency on flood risk has been undertaken. At this stage, the consultation has included:

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

14.16.5. The Environment Agency was supplied with a copy of the baseline model and its accompanying report for review. This model and the hydrology was reviewed by external consultants on behalf of the Environment Agency (14 April 2021).

14.16.6. Consultation has also been undertaken with Gloucestershire County Council as the Lead Local Flood Authority (LLFA), although principle matters have been dealt with by the Environment Agency.

14.17. Baseline conditions

14.17.1. Climate is defined as the typical weather conditions experienced in a place over a period of time, conventionally expressed as average weather over a 30-year period.

14.17.2. The baseline for climate change vulnerability is presented in two parts:

- The first section describes the current climatic conditions in the study area; and
- The second presents a range of possible future climate projections in the study area.

14.17.3. It should be noted that climate change is not only a challenge for the future. The UK is already observing changes in its climate.

Current climate baseline

14.17.4. The Scheme is situated within the River Severn catchment. To inform adaptation decisions this section presents data from the Meteorological Office to summarise the River Severn's catchment current climate. The Met Office's standard average data tables are used, they show the latest set of 30-year averages covering the period 1981-2010. Context to this is provided by including comparison to the equivalent national dataset (UK minimum, average and maximum temperatures).

14.17.5. To support the above average regional data a local dataset has also been collected from the closest long running climate station to the Scheme. The closest climate station is located at Ross-On-Wye (359800E, 223800N – approximately 20 miles east of the scheme) and has been recording observations since 1931.

Current temperature

14.17.6. The climate in the River Severn catchment is one of relatively mild winters and warm summers. As shown in Figure 14-1 and Figure 14-2, monthly average and mean maximum temperatures are high for the UK. Across the timeseries, 1981-2010, peak summer (July) average maximum temperatures of 22 °C in the River Severn catchment are equal to the maximum across the UK. Note that mean maximum temperatures are calculated as the monthly average of daily maximums – as such some individual days are likely to have recorded hotter temperatures than those stated.

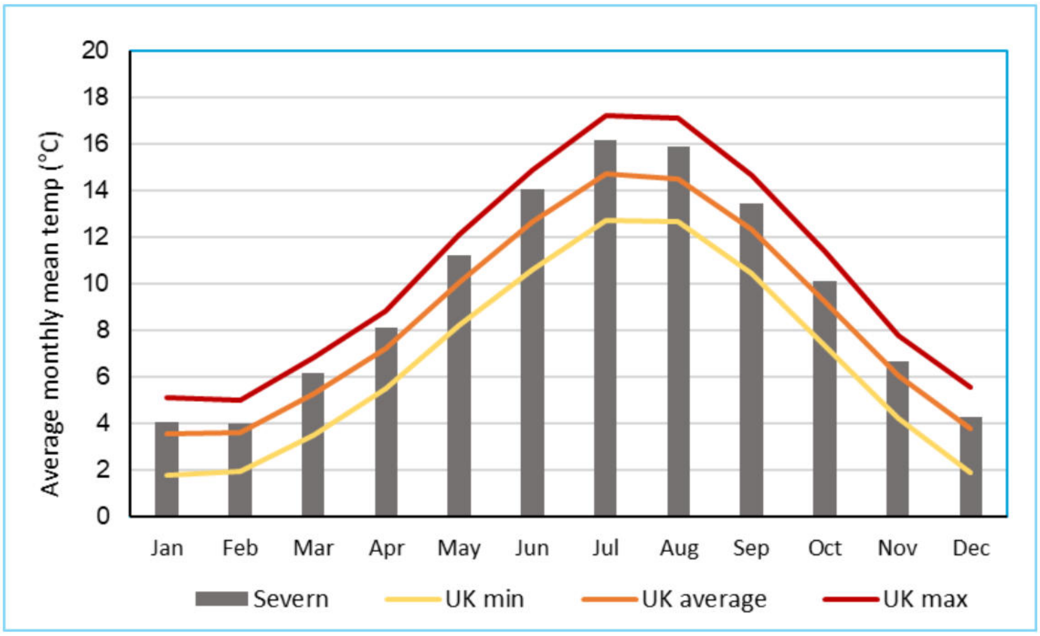

Figure 14-1 - Long-term average monthly mean temperature (°C) (1981-2010)

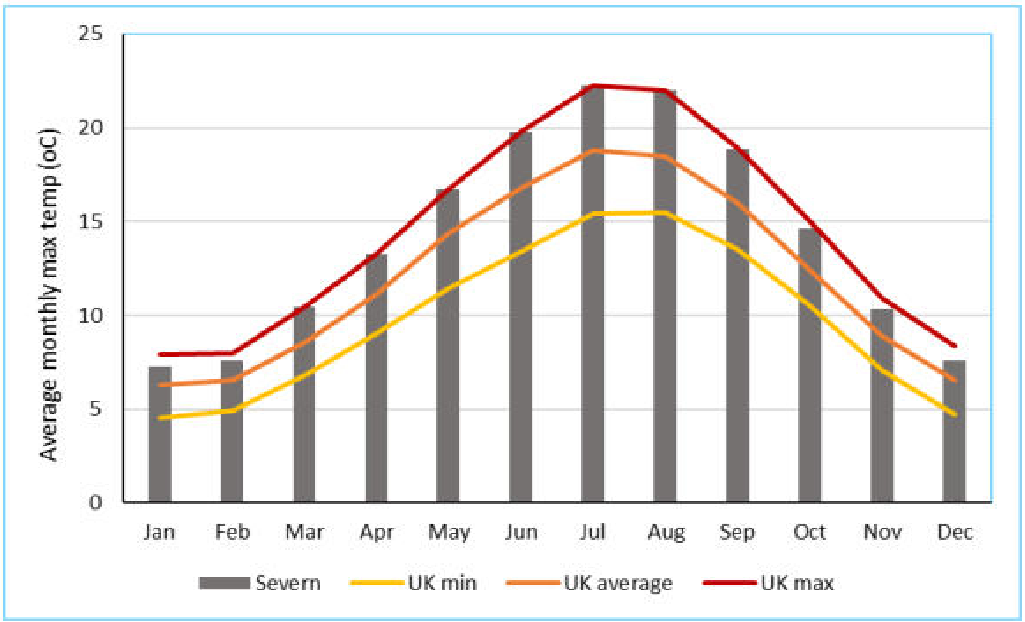

Figure 14-2 - Long-term average monthly maximum temperature (°C)(1981-2010)

Note: the maximum data presented is a monthly average of daily maximums.

14.17.7. Observations for the UK show that the decade leading up to the publication of UKCP18 (2008-2017) was on average 0.3°C warmer than the 1981-2010 average and 0.8 °C warmer than 1961-1990. All of the top ten warmest years have occurred since 1990.

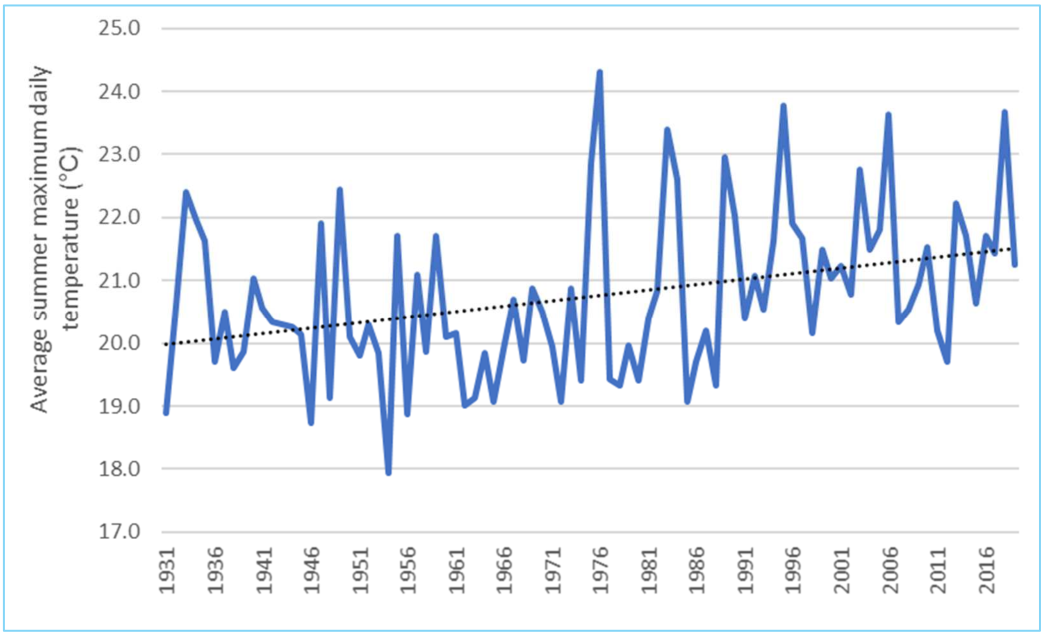

Figure 14-3 - Average summer maximum daily temperature (°C) (1930-2019) (Ross-On-Wye)

14.17.8. 1976 was the second hottest summer recorded in the UK. It was one of the driest, sunniest and warmest summers (June/July/August) in the 20th century. During the summer the hottest day was the 3 July where a temperature of 35.9 °C (96.6 °F) recorded in Cheltenham was the hottest in the UK[27].

14.17.9. Observation from the Ross-On-Wye climate station reveal that three of the five highest monthly mean daily maximum temperatures (t-max) it has recorded have been since 2006. They also show that over the period 1930 to 2019 both the average daily summer maximum temperatures and average daily winter maximum temperatures have been increasing (conclusion based on linear trendlines on Figure 14-3 and Figure 14-4).

