M25 junction 10/A3 Wisley interchange
TR010030
6.3 Environmental Statement: Chapter 15: Climate

Regulation 5(2)(a)
Planning Act 2008
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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Planning Act 2008

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

M25 junction 10/A3 Wisley interchange

The M25 junction 10/A3 Wisley interchange Development Consent Order 202[x]

6.3 ENVIRONMENTAL STATEMENT
CHAPTER 15: CLIMATE

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15. Climate

This Chapter is split into two parts:

- Effects of the Scheme on climate – particularly the impacts of greenhouse gas emissions (section15.1); and
- Vulnerability of the Scheme to climate change – particularly the resilience of the Scheme to climate change and extreme weather (section 15.2).

Executive summary - Emissions

The potential effects of the Scheme on the earth's climate by the increased emission of greenhouse gases during construction and throughout its operational life, have been assessed. The earth absorbs energy from the sun and re-emits it as thermal infrared radiation. Greenhouse gases in the atmosphere absorb this radiation, preventing it from escaping into space. The higher the concentration of greenhouse gases, the more heat energy is retained and the higher global temperatures become. This is a natural process. However, due to human activities the concentration of greenhouse gases in the atmosphere has increased dramatically, and is correlated with global warming. This leads to myriad indirect effects as the climate responds to the increased atmospheric temperature.

Section 15.1 assesses the effects of the Scheme on climate by quantifying likely emissions of greenhouse gases to the earth's atmosphere.

The 'Do Something' scenario will generate the following variations in emissions over the 'Do Minimum' scenario:

- Construction: 92,392 tCO_2e
- 2022 Opening Year: -860 tCO_2e
- 2037 Design Year: 98 tCO_2e

The construction phase and Opening Year together contribute 0.004% of the UK's 3rd carbon budget (2018-2023). This is not considered to be a significant impact. There is currently no carbon budget set for the period covering the Design Year and a quantitative comparison cannot be carried out, however the magnitude of generated emissions is considered to be minor and also not significant.

Regardless of the low significance, at all stages, emissions will be mitigated as far as possible. It is Highways England's commitment to reduce emissions wherever practicable, to support the UK Government in meeting its carbon reduction targets.

Executive summary - Climate Vulnerability

The Scheme has the potential to be affected by climate change.

The Climate Vulnerability section (section 15.2) includes an assessment of the vulnerability of the Scheme to climate change, providing:

- An examination of the current climate baseline using the Met Offices latest regional dataset of 30-year averages;
- A consideration of the projected future climate baseline for the 2050s, which represents the middle decade of the 30-year climate average from 2040 to 2069;
- 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, in accordance with Highways England Guidance, considers the likelihood and consequence of each potential vulnerability.

15.1 Effects on Climate

15.1.1 Introduction

15.1.1.1 This chapter details an assessment of the Scheme's effects on climate during construction and operation.

15.1.1.2 The potential effects of the Scheme on the earth's climate by the increased emission of greenhouse gases during construction and throughout its operational life, have been assessed. The earth absorbs energy from the sun and re-emits it as thermal infrared radiation. Greenhouse gases in the atmosphere absorb this radiation, preventing it from escaping into space. The higher the concentration of greenhouse gases, the more heat energy is retained, and the higher global temperatures become. Due to human activities the concentration of greenhouse gases in the atmosphere has increased dramatically, leading to global warming. This leads to myriad indirect impacts as the climate responds to the increased atmospheric temperature.

15.1.1.3 This chapter addresses the part of the climate change requirement outlined in The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (SI 2017/572) (herein referred to as the 'EIA Regulations 2017'), which states that the assessment should consider the potential effects of the Scheme on climate, in particular the magnitude of greenhouse gases emissions released during both construction and operation.

15.1.2 Competent expert evidence

15.1.2.1 This effects on climate chapter has been undertaken by a qualified Principal Environmental Consultant (BA (Hons) Environmental Studies, BSc Environmental Resources) and holds professional membership with the Institution of Environmental Sciences. They have over 18 years of knowledge and experience in infrastructure sustainable design and carbon management and has used their knowledge and professional judgement to undertake this assessment.

15.1.3 Legislative and policy framework

Table 15.1: Legislative, regulatory and policy framework

Legislation/ Regulation	Summary of Requirements
National	
Infrastructure Planning (Environmental Impact Assessment) Regulations 2017	The Regulations require: "A description of the likely significant effects of the project on climate (for example the nature and magnitude of greenhouse gas emissions)."
National Policy Statement for National Networks (NPSNN)	With relevance to this Chapter, the NPSNN (2014) highlights that the impact of road improvements on aggregate emission levels is likely to be small. However, it requires that applicants should both provide evidence of the carbon impacts of a Scheme and undertake an assessment of the

Legislation/ Regulation	Summary of Requirements
	proposed Scheme against the Government's carbon budgets. This will be implemented through the methodology presented below.
National Planning Policy Framework (NPPF) 2018	The NPPF includes the mitigation of climate change as part of its overarching objectives for achieving sustainable development. It provides that the planning system should support the transition to a low carbon future, shaping places in ways that contribute to radical reductions in greenhouse gas emissions. This includes supporting low carbon infrastructure.
The Climate Change Act 2008	The Climate Change Act (2008) creates a new approach to managing and responding to climate change in the UK. The Government has established legally binding carbon reduction targets through the Climate Change Act (2008) to drive the reduction requirements required by the Kyoto Protocol, as set out in Table 14.2. The overall objective is to reduce emissions by at least 80% of the 1990 base level year by 2050.
The Carbon Plan	The Carbon Plan (2011) sets out how the UK will achieve the emissions reduction commitment of 80% by 2050, made in the Climate Change Act (2008). It sets out how the UK will make the transition to a low carbon economy, maintain energy security and minimise costs to consumers. The Plan does not relate directly to road improvement schemes, but the Scheme should support implementation of the plan by prioritising low carbon materials and construction and operational energy efficiency, where practicable.
Construction 2025	Construction 2025 (2013) sets out how efficiency improvements will be created in construction covering sustainability and carbon and including a target to reduce emissions by 50%. 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.
Road Investment Strategy: for the 2015/16 – 2019/20 Road Period	The Road Investment Strategy (2015), as amended in 2016, published by the Department for Transport, sets out the strategy for the transformation of the strategic road network (SRN) by 2040 to create a modern SRN that supports a modern Britain. The Strategy also specifies objectives to significantly reduce emissions across the SRN, including emissions reductions from SRN construction activities. The Scheme should support implementation of the strategy delivering carbon requirements specified as relevant to it.
Highways England: Strategies and Frameworks	Highways England has a range of strategies, frameworks and tools in place for carbon reduction, including carbon objectives in their Sustainable Development Strategy (2017), and the Highways Agency Carbon Routemap (2014). Such strategies, frameworks and tools provide emission (i.e. carbon) projections and are intended to enable options to be considered. The Scheme should support the implementation of the strategies, frameworks and tools by delivering mitigation measures of relevance to the Scheme.

Legislation/ Regulation	Summary of Requirements
Regional	
Carbon and Energy Policy 2015 to 2019	The Carbon and Energy Policy 2015 to 2019, issued by Surrey County Council and is underpinned by the Surrey Climate Change Strategy (2009), sets out its objectives for managing energy and fuel use and reducing carbon emissions across its estate and activities. One of the objectives outlined in the Carbon and Energy Policy 2015 to 2019 is to review and consider life cycle energy and carbon implications for major projects and strategic decisions occurring with the reporting area of Surrey.
Surrey Transport Plan: Climate Change Strategy	The aim of the Surrey Transport Plan: Climate Change Strategy (2011), issued by Surrey County Council, is, with particular reference to this chapter, intended to reduce emissions from transport operations in Surrey, including street lighting and maintenance activities for example. The Scheme should consider the Surrey Transport Plan: Climate Change Strategy (2011) when specifying mitigation measures of relevance to the Scheme.

Table 15.2: UK carbon reduction targets

Carbon Budget	Carbon Budget Level	Reduction Below 1990 Levels
3rd carbon budget (2018 to 2023)	2,544 MtCO2e	37% by 2023
4th carbon budget (2023 to 2027)	1,950 MtCO2e	51% by 2025
5th carbon budget (2028 to 2032)	1,725 MtCO2e	57% by 2030

Table Source: Committee on Climate Change (2017)

15.1.4 Study area

15.1.4.1 The study area has been defined according to Highways England guidance, and covers the emission of greenhouse gases resulting from the Scheme in its construction and operation 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 materials production.

15.1.4.2 The activities for which emissions have been quantified in the assessment include the direct and supply chain activities for the ‘Do Something’ scenario of the Scheme's life cycle, for both the construction and operation stages of the Scheme. The specific elements of the Scheme lifecycle, referred to as modules, included in the assessment boundary are listed in Table 15.3 and Table 15.5. The ‘Scheme boundary’ specifies the life cycle, spatial and/or temporal extent of the quantification for each life cycle module, and the ‘emissions scope’ defines the source of emissions considered, including direct or supply chain emissions.

15.1.4.3 The life cycle modules listed in Table 15.4 and Table 15.6 have been excluded from the assessment on the basis that the associated emissions are either negligible, or the module is not applicable to the Scheme.

15.1.4.4 The emissions boundaries are in line with the boundaries set out in the Publicly Available Standard (PAS) 2080:2016 ‘Carbon Management in Infrastructure’[1], which is the technical standard for measuring and managing emissions from infrastructure.

15.1.4.5 The timescale of the assessment covers:

- Construction, as a single time period;
- Total annual operation for the Opening Year; and
- Total annual Operation for the Design Year.

Construction

Table 15.3: Scheme emission boundary and emission scope

<table>
<tr><th>Life cycle module</th><th colspan="2">Scheme boundary</th><th>Emissions scope</th></tr>
<tr><td>Materials</td><td colspan="2">The boundary covers the use of construction materials within the construction site boundary and the supply chains associated with these. Consumables are excluded as they are small, and plant is excluded on the basis of shared use across schemes.</td><td>The emissions scope accounts for primary raw material extraction, manufacturing and intra-manufacturing transportation, as captured in the relevant emissions factor values.</td></tr>
<tr><td>Transport</td><td colspan="2">The boundary covers transportation of the construction materials and the distances travelled from the primary site of manufacturing, not the supply depot. The primary site of manufacturing is used because transportation from a local supply depot does not represent the realistic transportation emissions, so can lead to significant under reporting.</td><td>The emissions scope considers direct vehicle emissions.</td></tr>
<tr><td rowspan="4">Construction process</td><td>Construction plant use</td><td>The boundary for construction plant covers the plant quantities, sizes and operating hours within the Red Line Boundary.</td><td>The emissions scope considers well-to-tank and direct plant emissions, according to engine on-time, engine size, hours of operation.</td></tr>
<tr><td>Construction water use</td><td>This boundary covers mains water use only within the Red Line Boundary.</td><td>The emissions scope considers emissions from all activities for the treatment and supply of water to site.</td></tr>
<tr><td>Construction waste transportation</td><td>The boundary covers transportation of bulk construction waste and the distances travelled from the construction site to the primary processing site.</td><td>The emissions scope considers direct vehicle emissions.</td></tr>
<tr><td>Construction waste off-site processing</td><td>The boundary covers processing of bulk construction waste, and is the same as</td><td>The emissions scope considers emissions</td></tr>
</table>

[1] PAS 2080:2018 *Carbon Management in Infrastructure*.

Life cycle module	Scheme boundary		Emissions scope
		available and quantified and in the waste assessment (Chapter 12 Materials and Waste).	from all waste processing activities.
	Employee commuting	The boundary includes transportation of workers to the site for the duration of the construction works.	The emissions scope considers direct vehicle emissions.

Table Source: Interpreted Highways England guidance and from PAS 2018:2016.

Table 15.4: Exclusions from construction Scheme emissions boundary

Life cycle module	Reasons for exclusion
Preliminary studies and consultations	This module includes a very wide range of office activities and travel from a wide range of locations. Emissions for this life cycle stage are minimal in comparison to both construction and in-use emissions and it is therefore excluded from the assessment.

Operation

Table 15.5: Operation Scheme Emissions Boundary

Life Cycle Module	Scheme Second draft for HE commentBoundary	Emissions Scope
Road User Carbon	The boundary includes traffic use of the infrastructure within the red line boundary for the proposed Scheme, and also traffic use of the wider road network, as outlined in the air quality assessment (Chapter 5 Air Quality).	The emissions scope considers direct vehicle emissions.
Maintenance / Refurbishment	This includes ongoing maintenance, repair, replacement and refurbishment activities.	Project-specific data is not available for a calculation to be undertaken. Therefore, operation and maintenance emissions are estimated using the same methodology as for the Scheme Emission Baseline (i.e. applying a typical percentage of in-use traffic emissions).
Operational energy use	The boundary for operational energy includes the electricity and direct fossil fuel consumption for operation of the infrastructure within the red line boundary for the proposed Scheme, over the planned operational life-time of the proposed Scheme.	Project-specific data is not available for a calculation to be undertaken. Therefore, operation and maintenance emissions are estimated using the same methodology as for the Scheme Emission Baseline (i.e. applying a typical percentage of in-use traffic emissions).

Table Source: Interpreted from Highways England guidance and PAS 2080:2016

Table 15.6: Exclusions from Operation Scheme Emissions Boundary

Life Cycle Module	Reason for ExclusionSecond draft for HE comment
Direct operational emissions	This only covers emissions from the infrastructure itself whilst in use. It does not include emissions from traffic, nor does it include energy use, both which are accounted for elsewhere. Direct emissions from the infrastructure itself will be negligible and are therefore excluded from this assessment.
Operational water use	There is no specific water use for the operation of the Scheme, and it is therefore excluded from the assessment.
Other operational processes	There are no operational processes relevant to the Scheme emissions other than the use of the Scheme by traffic and infrastructure energy. This module is therefore excluded from the assessment.
End of life stages	There are no plans to decommission the Scheme, so no end of life activities will take place. This module is therefore excluded from the assessment.
Offsetting	Carbon offsetting – including vegetation for sequestration, solar PV for electricity export, or financial support of low-carbon projects – is specifically excluded from the study. Any carbon savings achieved through offsetting should be reported separately.