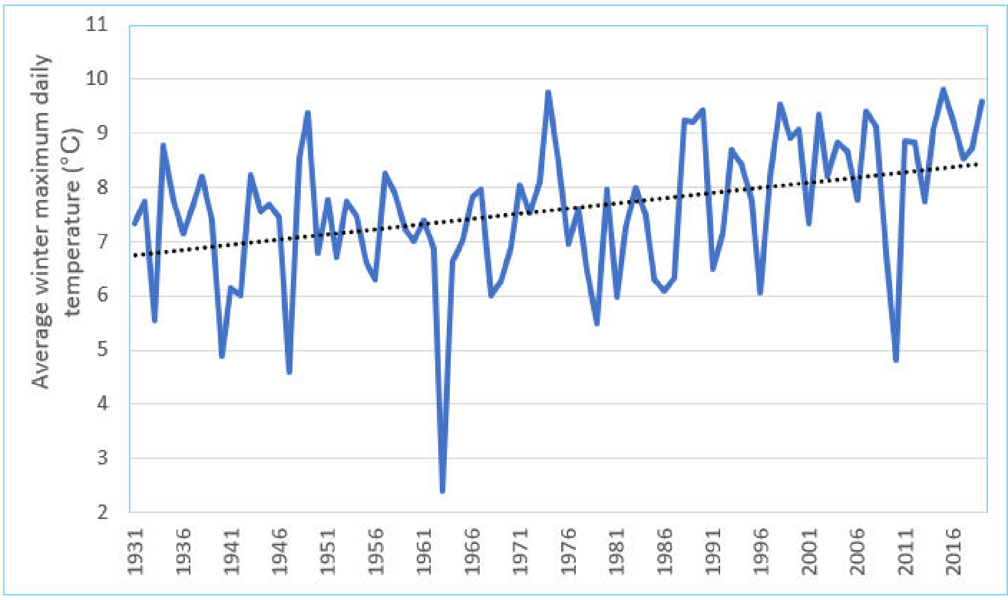

Figure 14-4 - Average winter maximum daily temperature (°C) (1930-2019) (Ross-On-Wye)

14.17.10. As shown in Figure 14-5 the long-term average days with ground frost (1981-2010) in the River Severn catchment are close to average for the UK.

[27] https://www.bbc.co.uk/news/newsbeat-40358961

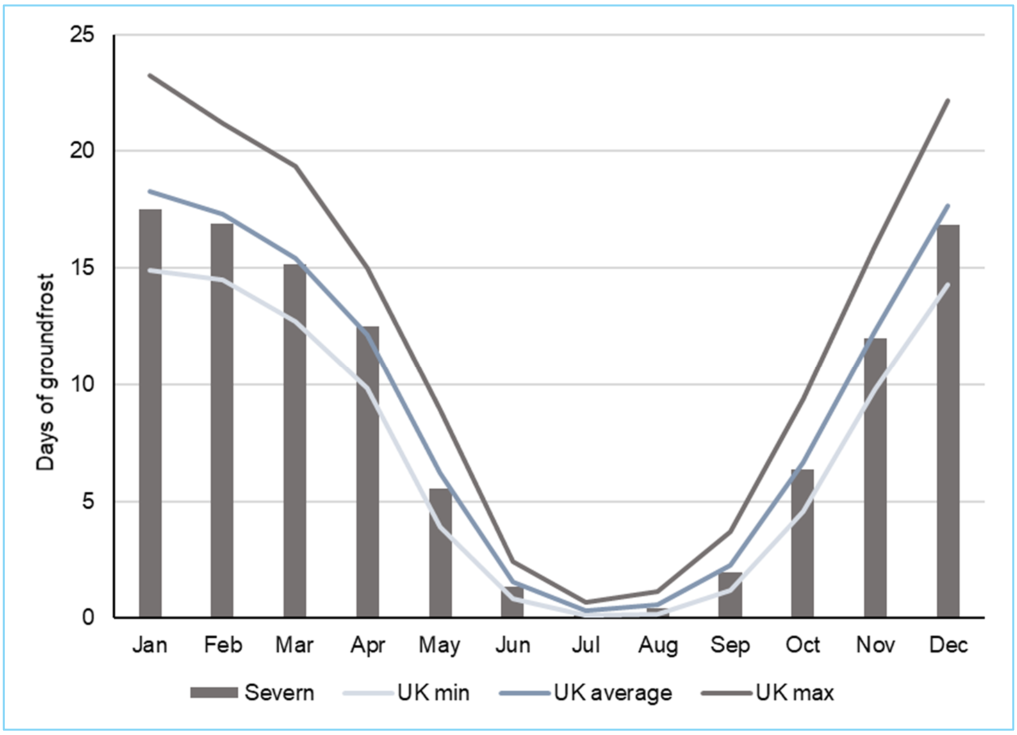

Figure 14-5 - Long-term average days with ground frost (1981-2010)

14.17.11. In accordance with the observed increasing winter temperatures (see Figure 14-4) the linear trendline on Figure 14-6 shows the number of days with air frost each winter has been reducing since 1930.

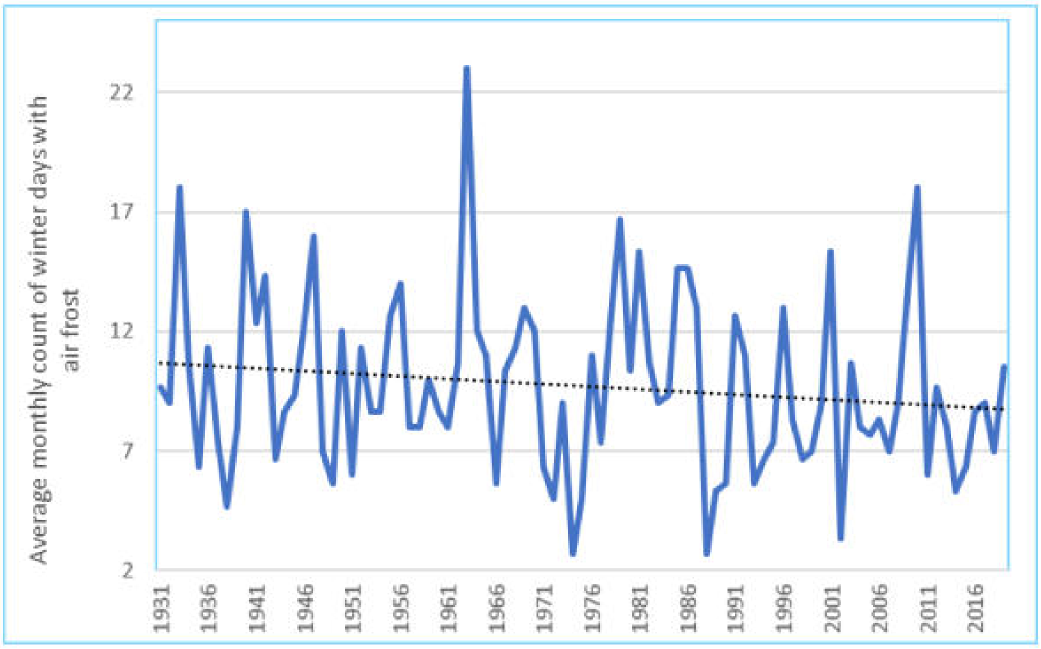

Figure 14-6 - Average monthly count of winter days with air frost (1930-2019) (Ross-On-Wye)

Current precipitation

14.17.12. Observations across the UK show a high level of variability in precipitation from year to year, with a slight overall increase in UK winter precipitation in recent decades.

14.17.13. As shown in Figure 14-7, long-term average monthly rainfall (1981-2010) in the River Severn catchment is below average for the UK.

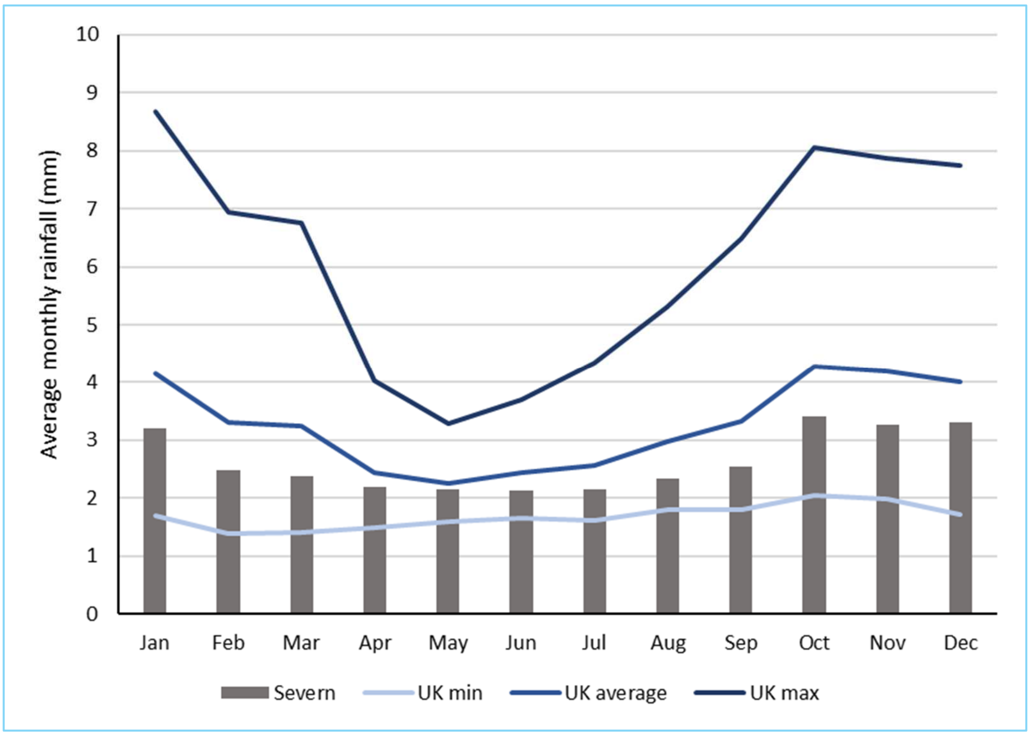

Figure 14-7 - Long-term average monthly rainfall (1981-2010)

14.17.14. Figure 14-8 shows the long-term average number of days that had rainfall over 10mm. It shows that for most of the year the River Severn catchment experiences fewer heavy rainfall days than its usual (average) for the UK.

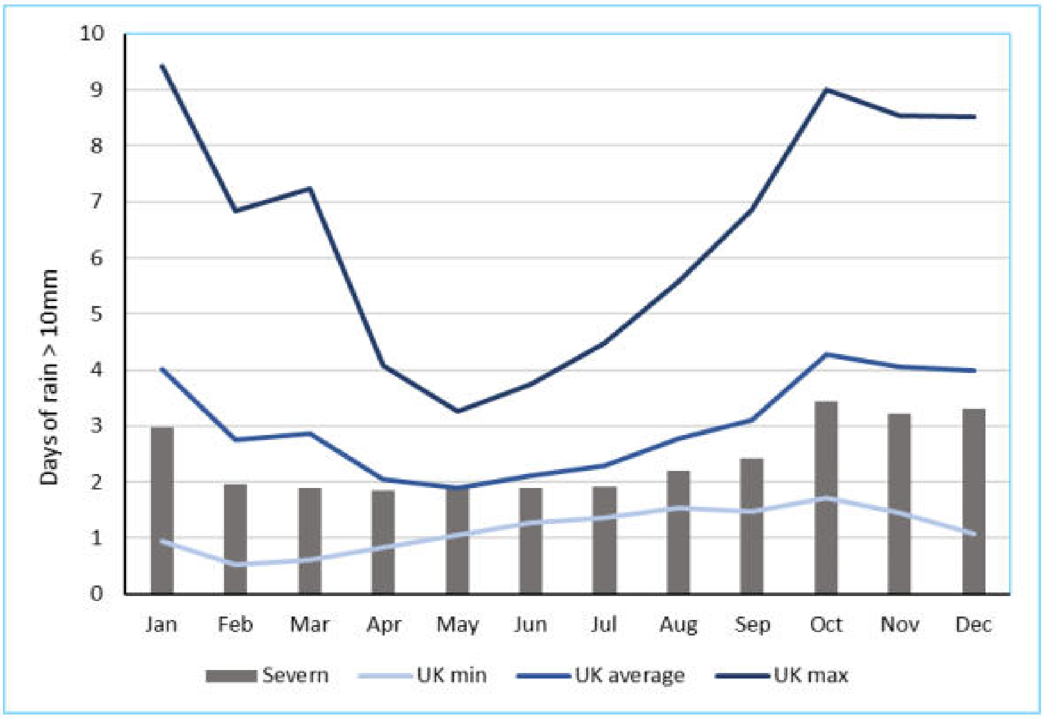

Figure 14-8 - Long-term average days with rainfall above 10mm (1981-2010)

14.17.15. Data from the Ross on Wye climate station shows that both summers and winters have variable precipitation and that rainfall in both these seasons has been increasing since 1930 (conclusion based on fit of linear trendline on Figure 14-9 and Figure 14-10).

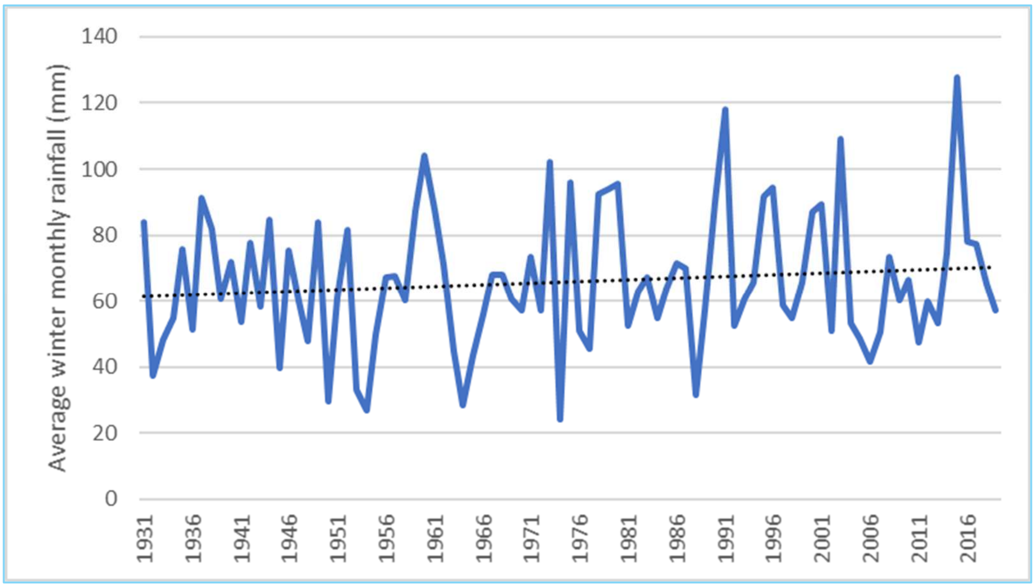

Figure 14-9 - Winter average monthly rainfall (mm) (1930-2019) (Ross-On-Wye)

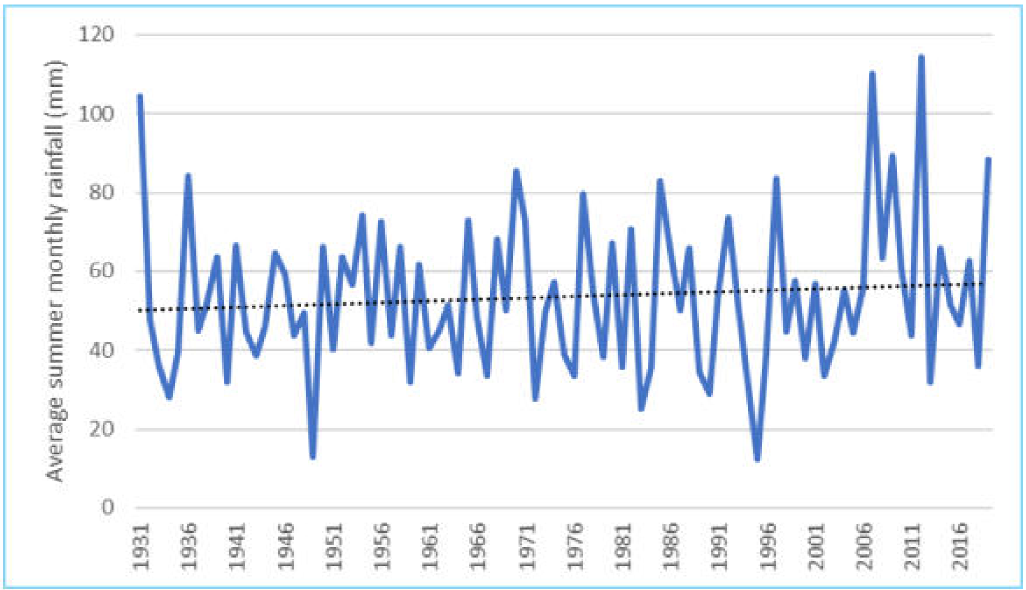

Figure 14-10 - Summer average monthly rainfall (mm) (1930-2019) (Ross-On-Wye)

14.17.16. Across the UK the amount of rain from extremely wet days has increased by 17% when comparing the period 2008-2017 to 1961-1990 period (Met Office, 2018). These changes are largest for Scotland and not significant for most of southern and eastern areas of England. Other extreme rainfall indices exhibit large inter-annual variability but are broadly consistent with increased rainfall over the UK. Other extreme rainfall indices exhibit large inter-annual variability but are broadly consistent with increased rainfall over the UK[28].

14.17.17. In the study area impacts from extreme weather have been recorded, for example:

- In October 2021 5 flood warnings were issued across Gloucestershire. They covered the Bow and Piddle Brook, River Leadon catchment areas, River Lugg south of Leominster and the River Wye[29];
- In December 2020 drivers on the A435 were stranded when flash flooding inundated the road. Police closed the road to prevent further vehicles getting

[28] http://research.ncl.ac.uk/convex/ [accessed 21st February 2018]
[29] https://www.gloucestershirelive.co.uk/news/gloucester-news/flood-warnings-issued-gloucestershire-amid-6137749

stranded[30].

- In July 2007 two month's rain (78 mm) fell in one day causing rapid and intense flash flooding that killed 3 people. Traffic on the M5 came to a standstill with about 10,000 motorists stuck overnight between junctions 10 and 12. Some 500 people were stranded at Gloucester Railway Station and rest centres were set up in Moreton-in-Marsh, Chipping Campden, Gloucester, Cheltenham and Tewkesbury for 2,000 people. Severn Trent Water's Mythe Water Treatment works was breached by floodwater leaving 350,000 people without clean, running water for 18 days. The following day the Castle Mead electricity sub-station was overwhelmed, cutting power to 48,000 people in Gloucester. 825 households – 1,950 people – had to leave their homes[31].

14.17.18. With regard to storminess, across the UK historical data provides no compelling trends as determined by maximum gust speeds from the UK wind network over the last four decades (UKCP18).

Projected future climate baseline

14.17.19. This section presents the outputs of climate change models that cover the study area. In summary it finds that, on average, the UK is likely to experience hotter and drier summers and warmer and wetter winters. This is a widely agreed finding. Alongside these changes in the average conditions, it is possible that climate change will also increase the frequency and severity of extreme weather events, such as heavy rainfall, storms and heatwaves.

14.17.20. The climate projections presented in this section are from UKCP18. These projections have been developed by the Met Office Hadley Centre Climate Programme which is supported by the BEIS and DEFRA. They provide the most up-to-date assessment of how the climate of the UK may change over the 21st century. The projections presented are for the River Severn catchment, within which the Scheme is located. The data is presented as averages for the period running from 2071 to 2089. For temperature and precipitation seasonal averages are provided for summer and winter, which represent the most extreme changes in response to climate change.

14.17.21. In accordance with LA114 the UKCP18 projections presented are for emissions scenario Relative Concentration Pathway 8.5 (RCP8.5). This is the most extreme emissions scenario, it represents a future where GHG emissions continue to rise, and the nations of the world choose not to switch to a low carbon future.

Temperature projections - warmer winters

14.17.22. Figure 14-11 shows that under RCP8.5 average winter temperatures in the River Severn catchment are expected to increase from 4.1ºC (observed average 1981-2010) to 7.0ºC (projected average 2071-2089), an increase of 2.9ºC (based on the central estimate, i.e. 50th percentile). The uncertainty around this estimate of change ranges from 1.1ºC to 4.8ºC (represented by the 10th and 90th percentiles respectively).