15.1.5 Assessment methodology

Proposed Level and Scope of Assessment

15.1.5.1 There is currently no specific guidance in the Design Manual for Roads and Bridges (DMRB) for assessing the effects of this type of Scheme on climate. A proportionate approach has been adopted which focuses on capturing the principal contributing factors to the effects on climate and quantifying the magnitude of emissions.

Emissions Quantification Goal

15.1.5.2 The goal of the emissions quantification exercise is to calculate the emissions anticipated to be generated by the Scheme (according to the Scheme boundary and emissions scope set out in section 15.5). The purpose of this is to:

- Determine the magnitude of the Scheme's emissions, for the relevant scenarios;
- Enable comparison of the ‘Do Something’ scenario against the ‘Do Minimum’ scenario and UK carbon reduction targets; and
- Enable identification of emissions hot spots within the ‘Do Something’ scenario to inform identification and prioritisation of further appropriate mitigation measures.

Calculation methodology

15.1.5.3 The Scheme emissions have been quantified by calculation, using project data from the emerging design and relevant carbon conversion factors. Different greenhouse gases have different global warming potentials, and to account for this they have been reported throughout this assessment as their carbon dioxide equivalent (CO_2e) value.

15.1.5.4 Emissions calculations are undertaken using the following methodology:

- Individual calculations are carried out for each item or activity (or sub-part thereof) included in the Scheme boundary using relevant project data, to determine the size of the item or activity in appropriate units of measurement, e.g. for a concrete kerb stone:
  - Length (m) x width (m) x depth (m) x density kg/m^3 = kg/kerb stone, OR
  - A direct unit value is used if available, e.g. kg/kerb stone.
- The individual item or activity values are then multiplied by the associated carbon conversion factors to determine total emissions per unit, e.g.
  - kg/kerb stone x kgCO_2e/kg for concrete = kgCO_2e/kerb stone.
- The emissions per item or activity are multiplied by the total number of items or activities to quantify the total emission for the total number of items or occurrences of an activity, e.g.
  - kgCO_2e/kerb stone x number of kerb stones = total kgCO_2e emissions for kerb stones.
- The total emissions for a scheme are quantified by summing the calculations for the individual items and activities (e.g. sum of total emissions, for kerb stones, asphalt, plant use, direct vehicle use, etc).

15.1.5.5 For the construction stage of the Scheme, calculations have been undertaken by using Highways England's Carbon Tool, which will allow comparison of the results to other highway scheme assessments using the same tool. The Carbon Tool is spreadsheet-based, and provides space to input material and non-material construction information under the following categories:

- Bulk materials;
- Earthworks;
- Fencing, barriers and road restraint systems;
- Drainage;
- Road pavements;
- Street furniture;
- Civil structures and retaining walls;
- Fuel, electricity and water use;
- Business and employee transport; and
- Waste.

15.1.5.6 The Tool then uses a range of pre-programmed materials data (e.g. mass) and carbon factors to calculate an itemised and overall emissions total.

15.1.5.7 Operational emissions are calculated separately from the Carbon Tool, which is focused specifically on construction-phase emissions. Road user carbon emissions have been modelled in accordance with DMRB, Volume 11, Section 3, Part 1 Air Quality: HA 207/07.

15.1.5.8 There are no project-specific data available for operational energy use, or maintenance and refurbishment during the Scheme's operational life, so emissions cannot be calculated using the above methodology. Instead they have been estimated using published data from other highways schemes, based on the assumption that emissions from the operation and maintenance of similar highways is broadly consistent across the UK road network.

Data collection

15.1.5.9 The data for the assessment has been obtained from the design team and contractor. Table 15.7 summarises the specific data collected for each life cycle, and the emissions factors used.

Table 15.7: Data collection methodology

Life Cycle Module	Data Source
Materials	Temporary and permanent construction materials data have been provided by the design team based on the current Scheme design. Where the design is not finalised, assumptions were made by engineering specialists based on professional judgement. The carbon factors for materials integral to the HE Carbon Tool were used.
Transport	At this stage the specific sources of materials are not known. It has been assumed that all materials have been transported an average distance of 200km. The carbon factors for materials integral to the HE Carbon Tool were used.
Construction Processes	**Construction Plant Use** Plant quantities and operating hours where provided by the contractor and are presented in. Engine sizes were assumed based on typical ratings for each plant type, using manufacturer specifications. The assumptions made are presented in Appendix 15.1. The carbon factors for different fuels integral to the HE Carbon Tool were used. **Construction Water User** Water use during the construction process was estimated by the contractor based on experience from a similar scheme. The carbon factor for mains water use integral to the HE Carbon Tool was used. **Construction Waste** Waste quantities were provided by the design team. At this stage data on the distance that the waste is due to be transported is not available and is therefore assumed based on the proximity principle. The waste treatment / disposal options have been estimated as part of the waste assessment (Chapter 12 Materials and Waste). The carbon factors for waste integral to the HE Carbon Tool were used. **Employee Commuting** The assumption for numbers of workers was made by the contractor. The carbon factors for travel integral to the HE Carbon Tool were used.
Road user carbon	Modelled in accordance with DMRB, Volume 11, Section 3, Part 1 Air Quality: HA 207/07. This uses emission factors provided by Defra in the Emissions Factors Toolkit v8, which makes assumptions about the makeup of future fleets based on Department for Transport projections. This allows

Life Cycle Module	Data Source
	for predicted uptake of electric and hybrid vehicles as well as conventional vehicles (petrol and diesel).
Operation and maintenance	Emissions have been estimated using published data from other highways schemes, based on the assumption that emissions from the operation and maintenance of similar highways is broadly consistent across the UK road network as a proportion of road user emissions.

Table Source: Interpreted from PAS 2080:2016.

Emissions analysis and significance comparison

15.1.5.10 There is no accepted technical or policy guidance on how to determine the significance of a project's effects on climate. However, the National Policy Statement for National Networks (NPSNN) 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. The NPSNN specifically 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'*. Based on this, it is considered unlikely that the Scheme's emissions will be of a quantity great enough to cause a significant effect on climate.

15.1.5.11 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. Highways England is committed to reducing emissions where practicable, and therefore emissions have been quantified and presented as part of the Environmental Statement.

15.1.6 Assumptions and limitations

15.1.6.1 Where assumptions have been made, they have been selected to present the worst-case scenario for that particular item/factor.

15.1.6.2 Assumptions/judgements in each case have been made from either:

- Emerging design detail;
- Engineering specialist knowledge;
- Environmental specialist knowledge;
- Climate change/carbon specialist knowledge;
- Manufacturer specifications; or
- Proxy engineering data from previous projects.

Materials

15.1.6.3 The materials and quantities listed in Table 15.8 were included in the assessment; this is the complete list of materials provided by the design team. Materials are presented in the units they were input into the Carbon Tool.

Table 15.8: Construction materials

Category	Item	Type	Unit	Quantity
Bulk Materials	Ready mix concrete	C25/30	m^3	4,251
		C28/35	m^3	191
		C32/40	m^3	1,832
		General	m^3	17,217
	Reinforcement steel	Steel bar and rod	tonnes	898
	Asphalt	General asphalt	tonnes	145,273
	Fill and aggregate	General fill / aggregate	tonnes	442,646
		Recycled site-won fill / aggregate	tonnes	34,815
Earthworks	Geotextiles	Polypropylene geotextile / matting	m^2	5,330
Fencing, Barriers & Road Restrain Systems	Noise Barriers	Timber barrier 2m	metres	2,500
	Road Restraint / Safety Barrier	Steel RRS barrier single sided	metres	11,000
		Pre-case concrete step barrier	metres	11,000
		Steel RRS barrier double sided	metres	50
Drainage	Plastic pipework (PVC)	300mm diameter	metres	16,746
		150mm diameter	metres	33,492
	Petrol interceptor	Plastic (Polyethylene)	no.	3
	Precast concrete inspection chambers	600mm diameter, up to 1.2m depth	no.	167
Road Pavement	Kerb	Pre-cast concrete 125x255mm	metres	50,309
	Road markings	Thermoplastic road marking	tonnes	0.3
Street Furniture & Electrical Equipment	Road studs	Any type	no.	79
	Road lighting and columns	LED light	no.	615
		Steel columns 8m	no.	20
		Steel columns 12m	no.	595
	Plastic cable ducting	50mm diameter	metres	193
		150mm diameter	metres	147,768
Civils Structures & Retaining Walls	Retaining walls	Steel sheet piles	tonnes	19
	Gantries	14m ADS Tubular Cantilever	no.	1
		Up to 33m Portal	no.	16
	Steelwork	General steel	tonnes	568

Transport

15.1.6.4 Information relating to where materials will be sourced from is not yet available, as this will be determined at a later date by the contractor. An assumed 200 km travel distance has been applied based on previous experience by specialists of materials transportation for infrastructure schemes including highway schemes. The emission factor used for transportation is based on a heavy goods vehicle having an assumed average load.

Construction process

15.1.6.5 The construction period has been approximated at 3 years, based on the Buildability Report provided by the contractor. Working days are stated to be 10 hours per day, 5 days per week, with 10 days holiday.

15.1.6.6 Construction plant use was estimated by the contractor and is presented in Appendix 15.1.

15.1.6.7 Water use was estimated by the contractor to be 71,883 m^3 for the Scheme, based on experience of other, similar, highway Schemes.

15.1.6.8 In a similar way, the electricity use for the construction phase has been estimated to be 1,050,000 kWh.

15.1.6.9 Waste is assumed to be transported 50 km, as specific details are not available at this stage of the project. As above, 50 km is based on previous experience by specialists. It is considered likely that waste will be dealt with within 50 km to adhere to the proximity principle. The waste transport has been assumed to be a heavy goods vehicle having an assumed average load. Table 15.9 below presents the data used to calculate emissions from waste transport and processing.

Table 15.9: Construction Waste

Waste	Disposal Method	Quantity (tonnes)
Mixed construction & demolition waste	Recycled	37,889
Mixed metals	Recycled	70
Hazardous waste	Landfill	291

15.1.6.10 Employee commuting has been estimated based on 600 workers each travelling 10 kilometres each way for the 3-year construction period.

Maintenance and Refurbishment

15.1.6.11 There is no operational energy use or maintenance and repair data available for the ‘Do Something’ scenarios. However, the emissions can be considered to be proportionally similar to the Operation + Maintenance per annum CO_2e ($OpCO_2e$) levels of other Highways Schemes as defined in Table 15.10 on the basis that operation, maintenance and use of highways is sufficiently consistent across the UK road network.

Table 15.10: Typical Highway Scheme Emissions

Carbon Footprint Life Cycle Modules	Project/Length and width Component							
	M4 Corridor around Newport	A14	A465	HA project A	HA project B	HA project C	HA project D	HA Project E
	23km New relief road	37km improvement scheme	7.8km embankment section	26.6km widening of A road	6.5km single to 2 lane dual carriageway	4km upgrade of existing junction	0.7km Refurbished existing viaduct	22.1km Upgrade from dual to 3 lanes
CapCO_{2}e (tCO_2e)								
Material	436,600	740,100	44,300	74,500	77,300	36,100	5,800	213,700
Labour + Plant	42,800	243,800	5,800	38,500	27,500	8,200	4,000	20,900
Earthworks	43,200	n/a	2,500	n/a	n/a	n/a	n/a	n/a
Construction tCO_2e/km	21,800	26,600	6,700	4,300	16,100	11,100	13,900	10,600
OpCO_{2}e (tCO_2e)								
Operation + Maintenance/ annum	1,600	2,400	2,600	n/a	n/a	n/a	n/a	n/a
UseCO_{2}e (tCO_2e)								
Use/annum	2,268,700	4,386,400	882,000	n/a	n/a	n/a	n/a	n/a
Table Source: Welsh Government (2016). M4 Corridor around Newport, Environmental Statement: Volume 3, Appendix 2.4 Carbon Report.								

15.1.6.12 The $OpCO_2e$ levels defined in Table 15.10 show that proportionally emissions for operational energy use and maintenance works equate to between 0.05 and 0.29% of in-use traffic emissions, as shown by the three schemes listed below:

- (Operation + Maintenance per Annum) / Use per Annum = Operational Proportion (%):
  - M4CaN: (1,600/ (1600 + 2,268,700)) x 100 = 0.07%;
  - A14: (2,400/ (2,400 + 4,386,400)) x 100 = 0.05%; and
  - A465: (2,600/ (2,600 + 882,000)) x 100 = 0.29%.

15.1.6.13 0.29% of road user emissions has been applied as a worst-case operation and maintenance figure.

15.1.7 Baseline conditions

15.1.7.1 The baseline conditions for the effects on climate 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 (2022), and the Design Year (2037), assuming the Scheme is not constructed, i.e. the 'Do Minimum' scenarios.

National emissions baseline

15.1.7.2 It is estimated that total global greenhouse gas emissions from all sources currently amount to approximately 50 billion tonnes of CO_2e[2]. However, it is not considered representative to compare any UK scheme against this, as any scheme will always be negligible. Instead, it is considered most appropriate to use the national baseline for comparison as its magnitude is more relevant and UK specific. The total UK emissions for 2016 (the last reported year) were 467.9 million tonnes of CO_2e[3]. The breakdown of this by sector, by final user is shown in Table 15.11.