[30] https://www.bbc.co.uk/news/uk-england-gloucestershire-55429889
[31] https://thefloods.gloucestershirelive.co.uk/

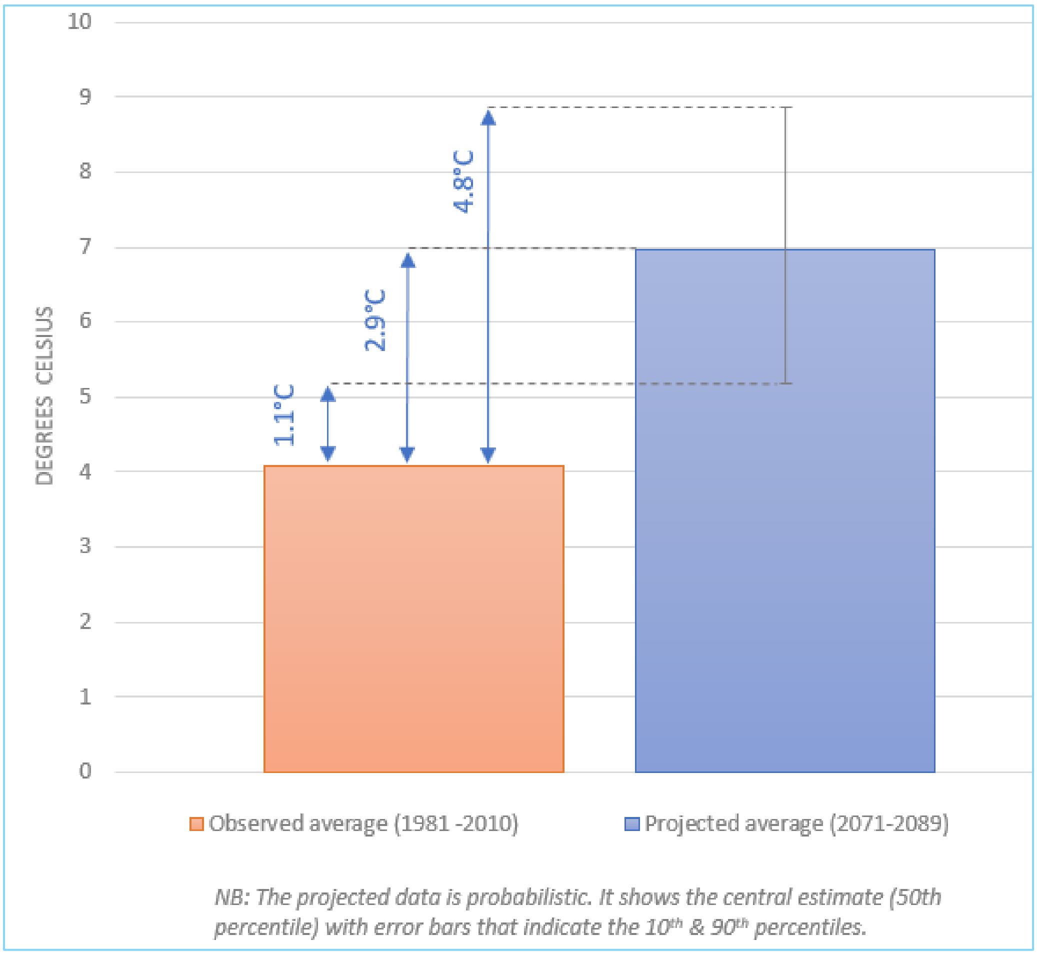

Figure 14-11 - Projected average mean winter temperatures (2071-2089)

14.17.23. In the UK, the heaviest snowfalls tend to occur when the air temperature is between zero and 2°C[32]. The projected increase in winter temperatures are therefore expected to reduce mean snowfall, number of snow days and heavy snow events[33]. While there is less certainty in the magnitude of these changes, there is confidence in the negative direction of the change[34]. This is supported by the fact that the decade leading up to the publication of UKCP18 (2008-2017) had 5% fewer days of air frost and 9% fewer days of ground frost compared to the 1981-2010 average, and 15% and 14% respectively compared to 1961-1990[35].

Temperature projections - hotter summers

14.17.24. In the recent past (1981-2000) the probability of seeing a summer as hot as 2018 in the UK was low (<10%). This probability has already increased due to climate change and is now estimated to be between 10-25%. With future warming, hot summers by the mid-century could become even more common (with probabilities of the order of 50% depending on the emissions scenario followed)[36].

[32] Met Office. (2013). Met Office. [online] Available at: http://www.metoffice.gov.uk/learning/learn-about-the-weather/weather-phenomena
[33] Brown, S., Boorman, P. and Murphy, J. (2010). Interpretation and use of future snow projections from the 11member Met Office Regional Climate Model ensemble. UKCP09 Technical note, Met Office Hadley Centre, Exeter, UK
[34] McColl, L., Palin, E. J., Thornton, H. E., Sexton,·D. M. H., Betts, R. and Mylne, K. (2012). Assessing the potential impact of climate change on the UK's electricity network. Climatic Change, 115: 821-835. OR McColl, L., Angelini, T. and Betts, R. (2012) UK Climate Change Risk Assessment for the Energy Sector. Department for Environment Food and Rural Affairs, London, UK
[35] Met Office, (2019) UKCP18 Science Overview Report, online: https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Overview-report.pdf
[36] Met Office (2019) UKCP18 Science Overview Report, online, available: https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Overview-report.pdf

14.17.25. In the River Severn catchment, within which the Scheme is located, projected mean daily maximum summer temperatures have been obtained from the UKCP18 probabilistic projections for 2071-89. Since these are an average of summer daily maximum temperatures it should be noted that some days in this period are likely to be hotter than the values indicated below. Figure 14-12 shows that an increase in summer temperatures is expected by the 2080s under RCP8.5. The central estimate (i.e. 50th percentile) projects an increase of 5.1ºC in summer mean daily maximum temperatures by 2071-89.

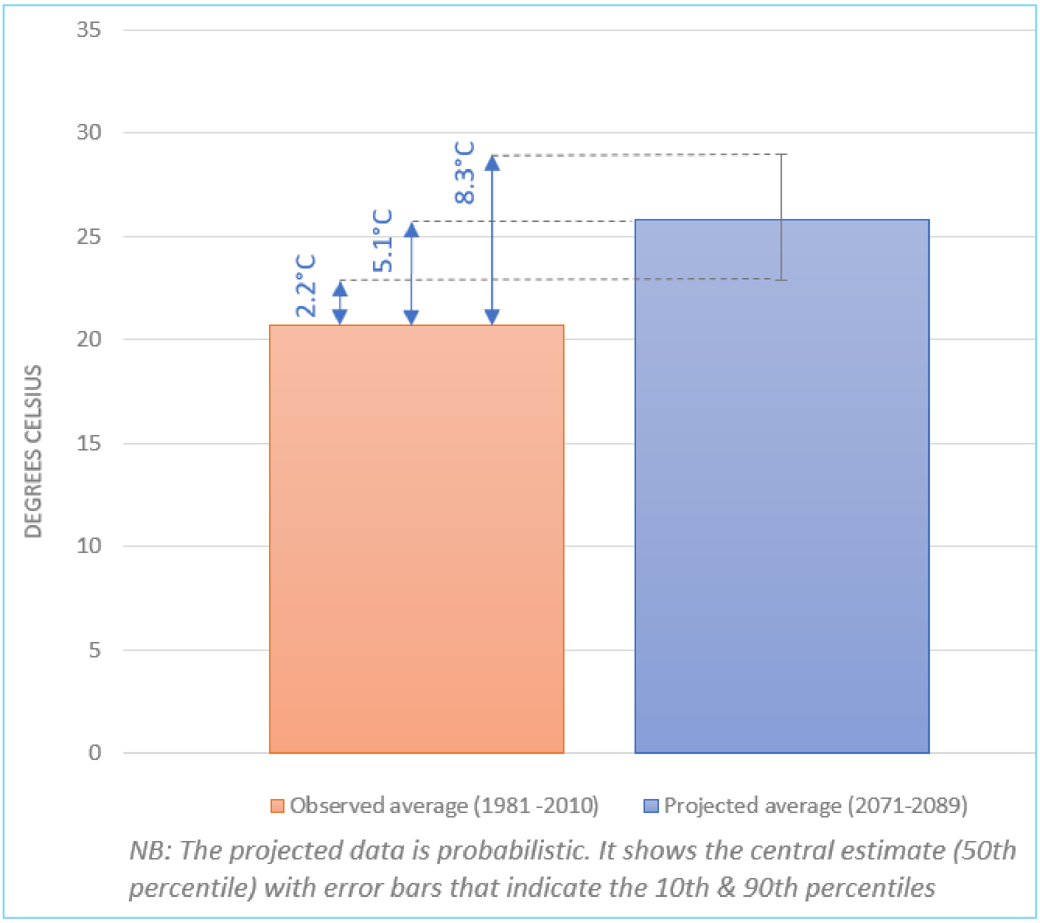

Figure 14-12 - Projected average maximum summer temperature (2071-2089)

Precipitation projections - drier summers

14.17.26. Projected precipitation levels for RCP 8.5 have been averaged across the River Severn catchment, within which the Scheme is located, to give a range of projected average rainfall change between the 10% and 90% probability levels. As shown in Figure 14-13 by 2071-89 this range amounts to a decrease in rainfall of between 0.1mm (7%) to 1.4mm (66%). The central estimate of change (i.e. 50th percentile) in mean summer precipitation for the same period is a 0.7mm reduction. These projections suggest that future average rainfall trends are uncertain, but it is more likely than not that summer rainfall will decrease. It is noted that historic observations recorded at the Ross-on-Wye climate station show average summer rainfall may have increased between 1930-2019 (see Figure 14-10). This supports the finding that future average rainfall trends are uncertain.

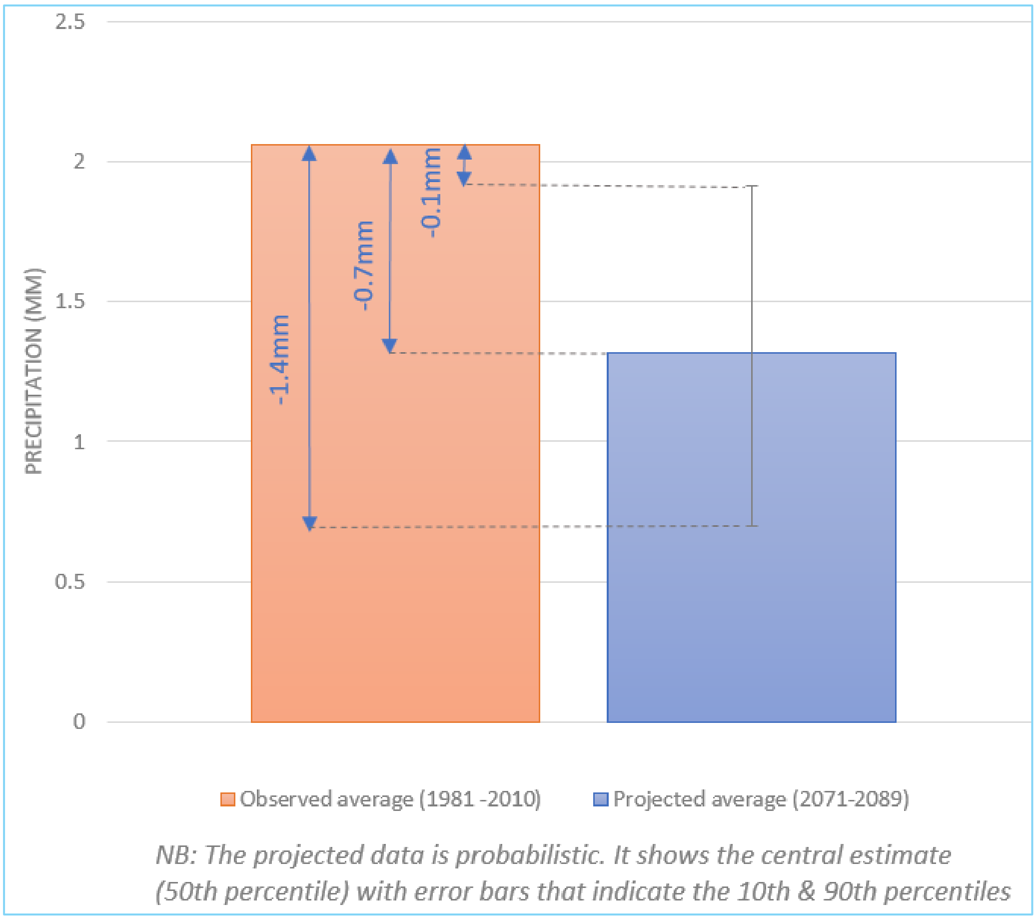

Figure 14-13 - Projected average summer precipitation (2071-2089)

Precipitation projections - heavier rainfall and wetter winters

14.17.27. Figure 14-14 shows that UKCP18 climate projections forecast that by 2071-89, under RCP8.5 central estimate (i.e. 50th percentile), winter mean precipitation will increase by 0.5mm. However, it should be noted that year to year levels are expected to continue to vary widely. This is demonstrated in the recent historical record in which the winters of 2013-14 and 2015-16 stand out as having particularly high amounts of rainfall (Figure 14-9), each with over 150% of the 1981-2010 average UK winter rainfall.

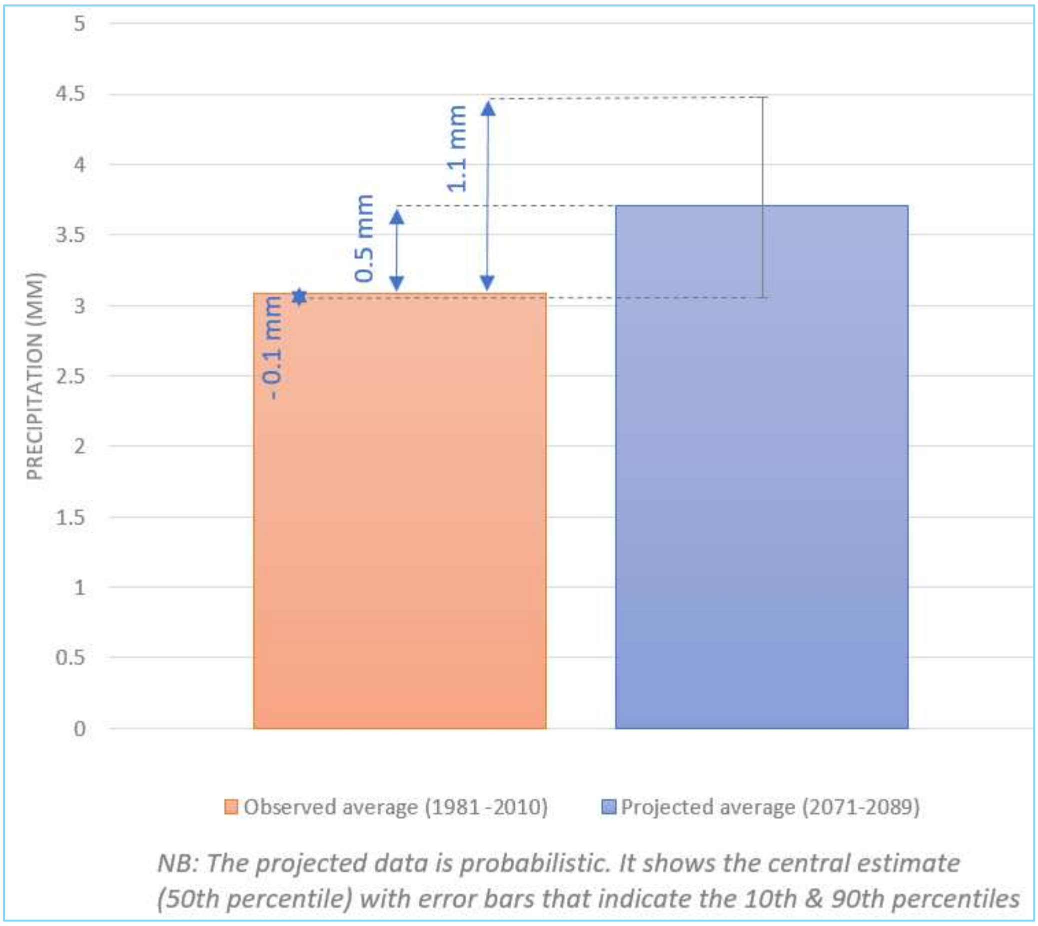

Figure 14-14 - Projected average winter precipitation (2071-2089)

14.17.28. Across the UK the amount of rain from extremely wet days has increased by 17% when comparing 2008-2017 with the 1961-1990 period[37]. Changes have been the largest for Scotland and are not significant for most of southern and eastern areas of England. Other extreme rainfall indices exhibit large inter-annual variability but are broadly consistent with increased rainfall over the UK.

Extreme weather projections

14.17.29. Future projections of storms and high winds are uncertain. They depict a wide spread of future changes in mean surface wind speed. This is partly due to large uncertainty in projected changes in circulation over the UK, and also because of wide ranging natural climate variability[38]. It is therefore difficult to represent extreme winds and gusts within regional climate models[39]. Global projections show an increase in near surface wind speeds over the UK for the second half of the 21st century for the winter season[40]. These studies suggest that climate-driven storm changes are less distinct in the Northern than Southern hemisphere[41]. There is some agreement of a projected poleward shift in storm tracks across the Atlantic Ocean. However, for mid-Atlantic storms, such as those that affected the UK in early 2014, projections are less certain[42]. Potentially, those mid-Atlantic

[37] Met Office, UK extreme events, 2018, https://www.metoffice.gov.uk/research/climate/understanding-climate/uk-extreme-events-_heavy-rainfall-and-floods
[38] Brown, S., Boorman, P., McDonald, R., and Murphy. J. (2012) Interpretation for use of surface wind speed projections from the 11-member Met Office Regional Climate Model ensemble. Post-launch technical documentation for UKCP09. Met Office Hadley Centre, Exeter, UK. Crown copyright
[39] Ibid
[40] Met Office, UKCP18 Factsheet: Wind, www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-fact-sheet-wind.pdf
[41] Bengtsson, L., Hodges, K. I. (2005). Storm Tracks and Climate Change. Journal of Climate, 19: 3518-3543. http://dx.doi.org/10.1175/JCLI3815.1
[42] Slingo, J., Belcher, S., Scaife, A., McCarthy, M., Saulter, A., McBeath, K., Jenkins, A., Huntingford, C., Marsh, T., Hannaford, J. and Parry, S. (2014). The recent storms and floods in the UK, Met Office, Exeter, 29pp

storms may become more intense, particularly with the long-term warming of the sub-tropical Atlantic that could increase the amount of moisture that those storms carry[43]. However, such is the wide range of inter-model variation, robust projections of changes in storm tracks over the UK are not yet possible, and there is low confidence in the direction of future changes in the frequency, duration or intensity of storms affecting the UK.

14.18. Potential impacts

14.18.1. This section summarises the potential impacts of climate change on the Scheme that are assessed in detail later in this chapter.

Construction

Construction process

14.18.2. The current climate in the study area is unlikely to change significantly between now and the commencement of the Schemes construction. However, the current climate has changed significantly when compared to the baseline period of 1981-2010 (see the Climate Vulnerability Baseline (Section 14.17). Construction impacts associated with the current climate are not expected to impact construction unless construction coincides with extreme weather event(s) such as drought or storms. These are not assessed in this Chapter as they would be managed through the Scheme's EMP (see application document TR010034/APP/7.2) and, where they are potentially significant, are addressed as required by the other topics within this report, for example see Chapter 8 Road Drainage and the Water Environment for the assessment of construction impacts associated with flood risk.