Table 15.11: UK national emissions (2016)

Sector (by final user)	Emissions (Million tonnes of CO_2e)	% of total
Transport	125.8	26.9%
Energy Supply	120.2	25.7%
Business	81.5	17.4%
Residential	69.8	14.9%
Agriculture	46.5	9.9%
Waste management	19.9	4.3%
Industrial Processes	10.5	2.2%

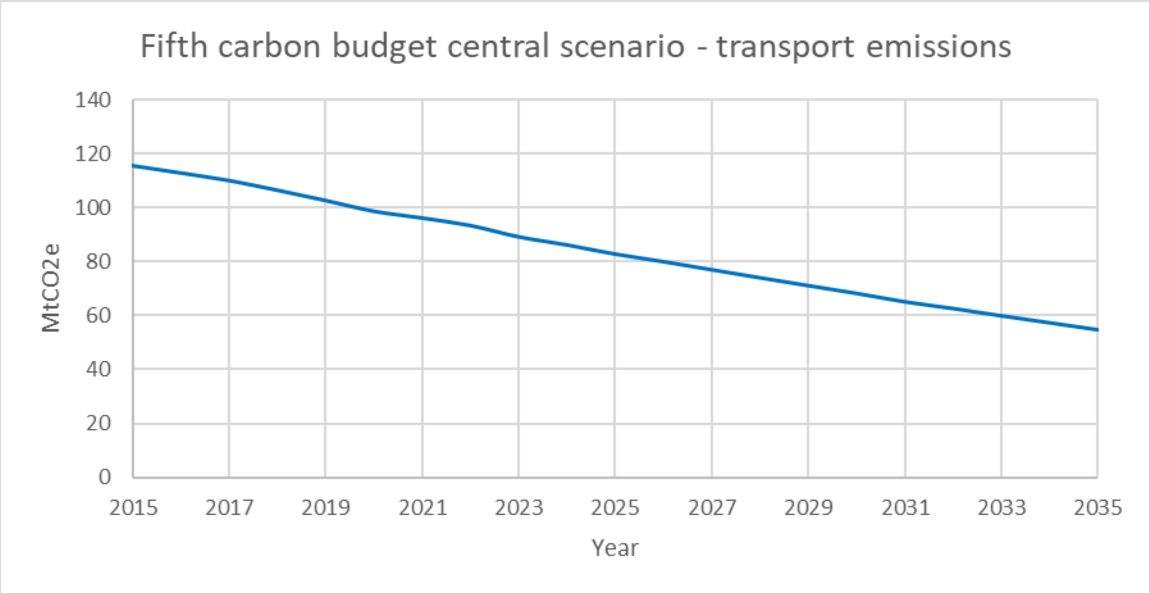
[2] PBL Netherlands Environmental Assessment Agency, Trends in global CO2 and total greenhouse gas emissions, accessed 2018, from https://www.pbl.nl/en/publications/trends-in-global-co2-and-total-greenhouse-gas-emissions
[3] UK Government, 2016 UK greenhouse gas emissions: final figures – statistical summary, accessed 2018, from https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2016

Sector (by final user)	Emissions (Million tonnes of CO_2e)	% of total
Public	8.2	1.8%
Land Use, Land Use Change and Forestry (LUKUCF)	-14.6	-3.1%
Total	467.9	100%

Table Source: 2016 UK greenhouse gas emissions: final figures – statistical summary

15.1.7.3 The dataset for the fifth UK carbon budget central scenario includes forecasts of emissions for different sectors. Figure 15.1 below presents the annual reduction in transport sector emissions (including shipping and domestic aviation) required to support the achievement of the carbon budgets.

Figure 15.1: Forecast UK Transport Sector Emissions



Source: adapted from the Fifth Carbon Budget Central Scenario Dataset (2016)

Scheme Emission Baseline

15.1.7.4 The calculated emissions for the 'Do Minimum' scenario regarding the Scheme cover the following life cycle modules:

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

15.1.7.5 Only these life cycle modules are included as they are the only stages relevant to an operational highway.

Road user carbon

15.1.7.6 The road user carbon emissions for the 'Do Minimum' scenarios have been modelled in accordance DMRB, Volume 11, Section 3, Part 1 Air Quality: HA 207/07. They are as follows:

- 2022 Opening Year: 219,048 tCO_2e

- 2037 Design Year: 244,849 tCO_2e

15.1.7.7 The data show an expected 11% increase in emissions between the Opening and Design Years, due to an increase in vehicle kilometres travelled.

Operational Energy Use and Maintenance

15.1.7.8 Applying 0.29% of road user emissions as a worst-case value, the Scheme's Do-Minimum scenario emissions for operational energy use and maintenance can be estimated as:

- 2022 Opening Year: 219,048 x 0.29% = 635 tCO_2e
- 2037 Design Year: 244,849 x 0.29% = 710 tCO_2e

Total Baseline Emissions

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

- 2022 Opening Year: 219,683 tCO_2e
- 2037 Design Year: 245,559 tCO_2e

15.1.8 Potential impacts

15.1.8.1 Climate is a wide-ranging and complex topic. In terms of potential sources of emissions it covers the whole project life cycle and supply chain emissions from a variety of sources that will most likely include international locations. However, in comparison, the receptor and impact of effects on climate are very specific, as follows:

- There is only one receptor, the atmosphere, which is non-site specific;
- There is only one direct impact, global warming, which is also non-site specific; and
- The impacts of emissions are global in nature, and so all units of CO_2e can be considered to have the same impact no matter where they are emitted.

15.1.8.2 These characteristics place the focus of the assessment of potential impacts on the sources and the quantity of emissions that they generate in comparison with the baseline. This is because it is the magnitude of emissions from each source, and in total, that defines the overall impact.

15.1.8.3 The construction stage of the Scheme would have an overall adverse effect on climate, as it would give rise to emissions. These emissions would arise from the production of materials to be used in construction, their transportation to site, and onsite through construction activities (for example from emissions from diesel-fuelled construction plant).

15.1.8.4 The operation stage of the Scheme would give rise to emissions from road users and operational energy use (for example street lights). However, whilst the operation of the Scheme would certainly cause emissions and therefore have a negative effect on climate, the Scheme may cause a reduction in emissions compared with the 'Do Minimum' Scenario due to reduced congestion and associated increased fuel efficiency, which would result in the Scheme presenting an improvement in effects on climate. The results of the assessment are presented below.

15.1.9 Design, mitigation and enhancement measures

15.1.9.1 Emissions have been and will be mitigated by applying Highways England's carbon reduction hierarchy:

1. 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).
2. 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;
3. 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.

15.1.9.2 Specific potential mitigation measures relevant to the construction and operation stages of the Scheme are suggested below. The defined measures are consistent with PAS 2080:2016, the carbon management technical standard relevant to all infrastructure projects.

Construction

15.1.9.3 Mitigation measures that will be used to reduce emissions in the construction life cycle modules are shown below.

Table 15.12: Construction emissions mitigation measures

Life cycle module	Mitigation measures
Materials	Reduction of materials consumption will be carried out in accordance with the mitigation measures outlined in the Materials and Waste Chapter (Chapter 12). In addition, consideration will be given to alternative low carbon materials e.g. recycled aggregates, cement substitution etc.
Transport	Materials transportation will be reduced and/or avoided by minimising the quantity of materials required, as per A1-3 above. Additionally, where possible detailed design and procurement measures will be specified to minimise the necessity to source materials from long distances.

Life cycle module		Mitigation measures
Construction Processes	Construction plant use	Construction plant emissions will be minimised by designing for efficient construction processes as part of design development. During construction plant emissions should be managed via the Construction Environmental Management Plan (CEMP), which should specify plant operator efficiency requirements.
	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 will 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	Suitable/ appropriate 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 will be used where possible, reducing the distance driven by employees.

Operation

15.1.9.4 Operational emissions can be mitigated by designing a Scheme which minimises emissions from traffic and operational energy use. Mitigation measures that will be employed to reduce in-use emissions are shown below.

Table 15.13: Operation emissions mitigation measures

Life Cycle Module	Mitigation Measures
Road user carbon	Mitigation of in-use emissions will be explored based on examination of traffic management scenarios over the network. Inclusion of Non-Motorised User (NMU) routes to encourage the utilisation of alternative means of transport, and help to achieve the goal of creating a more integrated and sustainable transport network, whilst reducing emissions.
Maintenance and repair	The mitigation measures detailed in **Error! Reference source not found.** for the construction stage are also application 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.

15.1.10 Assessment of effects

15.1.10.1 This assessment presents the emissions calculated for the 'Do Something' scenario, a comparison against the 'Do Minimum' baseline, and assessment against UK Government carbon budgets.

‘Do Something’ Scenario Emissions

Construction

15.1.10.2 Construction phase emissions are broken down in Table 15.14. The Carbon Tool used to calculation emissions is provided in Appendix 15.2. Emissions from the construction phase total 92,367 tCO_2e.

Table 15.14: Construction stage emissions

Category	Item	Materials		Transport	
		Emissions (tCO_2e)	Percentage of Construction Total	Emissions (tCO_2e)	Percentage of Construction Total
Bulk Materials	Ready mix concrete	6,210	7%	1,974	2%
	Reinforcement steel	1,257	1%	39	0.04%
	Asphalt	11,041	12%	6,360	7%
	Fill and aggregate	2,302	2%	19,379	21%
Earthworks	Geotextiles	17	0.02%	0.2	0.0002%
Fencing, Barriers & Road Restrain Systems	Noise Barriers	280	0.3%	13	0.01%
	Road Restraint / Safety Barrier	2,901	3%	565	1%
Drainage	Plastic pipework (PVC)	887	1%	12	0.01%
	Petrol interceptor	4	0.004%	0.1	0.0001%
	Precast concrete inspection chambers	17	0.02%	3	0.003%
Road Pavement	Kerb	664	1%	161	0.2%
	Road markings	2	0.002%	0.01	0.00001%
Street Furniture & Electrical Equipment	Road studs	0.01	0.00001%	Negligible	Negligible
	Road lighting and columns	336	0.4%	8	0.01%
	Plastic cable ducting	880	1%	15	0.02%
Civils Structures & Retaining Walls	Retaining walls	28	0.03%	1	0.001%
	Gantries	560	1%	16	0.02%
	Steelwork	829	1%	25	0.03%
Materials Total		**28,212**	**31%**	**-**	**-**
Transport Total		**-**	**-**	**28,581**	**31%**

Category	Item	Materials		Transport	
		Emissions (tCO_2e)	Percentage of Construction Total	Emissions (tCO_2e)	Percentage of Construction Total
Fuel, Energy & Water	Site offices, site vehicles and plant energy	34,729	38%	394	0.4%
	Water	25	0.03%	-	-
Business and Employee Transport	Business and Employee Transport	-	-	2	0.002%
Waste	Total waste	40	0.04%	419	0.5%
Construction Processes Total		**34,794**	**38%**	**-**	**-**
Transport Total		**-**	**-**	**815**	**1%**
Construction Phase Total					**92,392**

15.1.10.3 The largest magnitude of emissions (38%) occurs from on-site construction processes, the majority of which derive from fuel used in construction plant. Emissions from the production of construction materials equates to 31% of the total emissions, with the largest contributions from the asphalt, concrete, steel road restraint and safety barriers, and imported fill and aggregate. Transport of fill and aggregate to site contributes 21% of total emissions for the construction phase, with transport of all other materials making up a further 10%. Transport to facilitate construction processes equals 1% of total emissions.

Operation

15.1.10.4 Operation phase emissions for the Opening and Design Years are shown below.

Table 15.15: Operation stage emissions for 2022 and 2037

Life Cycle Module	Emissions (tCO_2e)	
	2022	2032
Road User Carbon	218,190	244,947
Maintenance and Operation	633	710
Total Operation	218,823	245,657

15.1.10.5 There is a 12% increase in operational and vehicle emissions from 2022 to 2037 in the ‘Do Something’ scenario, due to an increase in vehicle kilometres travelled.

Comparing ‘Do Minimum’ and ‘Do Something’ Scenarios

15.1.10.6 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 effect of releasing an additional 92,392 tCO_2e into the atmosphere in the ‘Do Something’ scenario.

15.1.10.7 The calculated operation stage emissions for the 2022 and 2037 'Do Minimum' and 'Do Something' scenarios are compared below in Table 15.16.

Table 15.16: 'Do Something' and 'Do Minimum' operational emissions comparison

Life Cycle Module	Emissions (tCO_2e)					
	2022 Do-Minimum	2022 Do-Something	Difference	2037 Do-Minimum	2037 Do-Something	Difference
Total Operational Emissions	219,683	218,823	-860	245,559	245,657	+98

15.1.10.8 The 'Do Something' scenario of the Scheme will lead to a reduction in emissions of 860 tCO_2e in the Opening Year, however generate an additional 98 tCO_2e in the Design Year compared with the 'Do Minimum'.

Total UK Carbon Budget Comparison

15.1.10.9 Highways England is committed to reducing greenhouse gas emissions wherever practicable and to supporting the UK Government in meeting its carbon reduction targets. Table 15.17 shows the proportion of the relevant carbon budgets that the Scheme would contribute. Table 15.18 shows how the Scheme compares as a proportion of the transport sector's annual emissions as forecast in the fifth carbon budget central scenario. This approximation assumes an even distribution of emissions across the 3-year construction period.

15.1.10.10 The reduction in operational emissions during the Opening Year will help offset construction emissions in the 3rd budget period.

Table 15.17: Comparison of Scheme to UK Government Carbon Budgets

Project Stage	Scheme tCO_2e per Carbon Budget Period	Relevant Carbon Budgets	UK Carbon Budget tCO_2e	Scheme Proportion of Budget
Construction and Opening Year	92,392 – 860 = 91,532	3rd carbon budget period	2,544,000,000	0.004%
Design Year Operation	98	Beyond 5th carbon budget period	Not yet published by UK Government	-

Table 15.18: Comparison of Scheme to UK Transport Sector Forecast Emissions

Project Stage	Annual Scheme tCO_2e	Relevant Year	Forecast Transport Sector Emissions[4]	Scheme Proportion of Forecast Transport Sector Emissions
Construction and Opening Year	30,797 – 869 = 29,650	2022	93,400,000	0.03%

[4] This assumes that the transport sector continues to emit 26.9% of the UK's total emissions, as in 2016, for the different budget periods

Project Stage	Annual Scheme tCO_2e	Relevant Year	Forecast Transport Sector Emissions[4]	Scheme Proportion of Forecast Transport Sector Emissions
Design Year Operation	98	2037	Not yet published by UK Government	-

15.1.10.11 The construction and Opening Year operation of the Scheme is expected to contribute 0.004% of the UK's 3rd carbon budget, and in the Design Year the Scheme will lead to a small increase in the magnitude of emissions. 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 NPSNN.