Operation

14.18.3. Potential operational impacts on assets (including their operation, maintenance and refurbishment) are listed below under the heading of the receptor they could affect:

- Road surfaces and pavements:
  - Warmer winters could reduce winter maintenance and associated traffic disruption (less road salting and freeze thaw damage);
  - Hotter summers could damage materials (rutting, shrinkage, and expansion) increasing maintenance requirements and associated traffic disruption; and
  - Heavier rain and wetter winters could increase pothole formation (by weakening the soil beneath the carriageway) increasing maintenance requirements and associated traffic disruption.
- Structures (including embankments, earthworks, and bridges):
  - Hotter summers could reduce the asset lives of structures (over expansion and buckling) increasing maintenance requirements and associated traffic disruption; and
  - Drier summers could cause soil instability (intensify and extend soil moisture deficits and impact groundwater levels and earth pressures) increasing maintenance requirements and associated traffic disruption.
- Drainage infrastructure:
  - Drier summers in combination with hotter temperatures could dry out soils and subsequently increase erosion. This may cause sedimentation within the Scheme's drainage infrastructure that reduces its drainage capacity and so increases the risk of flooding causing traffic disruption. Additional maintenance work to prevent flooding may also cause traffic disruption;

[43] Ibid

    - Heavier rain and wetter winters could increase the risk of pluvial or surface flooding. Flooding and additional associated maintenance requirements could both cause traffic disruption; and
    - Warmer winters could reduce freeze thaw erosion which can damage underground assets. Reducing maintenance requirements and associated traffic disruption.
- Road technology and street furniture:
    - The frequency of extreme weather impacts on electrical equipment may increase, for example lightning strikes become more regular and extreme, and hot temperatures become more common causing thermal over loading of circuits. Repair and maintenance may cause traffic disruption; and
    - High winds in more regular storms could overload small structures and signage and damage roadside planting and furniture. Repair and maintenance may cause traffic disruption.
- Landscaping:
    - Drier summers could damage the Scheme's landscaping. More regular maintenance may cause traffic disruption.

14.18.4. Potential operational impacts on end-users are listed below, the potential receptor for all of these would be driver experience:

- Warmer winters could improve winter driver safety (less ice) and so reduce traffic disruption caused by accidents;
- Hotter summers could increase the number of vehicle breakdowns and so increase traffic disruption and the number of associated accidents;
- Hotter summers could increase accident rates and so increase traffic disruption;
- Heavier rain and wetter winters could reduce driver safety and so increase traffic disruption associated with accidents; and
- Storms and high winds could reduce driver safety and so increase traffic disruption associated with accidents.

14.18.5. Potential operational impacts on environmental receptors that are related to, or could be intensified by, climate change are assessed as cumulative effects. These are summarised in Section 14.21.

14.19. Potential mitigation measures

14.19.1. To understand the exposure and resilience of the Scheme design to climate change, information has been gathered from the design team and the environmental team about the mitigation measures already built into the design (i.e. embedded mitigation).

14.19.2. The assessment of climate vulnerability impacts is undertaken after consideration of the Scheme design and mitigation. Embedded mitigation and additional mitigation that is specific to each potential impact is identified in Table 14-13 and Table 14-14.

14.20. Residual impacts

14.20.1. The likelihood of each potential impact, with embedded mitigation in place, has been assessed along with the consequence of that impact if it occurred. These assessments along with the resulting significance of effect are presented in two tables, one for each of type of receptor:

- The assets and their operation, maintenance, and refurbishment (Table 14-15); and
- End-users (Table 14-16).

Table 14-15 - Potential operational impacts on asset receptors (including their operation, maintenance, and refurbishment)

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
Road surfaces and pavements						
Warmer winters	The projected increase in winter temperatures and decrease in snowfall suggests a reduction in frequency of winter road maintenance (salting). Additionally, since freeze thaw erosion can damage underground assets, milder temperatures projected in the future may reduce the need for maintenance work that would otherwise disturb road surfaces and pavements.	NA as impact is beneficial.	NA as impact is beneficial.	Medium – Following the DMRB LA 114 standards and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that winter mean temperatures will increase over the Scheme's lifetime (in winter, under RCP 8.5, mean temperature is likely to increase by approximately 2.9ºC [central estimate]). However, projected changes to snowfall and the number of nights below freezing are less certain so the likelihood of this impact is found to be Medium.	Minor beneficial - During the Scheme's operation, road and pavement maintenance, upgrade works, and associated road traffic delays could reduce (minor beneficial). The reduced requirement for the operation of slow-moving salting vehicles would also avoid potential minor traffic disruption.	Not significant

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
Hotter summers	Hotter summers could damage materials, for example: • Ageing bituminous binders (deformation and rutting of road surfaces); • Softening, deforming, and damaging bitumen in asphalt; • Over expansion and buckling of concrete roads; • Failure of expansion joints; or • Wider temperature variations causing shrinkage and expansion that leads to cracking.	Best practice construction techniques and appropriate material quality standards will be followed to ensure the design lives specified can be met. For example, roads and pavements will use sufficiently hard binders in the asphalt. Polymer modified bitumen will be used in the pavement surface course and a resistance to permanent deformation will be specified as a requirement. Furthermore, heavy-duty macadam will be used in the binder and base course below which has an increased rut resistance. The drainage design will ensure the bound material is constructed on a sound foundation that should perform at it's optimum over the design life. To further improve the Scheme's longevity the design will investigate the use of warm mix asphalt, which has a reduced binder ageing during production as it is not heated to the same high temperatures as the conventional hot mix asphalt.	None	**Medium** - Following National Highways guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase over the Scheme's lifetime (by 2071-89 summer mean daily maximum temperatures could be up to +5.1ºC warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place the likelihood of impact is Medium. There is still likely to be some damage to assets during the lifespan of the Scheme.	**Minor adverse** - Emergency repairs and more regular maintenance interventions may be required, in response to changes in deterioration rates. These would create associated traffic delays (minor adverse). Under extreme temperature, certain maintenance activities may be required to be undertaken at night, to keep work to schedule, thus incurring higher programme costs (e.g. labour and illumination) but causing less traffic disruption (negligible).	Not significant
Heavier rain and wetter winters	Heavier rain and wetter winters will	The design will ensure continuity of drainage in the pavement and road	None	**Negligible** - Following National	**Minor adverse** - There may, in the	Not significant

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
	weaken the soil beneath the carriageway. Loads from traffic may then stress the surface past its breaking point.	layers. This will reduce the risk of water getting trapped in the foundation layers which could lead to an increase in moisture content and thus a decrease in performance i.e. lack of sufficient support to the overlaying bound material. A minimum water sensitivity category of 80 (indirect tensile strength ratio) and a minimum binder content based on the requirements of MCHW #942 will be specified where Thin Surface Course Systems (TSCS) are being applied. The design will specify that all materials within 450mm of the finished road level shall not be frost susceptible and in accordance with SHW Cl. 801.7 and 901.7. This may be reduced to 350mm if the Mean Annual Frost Index of the site is less than 50.		Highways guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is medium certainty that winter rainfall will increase over the Scheme's lifetime. Emission scenario RCP 8.5 suggests that a central estimate of mean winter precipitation change is an increase of 0.5 mm by 2071-89. Changes to extreme rainfall are less clear. The effect on pothole formation may be offset by the summers being drier and the winters being warmer (less freeze thaw erosion and less frost heaving; which are both significant contributors to pothole formation).	future, be an increase in the number and severity of potholes in the study area. Potholes can damage tires, wheels, and vehicle suspension. In extreme circumstances they can also cause road accidents, particularly where there are higher speed limits. To avoid this there would need to be an increase in maintenance and repair works. All the above could create traffic disruption (minor adverse).	

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
				It is therefore uncertain what the net impact of climate change will be. With the embedded mitigation the likelihood of impact is Negligible.		
Structures (including embankments, earthworks, bridges)						
Hotter summers	Hotter summers could reduce the asset lives of structures, for example causing: • Over expansion and buckling (e.g. of culverts or kerbs); or • Failure of expansion joints.	The design will ensure structures can adapt to expected future variations in temperature. The Eurocodes[44] used for the three bridges in the Scheme stipulate design to a temperature range of -18°C to 34°C which is adjusted to take account of altitude, material type and depth of surfacing thickness, etc.	Structures will be monitored throughout the life of the Scheme.	**Medium** - Following National Highways Guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase over the Scheme's lifetime (by 2071-89 summer mean daily	**Minor adverse** - Emergency repairs and more regular maintenance interventions may be required, in response to changes in deterioration rates. These would create associated traffic delays (minor adverse). Under extreme temperature, certain maintenance	Not significant

[44] The Eurocodes are European standards specifying how structural design should be conducted within the European Union. These were developed by the European Committee for Standardisation upon the request of the European Commission.

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
				maximum temperatures could be up to +5.1ºC warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place the likelihood of impact is Medium. There is still likely to be some damage to assets during the lifespan of the Scheme.	activities may be required to be undertaken at night, to keep work to schedule, thus incurring higher programme costs (e.g. labour and illumination) but causing less traffic disruption (negligible).	
Drier summers and wetter winters	Climate change could adversely affect soil stability impacting structures. This could affect physical assets (e.g. foundations) as well as semi natural features (e.g. embankments) and natural structures (e.g. trees). Impact pathways include: • The expected reduction in summer average rainfall is likely to intensify and extend soil moisture deficits	Risk will be managed by best practice design and construction. The geotechnical design will be in accordance with BS EN 1997-1:2004 Eurocode 7 Geotechnical Design Part 1 General rules. So, for example, cuttings and embankment works will be designed based on slope-stability analysis using site specific soil parameters. Additionally, to avoid waterlogging around embankments appropriate drainage will be included, for example so that runoff is collected and stored before being released gradually to infiltrate after a storm has passed,	Vulnerable assets in the study area will be regularly inspected to assess movements.	**Low** - Following National Highways guidance and in line with UKCP18 projections and the precautionary principle it is considered that there is medium certainty that summers will get drier over the Scheme's lifetime. The central estimate of change in mean summer precipitation by 2071-89 is -0.7 mm under RCP 8.5.	**Minor adverse** - Drier summers could damage assets and increase maintenance and upgrade works causing associated traffic disruption (minor adverse).	Not significant

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
	and impact groundwater levels. This could impact soil stability, for example causing subsidence or increasing earth pressures; • Wetter winters could cause soil instability as heave causes the upward movement of the ground; usually associated with the expansion of clay soils which swell when wet; • Wetter winters and heavier rain could cause weakening or washout of structural soils; and • Wetter winters may increase regularity of soil saturation and increase risk of embankment collapse, i.e. landslip.	see DMRB, CG501 - Design of highway drainage systems. The geotechnical construction will be in line with DMRB Standards (DMRB CD 622 Managing Geotechnical Risk) so risks will be controlled, for example, by: • Providing appropriate soil compaction; • Completing stability assessments as part of design. Including analysis and modelling to predict maximum and permittable magnitude of movement; • Undertaking appropriate ground investigations; • Collecting appropriate groundwater flow data; • Where foundations extend below the existing groundwater table or could extend below the future groundwater level, they are designed in accordance with industry standards; and • Monitoring during the construction works to measure movements, with agreed trigger level and action plan. In addition to the above, existing vulnerable assets in the study area will be regularly inspected to assess movements. This will be		However, the uncertainty around this estimate ranges from a 0.1 mm reduction (7% less) to a 1.4 mm reduction (66% less) (represented by the 10th and 90th percentile respectively). With embedded mitigation in place the likelihood of impact is reduced to Low.		