15.1.10.12 However, it is considered important to note that although the emissions increases and decreases are shown as negligible against the UK national budgets, they will affect the UK's ability to meet its targets.

Residual effects

15.1.10.13 Due to the embedded nature of the mitigation measures proposed, some of which have already been incorporated into the design 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. The assessment presented in this chapter is therefore of the residual effect, as assessment of the impacts of the Scheme pre-mitigation has not been possible.

15.1.11 Cumulative effects

15.1.11.1 The effects of all greenhouse gas 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, rather than in combination with other local developments.

15.1.12 NPSNN compliance

15.1.12.1 As previously stated, the NPSNN 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 NPSNN 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.

15.1.13 Monitoring

15.1.13.1 It is not possible to directly monitor greenhouse gas emissions. However, Highways England's Carbon Tool is designed to be populated on a quarterly / monthly return basis through the construction process and during maintenance activities. Completing this activity will allow tracking of construction emissions against those forecast in this assessment. For the operation phase, actual road user numbers could be modelled as per HA 207/07 to calculate emissions. Operational energy use data could be collected and converted into an emission figure, and maintenance works could be recorded and reported in the same way as the construction works, using the Carbon Tool.

15.1.14 Summary

15.1.14.1 This chapter assesses the effects of the Scheme on climate by quantifying likely emissions of greenhouse gases to the earth's atmosphere.

15.1.14.2 The 'Do Something' scenario will generate the following change in emissions over the 'Do Minimum' scenario:

- Construction: 92,392 tCO_2e
- 2022 Opening Year: -860 tCO_2e
- 2037 Design Year: 98 tCO_2e

15.1.14.3 The construction phase and Opening Year together contribute 0.004% of the UK's 3rd carbon budget. This is not considered to be a significant impact. There is currently no budget for the period covering the Design Year, however the generated emissions are considered to be minor and also not significant.

15.1.14.4 At all stages, emissions will be mitigated as far as possible as Highways England is committed to reducing emissions wherever practicable and to support the UK Government in meeting its carbon reduction targets.

15.2 Vulnerability to Climate

15.2.1 Introduction

15.2.1.1 This part of the chapter outlines the assessment of the vulnerability and resilience of the Scheme to climate change during construction and operation in accordance with Highways England guidance.

15.2.2 Competent expert evidence

15.2.2.1 This chapter has been undertaken by a Chartered Water and Environmental Manager and a Chartered Environmentalist and holds professional memberships including Member of the Chartered Institution of Water and Environmental Management (M.CIWEM) and Fellowship of the Royal Geographical Society (FRGS). They have 12 years of knowledge and experience in environmental impact assessment and has used their knowledge and professional judgement to complete this assessment.

15.2.2.2 The chapter was reviewed by an Associate Director in Climate Resilience. They have a PhD in hydrology and more than 20 years' experience of climate change risk assessment. This included technical leadership of the UK Government's first Climate Change Risk Assessment (Defra, 2012) which set out the main priorities for adaptation in the UK under 5 key themes identified in the CCRA 2012 Evidence Report. They were also involved in the development of "H++" climate change scenarios to support the second CCRA in 2017.

15.2.3 Legislative and policy framework

15.2.3.1 Table 15.19 sets out the legislation, regulatory and policy framework for the assessment of the Schemes vulnerability to climate change.

Table 15.19: Relevant Legislation and Policy

Legislation / Regulation	Summary of Requirements
National	
The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017	Requires a description of the likely significant effects of the development on the environment resulting from the impact of the project on climate (for example the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change.
Climate Change Act (2008)	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.

Legislation / Regulation	Summary of Requirements
	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 Committee on Climate Change will provide advice to, and scrutiny of, the Government's adaptation work.
National Policy Statement for National Networks (NPSNN)	Paragraph 4.41 states 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’. 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.
National Planning Policy Framework (NPPF; 2018)	The NPPF develops a planning system that contributes to radical reductions in greenhouse gas emissions, minimises vulnerability and improve resilience; encourages the reuse of existing resources, including the conversion of existing buildings; and supports renewable and low carbon energy and associated infrastructure. The NPPF states that “New development should be planned for in ways that avoid increased vulnerability to the range of impacts arising from climate change. When new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures, including through the planning of green infrastructure.
The Highways Agency Climate Change Adaptation Strategy and Framework (2009)	The Climate Change Act (2008) has 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. It will factor anticipated climatic changes into the delivery of their business and develop appropriate management and mitigation solutions to remove or reduce these risks.
Highways England Sustainable Development Strategy (2017)	The Climate Change adaptation vision is “in order to become more resilient to future changes in climate, which may result in more frequent and severe weather events, it is important that we adapt our network and make effective investment decisions. Climate adaptation today is tomorrow’s resilience.”
Regional	
The London Plan (2016)	Paragraph 1.48 outlines the Plan’s vison to address climate change, in terms of both adaptation and mitigation. Adaptation includes designing infrastructure with a changing climate in mind and protecting, enhancing and expanding the city’s stock of green space to help cool parts of the city. Mitigation includes reducing our emissions of greenhouse gases to minimise future warming and its impacts.
The Mayor’s Transport Strategy (2010)	The Mayor, through TfL, will prepare adaptation strategies to improve safety and network resilience to threats posed by climate

Legislation / Regulation	Summary of Requirements
	change, and ensure that new transport infrastructure is appropriately resilient. This will include 'guidelines for major procurement contracts (including design, construction and maintenance) to demonstrate a climate risk assessment for the lifetime of the investment'.

15.2.4 Study area

15.2.4.1 The Scheme is located within the Met Office UK Climate Projections 25 km gridded data (grid ID: 1629)[5]. The proposed spatial boundaries of the assessment are defined by this grid cell which will provide the data used to assess future changes in climate and extreme weather for the Scheme location.

15.2.4.2 The area of influence for potential climate vulnerability impacts is expected to be limited to the project boundary and the immediate area around this. It also includes downstream areas that could be affected by the Scheme's surface water runoff.

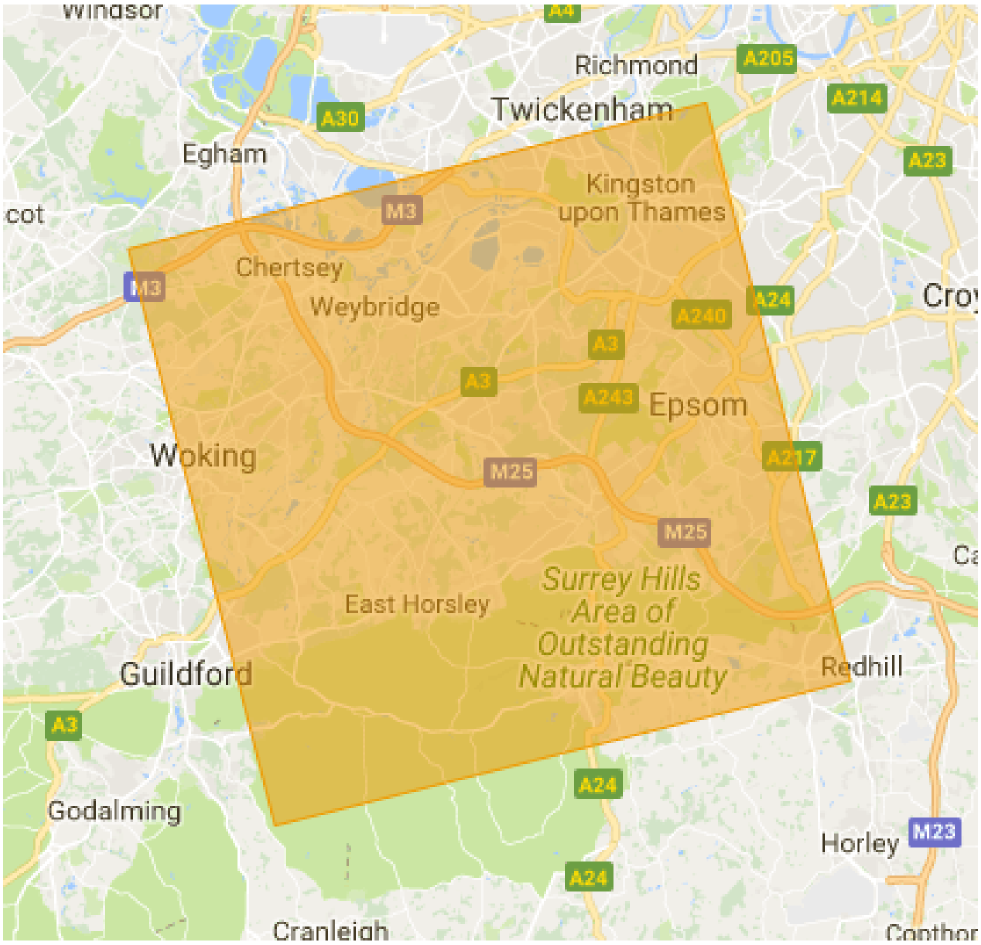


Figure 15.2: Area covered by Met Office climate grid square 1198

SOURCE:http://ukclimateprojections-ui.metoffice.gov.uk/ui/admin/login.php

[5] http://ukclimateprojections.metoffice.gov.uk/

15.2.5 Assessment methodology

15.2.5.1 Receptors which may be affected by climate change have been identified with consideration of both extreme weather events and gradual climatic changes in the study area over the Scheme's design life. In accordance with Highway England's guidance the assessment considers impacts on the following receptors during the Schemes construction and operational phases:

- Construction process (i.e. workforce, plant, machinery etc.);
- The assets and their operation, maintenance and refurbishment, including:
  - Road surfaces, pavements and structures (including embankments, earthworks, drainage and bridges);
  - Road infrastructure and technology such as signs, signals and traffic lights.
- End-users:
  - Nearby residential areas;
  - Members of the public;
  - Commercial operators; and
  - Road user safety and experience.

15.2.5.2 Consequential loss or damage to environmental receptors, such as surface water, flora and fauna and air quality, as a result of the Schemes vulnerability to climate change are also assessed in this chapter where they are not already covered in the relevant topic chapters.

15.2.5.3 In line with the Highways England guidance, the significance of impacts of extreme weather and climate change on the Scheme have been assessed based on:

- The likelihood of potential impacts (see Table 15.20 for categorisation); and
- The consequence of the impact to Scheme receptors (see Table 15.21 for categorisation).

Table 15.20: Likelihood categories

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

Table Source: Highways England Guidance (May, 2018)

Table Notes: - Project lifetime is considered to include construction and operational phases;

- Project lifetime is taken to be 60 years in line with Highways England guidance and WebTAG.

Table 15.21: Measure of consequence

Consequence of impact	Example description
Very large adverse	National level (or greater) disruption to strategic route(s) lasting more than 1 week.
Major adverse	Regional level disruption to strategic route(s) lasting more than 1 week. OR Regional level disruption to strategic route(s) lasting more than 1 week.
Moderate adverse	Regional level disruption to strategic route(s) lasting more than 1 day but less than 1 week.
Minor adverse	Regional level disruption to strategic route(s) lasting less than 1 day.
Negligible	Disruption to an isolated section of a strategic route lasting less than 1 day.

Table Source: Highways England Guidance (May, 2018)

15.2.5.4 Where impacts do not have consequences for road traffic disruption consideration has been given to the receptor's economic value (very large to negligible), level of designation (international to local) and the level to which it is dependent on prevailing climatic factors continuing in the future.

15.2.5.5 The likelihood assessment is undertaken with consideration of the Scheme design and embedded mitigation. Where additional mitigation measures are required to reduce significant impacts this is also identified. The assessment is informed by best practice approaches, climate guidance and literature as well as professional judgement.

15.2.5.6 The results of the likelihood and consequence assessments are combined to derive a 'significance of effect' classification as outlined in Highways England Guidance, this is reproduced in Table 15.22.

Table 15.22: Significance matrix

Impact consequence	Impact likelihood				
	Very Low	Low	Medium	High	Very High
Negligible	*NS*	*NS*	*NS*	*NS*	*NS*
Minor	*NS*	NS	NS	**S**	**S**
Moderate	*NS*	*NS*	**S**	**S**	**S**
Large	*NS*	**S**	**S**	**S**	**S**

Impact consequence	Impact likelihood				
	Very Low	Low	Medium	High	Very High
Very large	*NS*	S	S	S	S

Table Source: Highways England Guidance (May, 2018)

Table Notes: *NS = Not significant, S = Significant*

15.2.6 Assumptions and limitations

15.2.6.1 The assessment provides a broad, high-level indication of the potential impacts of climate change on the Scheme based on qualitative assessment and professional judgement.

15.2.6.2 The climate projections used are probabilistic. They do not provide a single 'best-guess' of the impact of climate change. This better represents the uncertainty of climate prediction science. Additionally, it should 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. This is considered when assessing the likelihood of impacts.

15.2.7 Baseline conditions

15.2.7.1 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.

15.2.7.2 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.

15.2.7.3 It should be noted, however, that climate change is not only a challenge of the future. We are already observing changes in the UK climate, with average temperatures having risen by around 1ºC over the last century.

Current climate

15.2.7.4 To inform adaptation decisions this section presents regional data from the Meteorological Office to summarise the study area's 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 regional baseline is provided by including comparison to the Met Office's equivalent national dataset.

Temperature

15.2.7.5 London's climate is one of relatively mild winters and warm summers. To provide some climatological context for the study region, long-term average monthly weather data for the period from 1981 to 2010 were sourced from the Met Office. The London administrative region was compared to the mean long-term average of all other administrative regions in the UK as well as the minimum and maximum.