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
		supported by reference to the full arboricultural survey that is being completed for the site and identifies large and/or unstable trees.				
Drainage infrastructure						
Drier summers	Drier summers combined with the projected increase in summer temperatures could lead to increased erosion as soils and their substrates dry out. This could affect the capacity of drainage infrastructure.	Embankments will be compacted and planted; topsoil retention systems may be used if necessary. Although the detailed drainage design is not yet available it is assumed that it will assist operational maintenance by including accessible sediment traps that will be regularly cleared. It is also expected that the design will include concrete channels and swales, which will collect eroded sediment. There will be a number of attenuation ponds, which will have sediment forebays with specific arrangements to remove sediment before the water reaches the watercourse outfall. Sizing and treatment configuration will be confirmed by a sediment transport assessment. In addition to the above the Landscape chapter (Chapter 9) of this ES has proposed the following embedded mitigation:	None	**Low** - Following National Highways Guidance and in line with UKCP18 projections and the precautionary principle it is considered that there is medium certainty that summers will get drier over the Scheme's lifetime. The central estimate of change in mean summer precipitation by 2071-89 is -0.7mm under RCP 8.5. However, the uncertainty around this estimate ranges from a 0.1 mm reduction (7% less) to a 1.4mm reduction (66% less) (represented by the 10th and	**Minor adverse** - Mobilisation of debris could lead to increased sedimentation within the Scheme's drainage infrastructure adversely affecting its capacity. This could increase maintenance requirements and risk of flooding which could both cause traffic disruption (minor adverse).	Not significant

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
		• Retain existing trees and vegetation wherever possible; and Replace areas of trees and grass lost to facilitate the works wherever practicable.		90th percentile respectively). With embedded mitigation in place the likelihood of impact is reduced to Low.		
Heavier rain and wetter winters	The projected climate trend of increasing frequency and intensity of heavy rainfall events (potentially during summer months) is likely to increase the risk of pluvial or surface flooding as surface run-off inundates small catchments and the urban landscape. Prolonged periods of excessive precipitation (e.g. wetter winters) saturates soil, increasing the risk of fluvial or river flooding. Above average precipitation for long periods can also lead to a raised water table, which can result in groundwater flooding	The drainage system will be designed in line with current standards set out in DMRB CG 501[45]. This provides guidance for surface drainage for trunk roads including motorways. The design will include raising the riding surface, using an appropriate camber, and providing appropriate maintenance. With regard to pluvial flood risk on the road surface, the surface water drainage system is designed to control runoff rates up to 1 in 100-year return period. Although there are various design storm-periods for different aspects of highway construction, ultimately the absolute rainfall thresholds are highly dependent on the local topography, adjacent land-use, gradient, and location within the wider catchment. The DMRB standards highlight the importance of this local information to assess absolute rainfall thresholds. This	None	**Low** - Following National Highways guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is medium certainty that rainfall will get heavier over the Scheme's lifetime. Emission scenario RCP 8.5 suggests that a central estimate of mean winter precipitation change is an increase of 0.5 mm by 2071-89. Changes to extreme rainfall are less clear. With embedded mitigation in place	**Minor adverse** - New assets could be damaged, for example by scour around structures, which would then require maintenance. Both flooding and additional maintenance/repair could cause road closures and associated traffic delays (minor adverse).	Not significant

[45] https://www.standardsforhighways.co.uk/prod/attachments/ada3a978-b687-4115-9fcf-3648623aaff2

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
	in areas where the geological characteristics are favourable.	information is provided in the Scheme's FRA (Appendix 8.1) which also includes consideration and allowance for climate change. The FRA sets out the allowance that has been used for the surface water drainage design with adjustment factors in line with the latest information in the PPG, Environment Agency and LLFA requirements. In short, a 70% climate change allowance has been used for the preliminary design as per section 5.7.7 of Flood & Water Management Supplementary Planning Document by Tewkesbury Borough Council (March 2018). A climate change allowance has also been applied to fluvial flows for the design of the flood compensation areas (to determine their volume) and to determine the freeboard needed between the soffit of structures and the design flood water level of the rivers being crossed. In consultation with the Environment Agency, the "upper end" allowance of +70% to peak flows has been used when investigating the designs resilience to climate change and the "higher central" (35%) allowance used to determine design levels. Since the programme of design, climate		the likelihood of impact is Low.		

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
		change allowances set out in the NPPF have been updated to include the H++ (90%) allowance. As such, a further sensitivity run of 90% increase in flows has been applied to examine the vulnerability of this type of development (Essential infrastructure) to future flood risk. Further information is presented in the Scheme's FRA (Appendix 8.1).				
Warmer winters	Warmer winters reduce freeze thaw erosion which can damage underground assets.	NA as impact is beneficial.	NA as impact is beneficial.	**Medium** - Following National Highways guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that winter mean temperatures will increase over the Scheme's lifetime (in winter, under the RCP8.5 emissions scenario, mean temperature is likely to increase by approximately 2.9ºC [central estimate]). However, projected changes to snowfall and the number of	**Minor beneficial** - During the Scheme's operation maintenance and repair works and associated traffic disruption could reduce.	Not significant

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
				nights below freezing are less certain so the likelihood of this impact is found to be Medium.		
Road technology and street furniture (including signs and signals)						
Changes to extreme weather	Extreme weather impacts on electrical equipment: • More regular and intense storms in the future could increase the regularity of lightning strikes on infrastructure which could damage electrical equipment; and • Extreme hot temperatures increase thermal loadings on electrical and control equipment reducing their life.	At the detailed design stage, electrical calculations will be carried out for the lighting and a risk assessment detailed in section 443 of BS7671:2018[46] will be undertaken to determine if protection against transient overvoltage (lighting strike) is required. In advance of this, based on professional judgement and consideration of the location of the lighting power supplies/feeder pillars, it is expected at this stage that transient overvoltage protection will be included in the final design.	Key electrical components will be regularly checked, and replacement cycles may be shortened if deterioration rates increase.	**Very low** – Climate projections show there is low certainty of how climate change will alter extreme weather in the future. With embedded mitigation in place the likelihood of impact is Very Low.	**Minor adverse** – Failure of the Scheme's lighting could cause traffic delays (minor adverse). To avoid this more regular maintenance may be required. This may itself cause traffic disruption (minor adverse).	Not significant

[46] https://shop.bsigroup.com/ProductDetail?pid=000000000030342613

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
Changes to extreme weather	High winds in more regular and intense storms could overload small structures and damage roadside planting and furniture, for example traffic signs.	• The landscape design will adhere to the Specification for Highways Works set out in Series 3000 (Landscape and Ecology) of the MCHW[47]. The design, within the M5 corridor, will also adhere to DMRB LD 117 which sets out that shrubs must not be planted within 4.5 m of the carriageway and large trees not within 9 m of it; and • Highways England's own Adaptation Assessment[48] found that the effect of wind on bridges is minimal as it is not the dominant load. Fatigue actions due to wind gusting shall be determined in accordance with BS EN 1991-1-4, DMRB 365 and DMRB 354.		**Very low** – Climate projections show there is low certainty of how climate change will alter extreme weather in the future. With embedded mitigation in place the likelihood of impact is Very Low.	**Minor adverse** – Partial road closures for unplanned minor repairs could cause traffic disruption (minor adverse). To avoid this more regular maintenance may be required for example shorter intervention/ strengthening intervals.	Not significant
Landscaping						
Hotter and drier summers	Hotter and drier summers will increase soil moisture deficits in the future which could negatively impact the Scheme's landscaping. The landscaping has aesthetic benefits but also prevents	The proposed landscape design will futureproof the Scheme in terms of climate change as well as in terms of pests/diseases by adhering to best practice. This will include diversifying planting species as much as possible, including drought tolerant species, whilst still having regard to the local	None	**Medium** - Following National Highways Guidance and in line with the UKCP18 projections and the precautionary principle it is considered that	**Negligible** – Additional maintenance would cause minimal traffic disruption as it is unlikely to require lane closures.	Not significant

47 Manual of Contract Documents for Highway Works (MCHW), 2019, www.standardsforhighways.co.uk/ha/standards/mchw/index.htm
48 Highways England Climate Adaptation Risk Assessment, 2016, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/596812/climate-adrep-highways-england.pdf

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
	excessive aeolian soil erosion and protects structures from surface water runoff scour.	character, and generally planting only native species. It will also adhere to best ecological practice.		there is high certainty that summer mean temperatures will increase over the Scheme's lifetime (by 2071-89 summer mean daily maximum temperatures could be up to +5.1ºC warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place the likelihood of impact is Medium. There is still likely to be some damage to assets during the lifespan of the Scheme.		