15.2.7.6 As shown in Figure 15.3 to Figure 15.5 the temperatures in the London administrative region are the highest across the UK.

Figure 15.3: Long-term average monthly mean temperature (1981-2010)

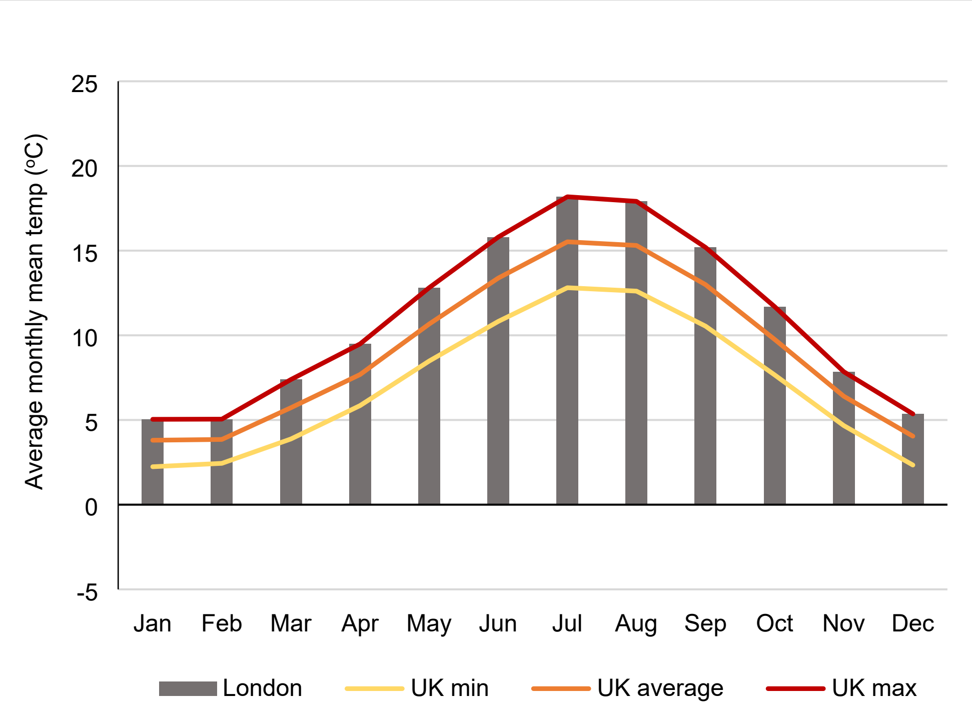


Figure 15.4: Long-term average monthly maximum temperature (1981-2010)

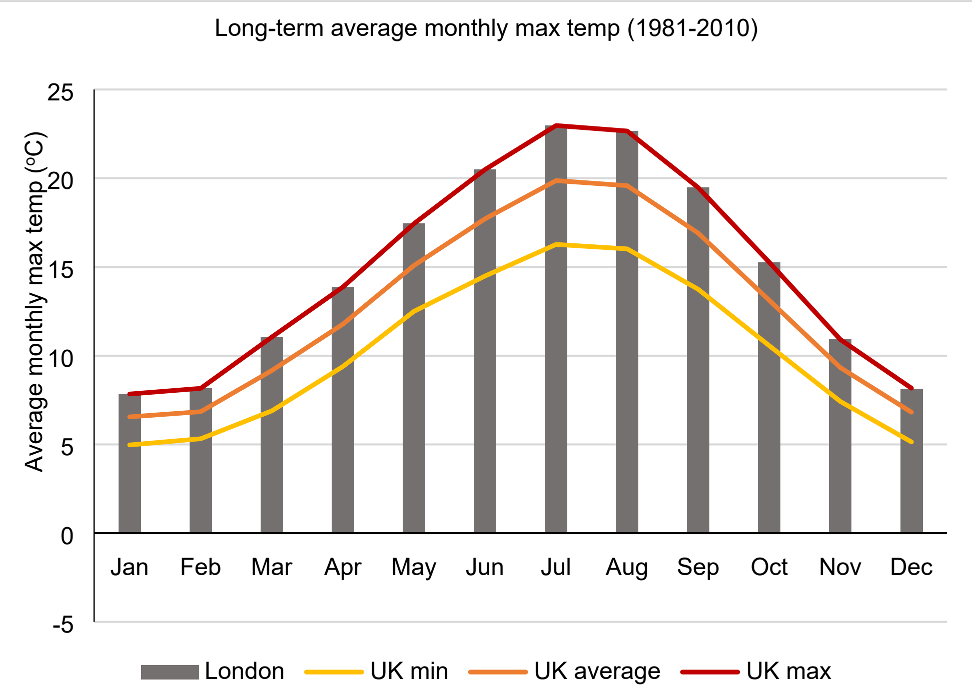
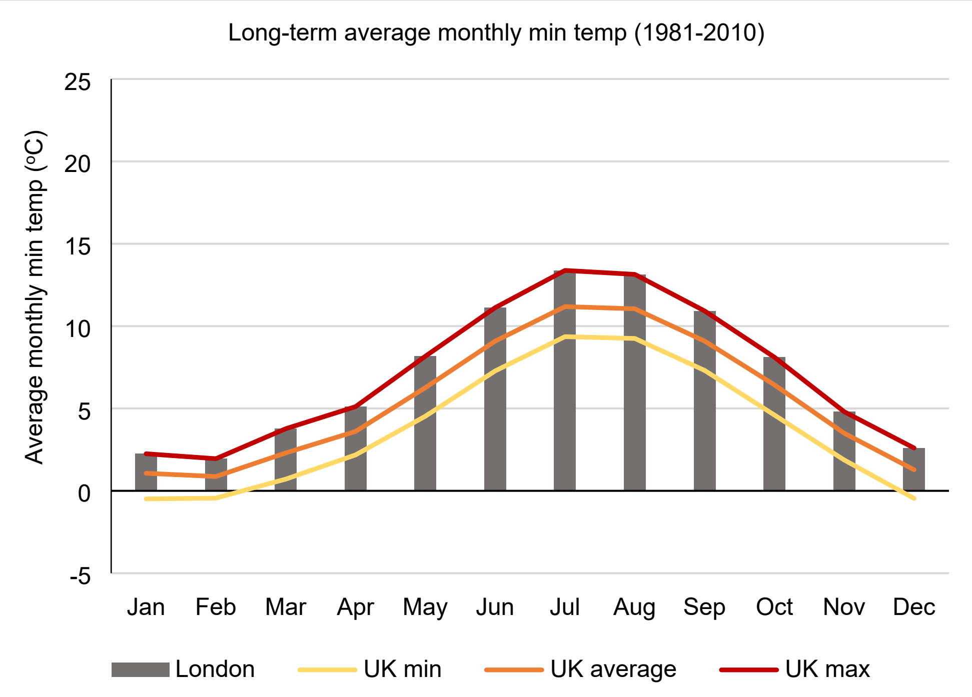


Figure 15.5: Long-term average monthly minimum temperature (1981-29010)



Precipitation

15.2.7.7 As shown in Figure 15.6, long-term average monthly rainfall (1981-2010) in the London administrative region is the lowest in the UK. Figure 15.7 shows the long-term average number of days that had rainfall over 10mm. If this is considered as a proxy for heavy monthly rainfall it suggests that the region has experienced fewer heavy rainfall days than the mean of all other administrative regions in the UK.

Figure 15.6: Long-term average monthly rainfall (1981-2010)

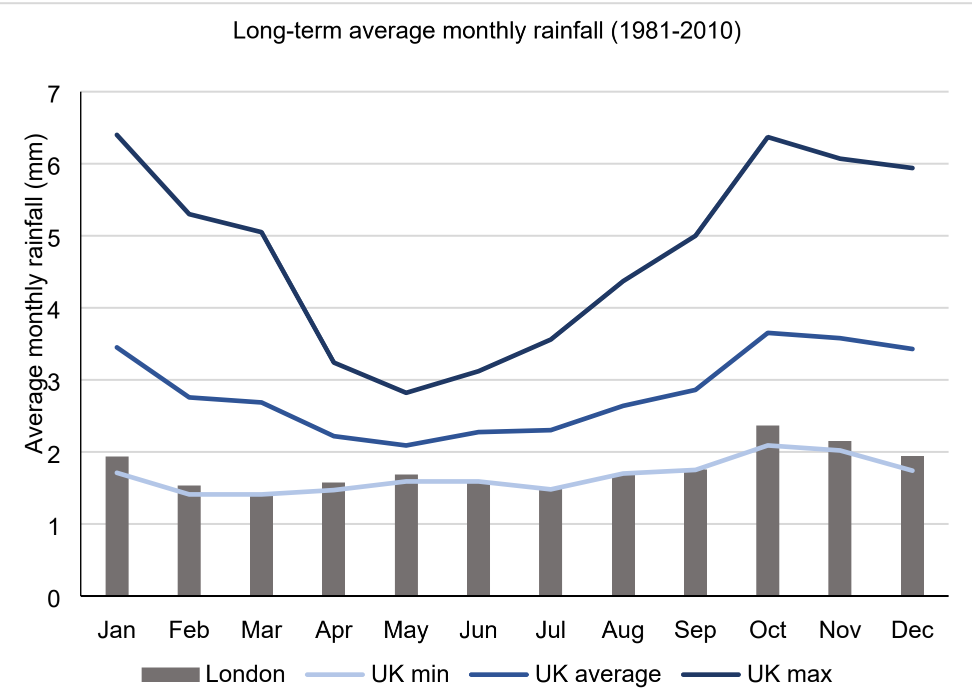
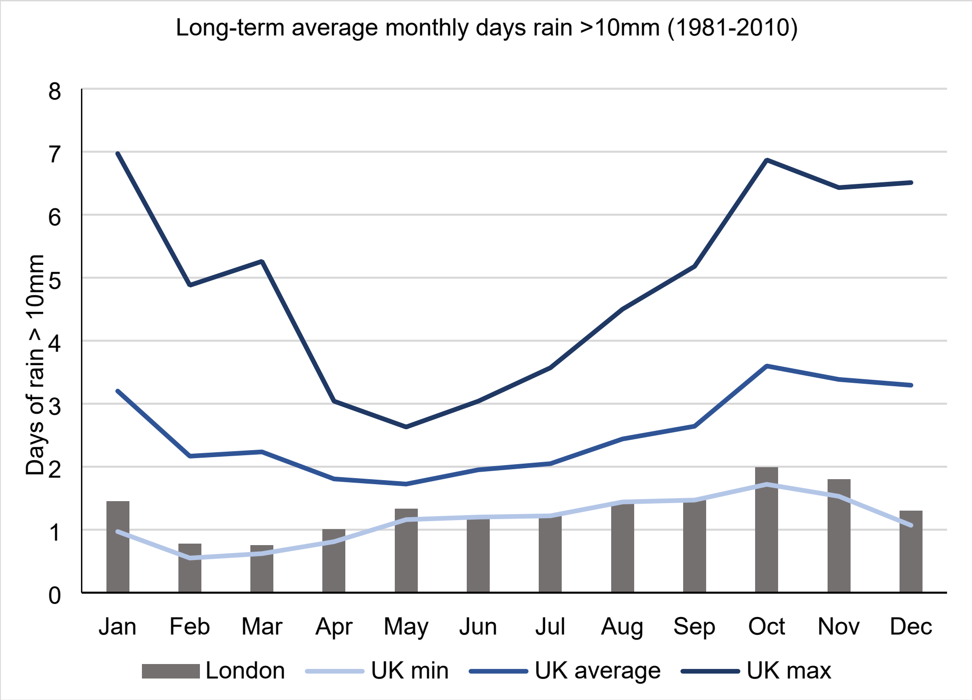
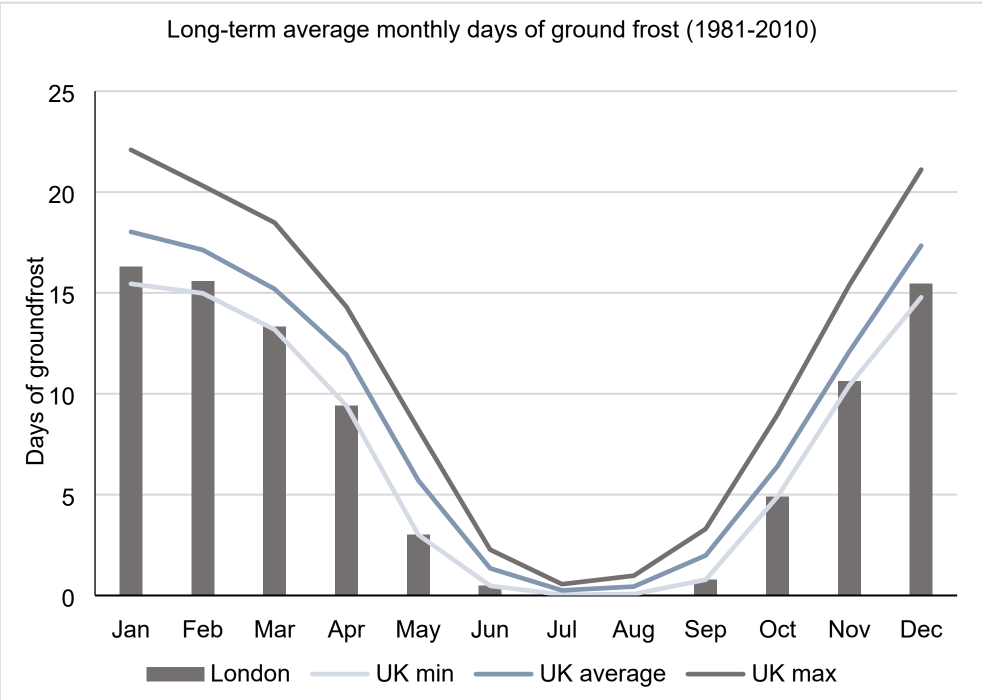


Figure 15.7: Long-term average days with rainfall above 10mm (1981-2010)



15.2.7.8 As shown in Figure 15.8 long-term average days with ground frost (1981-2010) in the London administrative region are low compared to recorded days across all other administrative regions in the UK.

Figure 15.8: Long-term average days with ground frost (1981-2010)



Climate change projections

15.2.7.9 This section presents the output 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, wetter winters. This is a widely agreed finding

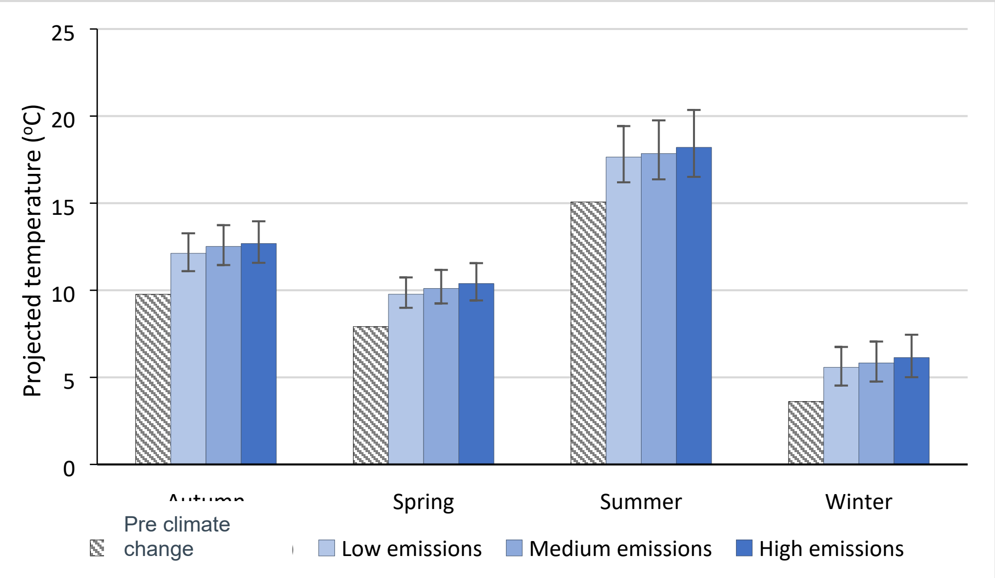
(Jenkins et al., 2010). Alongside these changes in the average conditions, it is likely that climate change will also increase the frequency and severity of extreme weather events, such as heavy rainfall, storms and heatwaves.

15.2.7.10 Future projections are based on the United Kingdom Climate Projections 2009 (UKCP09) for a 25km^2 area surrounding the site (grid ID: 1629). Data is presented for seasonal averages in the 2050s which represents the middle decade of the 30-year climate average from 2040 to 2069. For temperature and precipitation estimates, except for projections of the wettest day, the figures only show projections for the summer and winter averages in the 2050s as these represent the most relevant and extreme changes in temperature and precipitation in response to climate change. Although UKCP18 data is now available it is considered appropriate to continue using the UKCP09 at this stage so that this assessment aligns with the Scheme's scoping which also used UKCP09 data. It is noted that a 2016 study by the Met Office showed that UKCP09 continued to provide a valid assessment of the UK climate and can still be used for adaptation planning. It is unlikely that the results of this assessment would be different if UKCP18 data were presented instead.

Projected changes in temperature - Warmer winters

15.2.7.11 As shown by the long-term average mean temperature data in Figure 15.9 the coldest months in London are in the winter months (although still relatively mild). The projections show that by the 2050s, under the high emissions scenario, average mean temperatures are likely to increase throughout the year. In winter, under the high emissions scenario, mean temperature is likely to increase by approximately 2.5ºC (central estimate). The uncertainty around this estimate ranges from ~1.4ºC to ~3.9ºC (represented by the 10th and 90th percentile respectively).

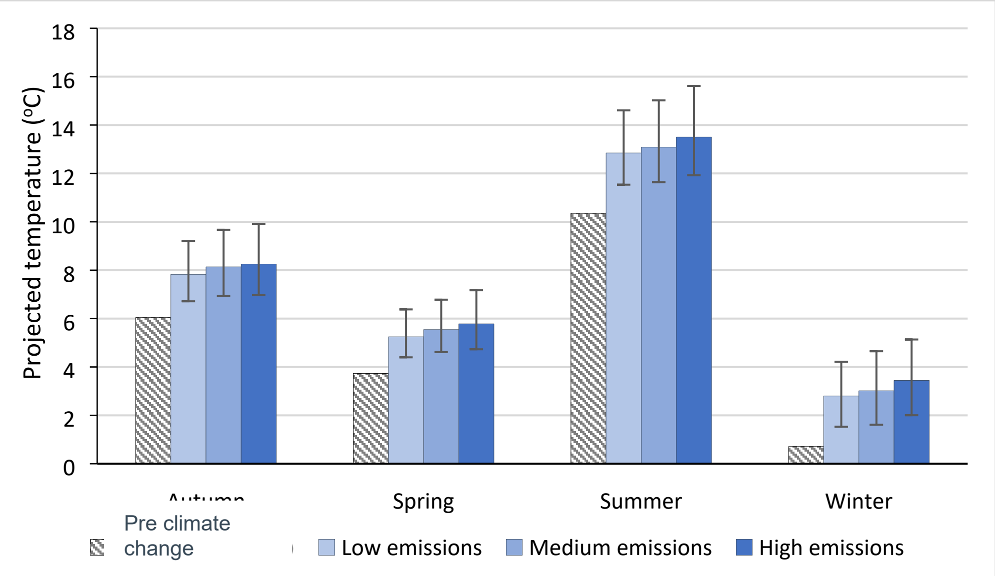
Figure 15.9: Average mean temperatures by the 2050s (error bars represent 10th to 90th percentile projections)



15.2.7.12 As shown in Figure 15.10, UKCP09 projects that by the 2050s, under the high emissions scenario, average minimum temperatures are likely to increase throughout the year. Under the high emissions scenario, the central estimate

(50th percentile estimate) of winter minimum air temperature by 2050s is approximately 3.4ºC. This is an increase of 2.7ºC. The uncertainty around this estimate ranges from ~1.3ºC to ~4.4ºC (represented by the 10th and 90th percentile respectively).

Figure 15.10: Average minimum temperatures by the 2050s (error bars represent 10th to 90th percentile projections)



15.2.7.13 Snow is precipitation that falls when the air temperature is below 2°C. In the UK, the heaviest snowfalls tend to occur when the air temperature is between zero and 2°C[6]. For snow projections are non-probabilistic based on an 11-member Regional Climate Model (RCM) ensemble, using a single emissions scenario (Medium). It should be noted that these do not encompass the full range of uncertainty and that projections are for the 2080s and medium emissions scenario only.

15.2.7.14 In line with the increased winter temperatures climate projections show a reduction of mean snowfall rates, number of snow days and heavy snow events by the end of the 21st century[7,8]. While there is less certainty in the magnitude of projected change, there is confidence in the negative sign of the change[9]. The 90th percentile of snowfall rate can be used as a measure of 'heavy' snow events. Ensemble projections for the 2080s suggest that for most of the UK, the intensity of winter 'heavy' snow events could decrease by over 80 percent[156].

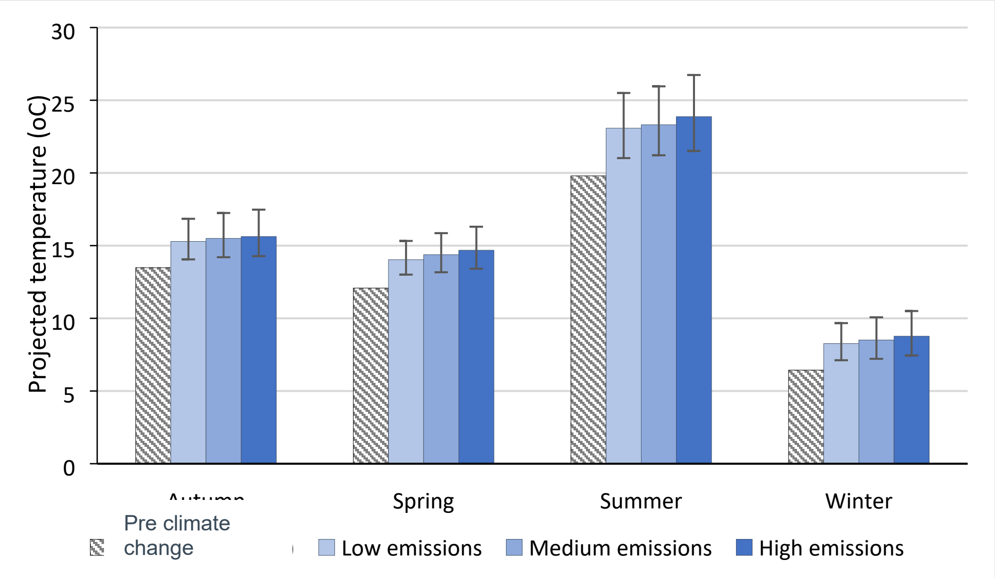
Projected changes in temperature - Hotter summers

15.2.7.15 Mean daily maximum temperatures are derived by calculating the (change in) the average of the warmest days in each 30-year timeslice. Therefore, it is worth noting that some days are likely to be even hotter. As shown in Figure 15.11, the projections suggest an increase in mean daily maximum temperature by the

[6] Met Office. (2013). Met Office. [online] Available at: http://www.metoffice.gov.uk/learning/learn-about-the-weather/weather-phenomena
[7] 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
[8] 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
[9] Jylhä, K., Fronzek, S., Tuomenvirta, H., Carter, T. R. and Ruosteenoja, K. (2008). Changes in frost, snow and Baltic sea ice by the end of the twenty-first century based on climate model projections for Europe. Climatic Change, 86: 441-462

2050s for all seasons under all emissions scenarios. By the 2050s, summer mean daily maximum temperatures could be up to ~4ºC warmer (50th percentile estimate under high emissions).

Figure 15.11: Average maximum temperature by the 2050s (error bars represent 10th to 90th percentile projections)



15.2.7.16 Although there is no official definition of a heat wave in the UK, the World Meteorological Organization definition is "when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5°C, the normal period being 1961-1990". Research published by the Met Office Hadley Centre suggests that the European summer heat wave from 2003 could become a normal event by the 2040s. By the 2060s, such a summer would be considered cool according to some climate models.

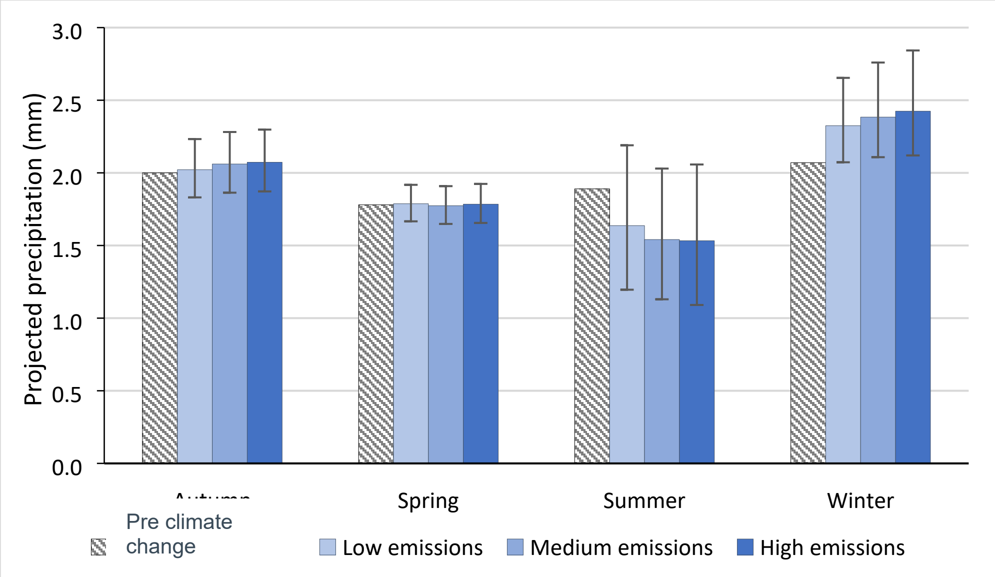
15.2.7.17 Research has found that it is very likely (confidence level >90%) that human influence has at least doubled the risk of a heat wave exceeding mean summer temperatures experienced in 2003[10].

Changes in precipitation - Drier summers

15.2.7.18 As shown in the figure below the central estimate of change in mean summer precipitation, by 2050s, is -18% under the high emissions scenario. The uncertainty around this estimate ranges from approximately -40% to 7% (represented by the 10th and 90th percentile respectively). These projections suggest that future average rainfall trends are uncertain, but it is more likely than not that summer rainfall will decrease.