Table 14-16 - Potential operational impacts on end user receptors

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
Driver experience						
Warmer winters	Warmer winters will improve winter driver safety by	NA as impact is beneficial.	NA as impact is beneficial.	High - Following National Highways guidance and in line with the UKCP18	Minor beneficial - Reduction in road traffic accidents and associated traffic	Not significant

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
	reducing driving risks for road users as roads will be less icy and snowfall will reduce visibility less often.			projections and the precautionary principle it is considered that there is high certainty that winter temperatures will increase over the Scheme's lifetime (in winter, under emissions scenario RCP8.5, mean temperature is likely to increase by approximately 2.9ºC [central estimate]). The likelihood of impact is therefore High.	disruption. Although it is noted that this beneficial impact would be equally present both with and without the Scheme.	
Hotter summers	Climate change will increase average summer temperatures. Vehicle breakdowns are more common during warm weather because the heat puts stress on critical components.	The M5 through Junction 10 will have a continuous hard shoulder throughout. MIDAS queue detection, CCTV and Emergency Roadside Telephones (ERTs) will be used to monitor traffic and breakdowns in line with standard motorway operating procedures.	None	Medium - Following National Highways Guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase over the Scheme's lifetime (by 2071-89 summer mean daily maximum temperatures could be up to +5.1 ºC	Minor adverse - Breakdowns can have the following adverse effects: • Cause drivers to lose control of their vehicle - e.g. in the event of a tyre blowout or brake failure (both can be associated with warmer weather); • Increase the likelihood of vehicle fires and	Not significant

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
				warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place the likelihood of impact is Medium.	associated risks for road users; • Be dangerous for drivers stranded in a live traffic lane, and • Cause secondary accidents involving other road users. All the above can cause minor adverse traffic disruption consequences (due to obstruction of traffic or as traffic slows to pass).	
Hotter drier weather	Climate change will increase average summer temperatures. During warm weather, accident rates typically increase. This is attributable to more solar glare, more people being out (particularly	The long-term landscape design does not include large areas of exposed soil that could become mobile in hot dry weather (blowing onto the road and reducing skid resistance). The design will utilise various elements of motorway technology which will combine to create a safer driving environment. Specifically, to monitor traffic conditions, Motorway Incident Detection and Automatic Signalling (MIDAS) system will be provided. Post or gantry mounted	Regular maintenance assessments of the road will follow the National Highways skid policy which takes into account climate change[49].	Medium - Following National Highways guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase over the Scheme's lifetime (by 2071-89 summer mean daily maximum	Minor adverse – More dangerous driving conditions in the future could increase road traffic accidents and associated traffic disruption (minor adverse).	Not significant

[49] Skidding resistance requirements, 2019, http://www.standardsforhighways.co.uk/ha/standards/dmrb/vol7/section3/CS%20228%20Skidding%20resistance-web.pdf

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
	in the evening), more pedestrians and bikes on the road and an increase in fine particulates on the road surface which reduces skid resistance. Additionally, other contaminants, such as oil and tyre rubber can build up in drier weather acting as lubricants further reducing skid resistance.	Advanced Motorway Indicators (AMIs) will also be provided to provide motorists with speed limit and lane control information. In addition, Pan Tilt Zoom (PTZ) Closed Circuit Television (CCTV) will be sited to provide coverage of the carriageway for the purpose of traffic monitoring, incident control and management. There will also be Variable Message Signs (VMS) to display real time information designed to improve safety and journey times. It is noted that risks associated with driving cannot be fully removed by changes to the Scheme design. This reflects the fact that the cause of most traffic accidents is composite and often includes driver error.		temperatures could be up to +5.1 ºC warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place the likelihood of impact is Medium.		
Heavier rain and wetter winters	In the future heavier rain resulting from climate change will create dangerous driving conditions more often as spray reduces visibility, stopping	To inform the design of the Scheme an FRA (Appendix 8.1) has been completed along with a detailed Drainage Strategy and the Road Drainage and the Water Environment chapter (Chapter 8). This describes how the Scheme has ensured drainage will be sufficient for future rainfall. It is noted that risks associated with driving cannot be fully	None	Low - Following National Highways guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is medium certainty that rainfall will get heavier over the Scheme's lifetime.	Minor adverse - Accident rates could increase creating more traffic disruption (minor adverse).	Not significant

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
	distances increase and standing water creates an aquaplaning risk.	removed by changes to the Scheme design. This reflects the fact that the cause of most traffic accidents is composite and often includes driver error.		Emissions scenario RCP8.5 suggests that a central estimate of mean winter precipitation change is an increase of 0.5 mm by 2071-89. Changes to extreme rainfall are less clear. With embedded mitigation in place the likelihood of this impact is reduced to Low.		
Changes to extreme weather	More frequent storms and high wind events could affect road user safety. High-sided vehicles can become unstable in gusts of wind over 45 mph. Windblown debris, including loads detached from vehicles and third-party structures	The road alignment is not at a high elevation or particularly exposed, e.g. along a ridge. Significant traffic disruption related to wind exposure is therefore not expected. The landscape design will adhere to the Specification for Highways Works set out in Series 3000 (Landscape and Ecology) of the MCHW[50]. The design will also adhere to DMRB LD 117 which sets out that shrubs must not be planted within 4.5 m of the carriageway and large trees not within 9 m of it.	None	Very low – Climate projections show there is very low certainty of how climate change will alter extreme weather in the future.	Minor adverse - road traffic accidents and associated traffic disruption (minor adverse).	Not significant

[50] Manual of Contract Documents for Highway Works (MCHW), 2019, www.standardsforhighways.co.uk/ha/standards/mchw/index.htm

Climate trend	Potential impact	Embedded mitigation	Additional mitigation	Likelihood	Consequence	Significance
	blowing onto the network, as well as fallen trees could also be a hazard to vehicles traveling at speed.					

14.21. Cumulative effects

14.21.1. This section considers potential cumulative climate impacts affecting environmental receptors that are not covered elsewhere in this report, i.e. by the relevant topic chapters. It includes consideration of existing potential impacts on environmental receptors that could be intensified by climate change as well as environmental impacts that could potentially emerge in the future.

Intensification of air quality impacts

14.21.2. In the future air quality impacts caused, in part, by vehicle emissions enabled by the Scheme will be intensified as hotter summers brought on by climate change will increase the formation of ground-level ozone, which is a dangerous air pollutant. A detailed assessment of air quality impacts is provided in the Air Quality chapter (Chapter 5). It is noted that air quality modelling undertaken to date does not account for expected climate changes that will intensify air quality impacts in the future. However, these impacts will likely be offset by the predicted future fleet wide shift toward electric and hybrid vehicles.

Reduced road salting providing benefit for water environment

14.21.3. Warmer winters in the future will reduce the requirement for road salting. This may have benefits for the water environment in the study area with regard to water quality as road salt can be transported in surface water runoff and, in large quantities, can be harmful to aquatic life.

Lower river levels intensifying impacts from surface water runoff discharges

14.21.4. Most of the Scheme's surface water runoff will ultimately be discharged to surface or groundwater. Hotter and drier summers may lower water levels in surface watercourses. In the future water quality impacts related to surface water drainage discharges, for example downstream of outfalls, could increase as the capability of these watercourses to dilute discharges reduces. The design includes SuDS which will maintain and manage the water quality and flow of discharges within appropriate thresholds prior to discharge. The Scheme's surface water discharges therefore do not rely upon dilution to avoid environmental impacts. The SuDS have been sized with consideration of the impacts of climate change (heavier rain and wetter winters).

More polluted surface water runoff impacting water environment

14.21.5. Climate change is projected to make summers drier, with occasional heavier convectional rainfall. Water quality in the watercourses, that surface water runoff from the Scheme is discharged into, may therefore in the future become more vulnerable to impacts from first flush events. This is when long periods of dry weather enable contaminants to build up on road surfaces. This then mobilise in surface water runoff following a heavy rainfall event and enters aquatic systems via surface water runoff and drainage infrastructure en-masse. Pollutants in this runoff can be harmful to aquatic life.

14.21.6. Water quality impacts on the water environment are avoided by inclusion of adequate treatment within the Scheme's SuDS drainage infrastructure. This treatment is sized with regard to flood flows with a climate change allowance. The SuDS intercept any polluted run-off and treat it prior to discharge to a watercourse. The water treatment processes provided by the SuDS primarily comprises filtration and biological treatment within storage areas. The configuration of the SuDS and other treatment infrastructure is designed to manage the types of pollutant typically expected in road runoff.

14.22. NPS compliance

14.22.1. The NPS NN (Department for Transport, 2014) includes a section on climate change adaptation from 4.36 to 4.47. Paragraph 4.40 of the NPS NN sets out that "new national networks infrastructure should be typically long-term investments which should remain operational over 'many decades in the face of a changing climate". As per the NPS NN requirement this chapter therefore considers how projected climate changes in the project area could affect the Scheme allowing its design and operation to be adapted so that it will remain operational in the long term in the face of a changing climate.

14.23. Assumptions and limitations

14.23.1. The climate vulnerability assessment will provide a broad, high-level indication of the potential impacts of climate change on the Scheme based on professional judgement.

14.23.2. The climate projections used will be from UKCP18. The UKCP18 projections do not provide a single precise prediction of how weather and climate will change years into the future. Instead UKCP18 provides ranges that aim to capture a spread of possible climate responses. This better represents the uncertainty of climate prediction science. It should also be noted that the level of uncertainty of the projections is dependent on the climate variable, for example, there is greater confidence around changes in temperature than there is in wind. In the climate vulnerability assessment this will be considered when assessing the likelihood of impacts.

14.23.3. The climate vulnerability assessment will be based on data from RCP 8.5. This is a GHG concentration trajectory under which it is assumed that emissions continue to rise throughout the 21st century. There is considerable uncertainty regarding if, how far and how quickly emissions will be reduced in the future. Using RCP 8.5 represents a conservative position.

14.23.4. Other key caveats and limitations of UKCP18 data are presented on the Met Office website[51].

14.24. Chapter summary

14.24.1. This chapter has presented the Scheme's climate change vulnerability assessment. The assessment considered the potential impacts of extreme weather and possible future climatic conditions on the Scheme during both its construction and operation and has been undertaken in compliance with DMRB LA114.

14.24.2. Climate projections from UKCP18 have been examined. They confirm that the study areas climate is expected to change in the future. The assessment finds that the Scheme could be vulnerable to operational impacts linked to these changes in the climate. Mitigation measures that either avoids these impacts, minimises them or reduces their consequences are presented. After consideration of this mitigation none of the potential climate vulnerability impacts are found to be significant adverse.

[51] www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance---caveats-and-limitations.pdf

15. Cumulative Effects Assessment

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