[10] Stott, P. A., Stone, D. A. and Allen, M. R. (2004). Human contribution to the European heatwave of 2003, Nature, 432: 610-614

Figure 15.12: Average mean precipitation by the 2050s (error bars represent 10th to 90th percentile projections)



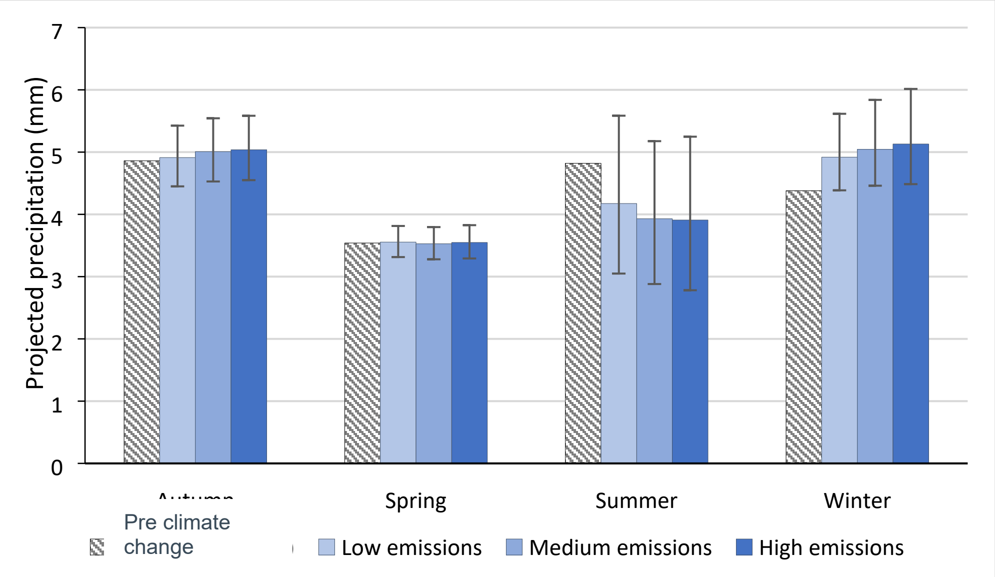
<u>Changes in precipitation - Heavier rainfall and wetter winters</u>

15.2.7.19 Climate projections show that by the 2050s, under the high emissions scenario, the central estimate (50th percentile estimate) there will be an increase in winter mean precipitation. Although average rainfall conditions are important, heavy rainfall events are more likely to cause flooding and damage to roads and other infrastructure. UKCP09 does not provide specific projections for flooding but instead includes probabilistic projections for precipitation on the wettest day defined as the 99th percentile of daily maximum precipitation on a seasonal basis.

15.2.7.20 The current climatological baseline analysis (see Figure 15.12 above) showed that the highest rainfalls in the study area are in winter months. Therefore, probabilistic data was source for projected change in winter rainfall on the wettest day (see Figure 15.13). As shown, the high emission scenario suggests that a central estimate of precipitation change on the wettest day in winter is approximately 17% increase by the 2050s. The uncertainty around this estimate ranges from approximately 2% to 37% (represented by the 10th and 90th percentile respectively). Although the projected percentage changes are large, London's baseline rainfall is low and therefore in absolute terms, these projections suggest that London could experience winter rainfall on the wettest day of ~5mm by 2050s (under high emissions) compared to 4.4mm in the baseline.

15.2.7.21 Figure 15.13 also demonstrates that there is great uncertainty in projections of future rainfall depending on the emission scenario or percentile.

Figure 15.13: Average mean precipitation on the wettest day by the 2050s (error bars represent 10th to 90th percentile projections)



15.2.7.22 Although the 50th percentile projections for summer heavy rainfall shown in Figure 15.13 suggests that summer heavy rainfall may decrease by the 2050s there is a great range of uncertainty represented by the 10th to 90th percentile projections. For example, under the high emissions scenario the 10th to 90th percentile projections range from a ~42% decrease to ~9% increase.

15.2.7.23 Recent research[11] has found that the UK may experience more heavy summer rainfall events in the future. Heavy summer rainfall events are predominantly caused by convective rainfall, brought about by thermal heating and evaporation. These localised convective rainfall events are currently not well replicated in climate models and, as a result, the models cannot provide information directly on how their intensity and frequency might change.

Changes to extreme weather (storms and high winds)

15.2.7.24 Future projections of storms and high winds are uncertain. They depict a wide spread of future changes in mean surface wind speed, however, there is large uncertainty in projected changes in circulation over the UK and natural climate variability contributes much of this uncertainty[12]. It is therefore difficult to represent regional wind extreme winds and gusts within regional climate models[13]. Other studies of future changes agree that confidence in future windiness is low[14,15,16].

15.2.7.25 A storm is defined by the Met Office as a wind event measuring 10 or higher on the Beaufort scale (equivalent to a wind speed of 24.5 m/s or 55 mph). Studies

[11] http://research.ncl.ac.uk/convex/ [accessed 21st February 2018]
[12] 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
[13] Ibid
[14] Thornton, H. (2010) Future UK circulation and wind projections and their relevance for the built environment. Met Office Hadley Centre, Exeter, UK. Crown copyright
[15] Pryor, S. C. and Barthelmie, R. J. (2010). Climate change impacts on wind energy: a review. Renewable & Sustainable Energy Reviews, 14: 430-437
[16] 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

suggest that climate-driven storm changes are less distinct in the Northern than Southern hemisphere[17]. 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 have affected the UK in early 2014, the signal is more complex[18]. Potentially, those mid-Atlantic 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[19]. However, such is the wide range of inter-model variation, robust projections of changes in storm track 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.

15.2.8 Potential impacts

15.2.8.1 The projects Scoping Report set out the extent of potential impacts to be considered in the climate vulnerability assessment. Impacts scoped out of further assessment:

- Operational impacts associated with wetter winters - noting that impacts associated with heavier rainfall remain a part of the assessment along with cumulative impacts associated with heavier rainfall and wetter winters;
- All impacts associated with sea level rise - the project is inland; and
- All construction impacts - Construction is not expected to be so far in the future that there would be enough time for the current climate to change significantly before construction is complete. Climate change will therefore not affect construction.

15.2.8.2 Although the current climate is unlikely to change further prior to construction it is noted that it has already changed from its natural state as a result of climate change. Construction impacts from this are expected to be negligible. However, if construction coincides with extreme weather events it should be noted that there may be impacts. Assessment of these is beyond the scope of a climate change assessment, examples are given below:

- During a heatwave the construction programme and activity schedule may need to be reviewed with those activities that are less vulnerable to the hot weather being prioritised. Additionally, construction staff health issues (e.g. heat stroke, dehydration, respiratory problems) could accompany work during a heatwave and/or time of reduced air quality. If construction coincided with a heatwave then Personal Protective Equipment (PPE) provision may need to be reviewed, extra drinking water provided etc. In extreme cases night work may be necessary to complete works.
- During fog, lightning or high winds it may not be possible to work safely, for example operating tall cranes. Some construction activities may need to be delayed on health and safety grounds; and
- During drought the construction schedule may be vulnerable to disruption if water availability is limited.

[17] 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
[18] 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
[19] Ibid

15.2.8.3 The CEMP and construction risk assessments should set out how extreme weather events are monitored so construction activities can be planned accordingly. This should include emergency planning for disastrous weather impacts.

15.2.9 Design, mitigation and enhancement measures

15.2.9.1 Likelihood and consequence assessments are undertaken after consideration of the Scheme design and embedded mitigation. Relevant embedded mitigation is set out in section 15.2.10. Where mitigation in addition to this is required to reduce otherwise significant climate vulnerabilities this is also identified in section 15.2.10.

15.2.10 Assessment of effects

15.2.10.1 The likelihood of an impact, with embedded mitigation in place, has been assessed to determine the climate vulnerability of the Scheme. The consequence of the impact, if it occurred, has also been assessed. Consequences are adverse unless otherwise stated. These assessments along with the resulting significance of each impact are presented in three Tables, one for each of the three types of receptor:

- The assets and their operation, maintenance and refurbishment (Table 15.23);
- End-users (Table 15.24); and
- The environment (Table 15.25).

Table 15.23: Potential operational impacts on asset receptors (including their operation, maintenance and refurbishment)

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
Warmer winters	There would be less freeze-thaw erosion with milder temperatures projected in the future – this can damage underground assets. Additionally, the projected increase in winter temperatures and decrease in snowfall suggests a reduction in frequency of winter road maintenance (salting).	NA	**Medium** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is high certainty that winter mean temperatures will increase over the Schemes lifetime (in winter, under the high emissions scenario, mean temperature is likely to increase by approximately 2.5ºC [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 Schemes operation road and pavement maintenance and repair costs could reduce. The difference in this reduction with and without the Scheme is considered to be similar.	**Not significant**
Hotter summers	Hotter summers could damage materials and reduce asset lives by, 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 and structures (e.g. culverts, kerbs);	The design will ensure structures can adapt to expected future variations in temperature. 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	**Medium** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase over the Schemes lifetime (by the 2050s, summer mean daily maximum temperatures could be up to +4ºC	**Minor beneficial** - Damage to assets may require additional maintenance and emergency repairs. However, the impact consequence without the Scheme would be larger as the older infrastructure that would have been replaced is in poorer condition and so has less resilience to future climates. Thus, the Scheme would provide a benefit as it	**Not significant**

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
	• Increased earth pressures to structures; • Failure of expansion joints; • Fires; • Increasing thermal loadings on electrical and control equipment; • Damaging vegetation that protects from erosion; and • Shrinkage and cracking.	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.	warmer [50th percentile estimate under high emissions]). 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.	would be more resilient to the impacts of climate change than the baseline.	
Drier summers	Hotter temperatures combined with the projected reduction in summer average rainfall could lead to increased erosion as soils and their substrates dry out.	The Landscape and Visual chapter has proposed the following embedded mitigation: • Retain existing trees and vegetation wherever possible; • Replace areas of trees and grass lost to facilitate the works wherever practicable; • Plant woodland and seed grass, to contribute to screening and amenity value and mitigate the loss of tree cover in the landscape. These measures will be delivered through the OEMP in accordance with the Environmental Mitigation Drawings. 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 filter drains to collect eroded sediment as well as	**Low** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is medium certainty that summers will get drier over the Schemes lifetime. The central estimate of change in mean summer precipitation, by 2050s, is -18% under the high emissions scenario. However, the uncertainty around this estimate ranges from approximately -40% to 7% (represented by the 10th and 90th percentile respectively). With embedded mitigation in place the likelihood of impact is low. With increased erosion under climate change a small amount of additional	**Minor beneficial** - Mobilisation of debris could lead to increased sedimentation within the Scheme's drainage infrastructure adversely affecting its capacity and so increasing maintenance costs and risk of flooding. However, the impact consequence without the Scheme would be larger as the older infrastructure that would have been replaced is in poorer condition and so has less resilience to future climates. Thus, the Scheme would provide a benefit as it would be more resilient to the impacts of climate change than the baseline.	**Not significant**

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
		flow attenuation devices to lower the risk of blockages.	sedimentation will occur in the drainage system.		
Drier summers	The expected reduction in summer average rainfall is likely to intensify and extend soil moisture deficits. This could impact soil stability effecting assets such as embankments.	Risk will be managed by best practice design, for example, embankments will be within best practice acceptable slope limits and compacted and stabilised to reduce the likelihood of future settlement. The Geology and Soils Chapter sets out in further detail how these risks will be controlled, including by: • Undertaking an appropriate ground investigation; • Inspection of existing infrastructure and assessment of movements which can be tolerated; • Design of the temporary and permanent works to minimise movement; • Appropriate analysis to predict magnitude of movements; and • Monitoring during the construction works to measure movements, with agreed trigger level and action plan.	**Low** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is medium certainty that summers will get drier over the Schemes lifetime. The central estimate of change in mean summer precipitation, by 2050s, is -18% under the high emissions scenario. However, the uncertainty around this estimate ranges from approximately -40% to 7% (represented by the 10th and 90th percentile respectively). With embedded mitigation in place the likelihood of impact is low.	**Minor beneficial** - Drier summers could damage assets and increase maintenance and repair costs. However, the impact consequence without the Scheme would be larger as the older infrastructure that would have been replaced is in poorer condition and so has less resilience to future climates. Thus, the Scheme would provide a benefit as it would be more resilient to the impacts of climate change than the baseline.	**Not significant**
Heavier rain and wetter winters	Heavier rain and wetter winters will weaken the soil beneath the carriageway. Loads from traffic may then stress the surface past its breaking point.	The design will ensure continuity of drainage in the pavement and road 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. The	**Negligible** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is medium certainty that rainfall will get heavier over the Schemes lifetime. The	**Minor beneficial** – There may, in the future, be an increase in the number and severity of pot holes in the study area. Pot holes can damage tires, wheels, and vehicle suspension. In extreme circumstances they can also cause road	**Not significant**

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
		design specifies a thin surface course system (TSCS) with a water sensitivity category of minimum 80%, use of PMB and a minimum binder content of 5.2% reflecting the revised requirements of MCHW 942 updated in May 2018. Where reflective cracking is considered a high risk the design includes a geosynthetic (i.e. geogrid) which will stop surface water penetrating the bound layers through the reflective cracks. To further improve the Scheme's longevity the detailed 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.	high emission scenario suggests that a central estimate of precipitation change on the wettest day in winter is approximately 17% increase by the 2050s. However, the uncertainty around this estimate ranges from approximately 2% to 37% (represented by the 10th and 90th percentile respectively). However, 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 pot hole formation). It is therefore uncertain what the net impact of climate change will be. With the embedded mitigation the likelihood of impact is negligible.	accidents, particularly where there are higher speed limits. To avoid this there would need to be an increase in maintenance and repair costs. However, the impact consequence without the Scheme would be larger as the older infrastructure that would have been replaced is in poorer condition and so has less resilience to future climates. Thus, the Scheme provides a benefit as it would be more resilient to the impacts of climate change than the baseline.	
Changes to extreme weather	More regular and intense storms in the future could increase the regularity of lightning strikes on infrastructure. High winds in these storms could also over load structures and	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 will be undertaken to determine if protection against transient overvoltage (lighting strike) is required. In advance of this, based	**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 beneficial** – Power loss for the Schemes lighting and electronic display equipment (signs) could cause traffic delays. Road closures for major repairs to structures would also cause delays. To avoid this more	**Not significant**

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
	damage roadside planting and furniture, for example traffic signs.	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. The landscape design will adhere to the Specification for Highways Works set out in Series 3000 (Landscape and Ecology) of the Manual of Contract Documents for Highway Works. The design does not propose to place large trees close to the carriageway. Where required, in Appendix 30/6 of the above listed document, root barriers shall be provided at the time of planting, in order to constrain the growth of tree roots.	Additionally, it is noted that the Highways England Adaptation Document states that the effect of wind on bridges is minimal as wind is not the dominant load.	regular maintenance may be required. However, the impact consequence without the Scheme would be larger as the older infrastructure that would have been replaced is in poorer condition and so has less resilience to future climates. Thus, the Scheme would provide a benefit as it would be more resilient to the impacts of climate change than the baseline.	
Heavier rainfall	The projected climate trend of increasing frequency and intensity of heavy rainfall events is likely to increase the risk of flooding in the project area, both pluvial and fluvial.	The drainage system will be designed in line with current standards set out in the Design Manual for Roads and Bridges (HA, 2009). 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. 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,	**Low** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is medium certainty that rainfall will get heavier over the Schemes lifetime. The high emission scenario suggests that a central estimate of precipitation change on the wettest day in winter is approximately 17% increase by the 2050s. However, the uncertainty around this	**Minor beneficial** – New assets could be damaged, for example by scour around structures, which would then require maintenance. Flooding could also cause road closures and associated traffic delays. However, the impact consequence without the Scheme would be larger as the older infrastructure that would have been replaced is in poorer condition and so has less resilience to future climates. Thus, the Scheme would provide a benefit as it	**Not significant**

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
		adjacent land-use, gradient and location within the wider catchment. The Design Manual for Roads and Bridges (DMRB) highlights the importance of local information to assess absolute rainfall thresholds for stretches of the Agency's network. This chapter does not include such detailed analysis but it is provided in the Schemes detailed Flood Risk Assessment which includes consideration and allowance for climate change. Further detail is also provided in Chapter 8 Road Drainage and the Water Environment. This 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 Planning Practice Guidance and EA and LLFA requirements. In short, a 20% climate change allowance has been used for the preliminary design as per HD33/16 and as discussed with the HE drainage SES (see drainage strategy report cl.2.4.1 and RIP DIS). Higher values of 40% allowance for climate change will be assessed during detailed design once further information is available. Where deep foundations extend below the existing groundwater table or could extend below the future groundwater level they are designed in accordance with industry	estimate ranges from approximately 2% to 37% (represented by the 10th and 90th percentile respectively). With embedded mitigation in place the likelihood of impact is low.	would be more resilient to the impacts of climate change than the baseline.	

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
		standards - taking into account the site-specific water level and flow monitoring data obtained from intrusive ground investigation for the Scheme.			

Table 15.24: Potential operational impacts on end user receptors

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
Warmer winters	Warmer winters will improve winter driver safety by reducing driving risks for road users as roads will be less icy and snowfall will reduce visibility less often.	NA	**High** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is high certainty that winter temperatures will increase over the Schemes lifetime (in winter, under the high emissions scenario, mean temperature is likely to increase by approximately 2.5ºC [central estimate]). The likelihood of impact is therefore high.	**Large beneficial**- Reduction in road traffic deaths & injuries and less accident related traffic disruption.	**Not significant** - the beneficial impact would be equally present with and without the Scheme. The Scheme will therefore not change the baseline and so the impact is assessed as not significant.
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 in the evening), more pedestrians	The long-term landscape design does not include large areas of exposed soil that could become mobile in hot dry weather. Skid resistance will therefore not be affected by new dust sources. The design will utilise various elements of motorway technology which will combine to create a safer	**Medium** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase	**Large** - Road traffic deaths & injuries and traffic disruption. The consequence of this impact would be greater (very large) without the Scheme which will	**Not significant** - When considered at the regional level, the impact could be considered to have a significant adverse effect on accident rates. However, at the Scheme level, since drivers would be exposed to the same risks on the existing road

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
	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.	driving environment. Specifically, to monitor traffic conditions, Motorway Incident Detection and Automatic Signalling (MIDAS) Radar is proposed to be installed on 17 masts across the Scheme in conjunction with MIDAS loop detection, providing detailed traffic information for all the major roads in the Scheme area. This information will be used to control signalling systems on 12 gantries on the M25 and 15 gantries on the A3. Information provided by the MIDAS system enables the signalling systems along the route to provide the road user with information on the conditions, set warning signs and allow them to make early decisions. It also allows Highways England to control the flow of traffic on the mainline and control traffic conditions. Typically, MIDAS queue protection delivers a benefit of around 10% in safety terms when applied to a motorway environment. Post and gantry mounted Advanced Motorway Indicators (AMIs) are also proposed. These will advise motorists of mandatory (M25) and advisory (A3) speeds to reduce congestion and advise the road user of any lane closures (red 'X's on gantries during incidents or maintenance operations). The Scheme will also introduce Pan Tilt Zoom (PTZ) CCTV cameras on	over the Schemes lifetime (by the 2050s, summer mean daily maximum temperatures could be up to +4ºC warmer [50th percentile estimate under high emissions]). With embedded mitigation in place the likelihood of impact is medium.	deploy new safety infrastructure.	regardless of whether or not the Scheme was constructed, the significance of the effect with and without the Scheme are considered to be the same and so the impact is assessed as being not significant. The Scheme will not change the existing significant high baseline risk of driving in dangerous conditions.

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
		masts and gantries. The PTZ cameras will be sited to provide coverage of the carriageway for the purpose of traffic monitoring, incident control and management. 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.			
Heavier rain	In the future heavier rain resulting from climate change will create dangerous driving conditions more often as spray reduces visibility, stopping distances increase and standing water creates an aquaplaning risk.	The Scheme design reduces some of the risk factors that contribute to accidents by introducing new safety infrastructure (see above). During extreme weather variable road speed limits can be set. As outlined above to inform the design of the Scheme a Flood Risk Assessment and Drainage Strategy has been undertaken (see Chapter 8 Road Drainage and the Water Environment). This details how the Scheme has ensured drainage will be sufficient for future rainfall. 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.	**Low** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is medium certainty that rainfall will get heavier over the Schemes lifetime. The high emission scenario suggests that a central estimate of precipitation change on the wettest day in winter is approximately 17% increase by the 2050s. However, the uncertainty around this estimate ranges from approximately 2% to 37% (represented by the 10th and 90th percentile respectively). With embedded mitigation in	**Large** – Accident rates could increase causing more road traffic deaths & injuries. There may also be associated indirect consequences for other road users by way of delays. The consequence of this impact would be greater (very large) without the Scheme which will deploy new safety infrastructure.	**Not significant** - When considered at the regional level, the impact could be considered to have a significant adverse effect on accident rates. However, at the Scheme level, since drivers would be exposed to the same risks on the existing road regardless of whether or not the Scheme was constructed, the significance of the effect with and without the Scheme are considered to be the same and so the impact is assessed as being not significant. The Scheme will not change the existing significant high baseline risk of driving in dangerous conditions.

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
			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 45mph. Windblown debris and fallen trees can also be a hazard to vehicles traveling at speed.	The existing motorway route is not being changed. No particularly exposed locations are identified along the route. The Scheme will introduce new safety infrastructure (see details above), this includes the installation of crash detection systems, entry signals, MS4, Advance Motorway Indicators, CCTV system and enforcement cameras. There will also be variable message signs which can be changed to show real time information designed to improve safety. The landscape design does not propose to place any large trees close to the carriageway that could cause disruption if uprooted in a storm.	**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. 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.	**Large** - road traffic deaths & injuries and potentially national level traffic disruption. It is noted, that the consequence of this impact would be greater (very large) without the Scheme which will deploy new safety infrastructure.	**Not significant** – It is noted that drivers would be exposed to the same risks on the existing road regardless of whether or not the Scheme was constructed, the significance of the effect with and without the Scheme are considered to be the same.
Hotter summers	During operation traffic using the Scheme will generate emissions. In the future the impact of these emissions on air quality receptors will be intensified by hotter summers brought on by climate change. Reduced air quality during heat waves is primarily a result of the formation of ground-level ozone. This requires four key	A detailed assessment of local air quality impacts associated with the Scheme is provided in the Air Quality Chapter. This did not identify any significant adverse effects on air quality arising from the Scheme. However, it is noted that the modelling upon which this assessment was based did not account for expected climate changes that will intensify air quality impacts in the future. Undertaking a detailed assessment of this is beyond	**Medium** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase over the Schemes lifetime (by the 2050s, summer mean daily maximum temperatures could be up	**Negligible** - The effect with and without the Scheme is considered to be similar (both will result in traffic emissions). Additionally, although health and wellbeing is dependent on climatic factors road users can	**Not significant**

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
	ingredients: nitrogen oxides (NOx), volatile organic compounds (VOC), heat and sunlight. The latter two are projected to increase with climate change.	the scope of this Chapter. The future effect of climate change on vehicle emissions from the Scheme and its impact on end users and other air quality receptors is therefore uncertain.	to +4°C warmer [50th percentile estimate under high emissions]). However, given the uncertainty regarding how this might affect air quality and air quality receptors, for the purposes of this assessment the likelihood of impact is considered to be medium.	tolerate a range of conditions.	

Table 15.25: Potential operational impacts on environmental receptors

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
Warmer winters	Warmer winters could reduce the number of road salt applications each year.	There may currently be one or more direct connection(s) between the existing stormwater drainage system and the water environment (specifically to Bolder Mere lake). This is to be confirmed by surveys during later design stages. The Schemes Drainage Strategy seeks to remove all direct connections using filter drains rather than open ditches, underground storage, soakaways and attenuation ponds. The inclusion of this in line treatment within the drainage infrastructure will make all connections to the water environment indirect and so mitigate potential water quality impacts on surface water receptors. The benefit or reduced road salt applications would therefore not be realised.	**Low** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is high certainty that winter temperatures will increase over the Schemes lifetime (in winter, under the high emissions scenario, mean temperature is likely to increase by approximately 2.5ºC [central estimate]). However, projected changes to the number of nights below freezing are less certain. With regard to this and with embedded mitigation in place the likelihood of impact is reduced to low.	**Minor** - The most commonly used de-icing chemical is sodium chloride (NaCl), known more commonly as road salt. Large quantities in the water environment can be toxic to aquatic life. The Scheme will increase the area over which de-icing is required and so will increase the benefit that a future reduction in the demand for de-icing would have on surface water receptors (water quality and indirect consequences for aquatic habitats and species).	**Not significant**
Drier summers	Drier summers will increase soil moisture deficits in the future.	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	**Low** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is medium certainty that summers will get drier over the Schemes lifetime. The central estimate of change in mean summer precipitation,	**Negligible** – The prevalence of species and habitats around the Scheme that are not able to adapt quickly could reduce. Those that are able to adapt will become more prominent. The consequence with and	**Not significant**

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
		tolerant species, whilst still having regard to the local character, and generally planting only native species. It will also adhere to best ecological practice.	by 2050s, is -18% under the high emissions scenario. However, the uncertainty around this estimate ranges from approximately -40% to 7% (represented by the 10th and 90th percentile respectively). With embedded mitigation in place the likelihood of impact is low.	without the Scheme is considered to be similar.	
Drier summers	Climate change is projected to make summers drier, with occasional heavy convectional rainfall. First flush events will therefore be more likely to affect the Scheme in the future. The term "first flush" refers to rapid changes in the quality of water in a watercourse after rainfall that follows a long period of dry weather. This can happen on roads when dry weather enables contaminants such as suspended solids, rubber, trace metals and polycyclic aromatic hydrocarbons to build up on road surfaces. When it eventually rains these mobilise and enter aquatic systems via surface water runoff and drainage infrastructure en-masse.	There may currently be one or more direct connection(s) between the existing stormwater drainage system and the water environment (specifically to Bolder Mere lake). This is to be confirmed by surveys during later design stages. The Schemes Drainage Strategy seeks to remove all direct connections using filter drains rather than open ditches, underground storage, soakaways and attenuation ponds. The inclusion of this in line treatment within the drainage infrastructure will make the connections to the water environment indirect and so mitigate first flush impacts on surface water receptors. Further details are provided in Chapter 8 - Road Drainage and the Water Environment.	**Low** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is medium certainty that summers will get drier over the Schemes lifetime. The central estimate of change in mean summer precipitation, by 2050s, is -18% under the high emissions scenario. However, the uncertainty around this estimate ranges from approximately -40% to 7% (represented by the 10th and 90th percentile respectively). With embedded mitigation in place the likelihood of impact is low.	**Minor** - Sudden water quality changes can have adverse impacts on aquatic systems (preventing sunlight from reaching aquatic plants, clogging fish gills, choking organisms, smothering fish spawning and nursery areas). Other road runoff pollutants degrade water quality and can harm aquatic life further (interfering with photosynthesis, respiration, growth, and reproduction etc). The effect with and without the Scheme is considered to be similar. It is noted that compared to the existing drained road area the additional area that the Scheme will create is relatively small.	**Not significant**

Climate trend	Potential Impact	Embedded mitigation	Likelihood	Consequence	Significance
Drier summers	Hotter and drier summers will lower water levels in rivers. Water quality impacts of the Schemes surface water drainage discharges to the environment could therefore increase as the capability of rivers to dilute discharges reduces.	There may currently be one or more direct connection(s) between the existing stormwater drainage system and the water environment (specifically to Bolder Mere lake). This is to be confirmed by surveys during later design stages. The Schemes Drainage Strategy seeks to remove all direct connections using filter drains rather than open ditches, underground storage, soakaways and attenuation ponds. The inclusion of this in line treatment within the drainage infrastructure will make the connections to the water environment indirect and will maintain the quality of discharges at acceptable levels into the future. Further details are provided in Chapter 8 - Road Drainage and the Water Environment.	**Low** - Following Highway England Guidance and in line with the UKCP projections and the precautionary principle it is considered that there is medium certainty that summers will get drier over the Schemes lifetime. The central estimate of change in mean summer precipitation, by 2050s, is -18% under the high emissions scenario. However, the uncertainty around this estimate ranges from approximately -40% to 7% (represented by the 10th and 90th percentile respectively). With embedded mitigation in place the likelihood of impact is low.	**Minor** - Surface water drainage discharges to the water environment may have water quality related impacts that become environmentally unacceptable over time (with adverse consequences for aquatic habitats and species). The reduced dilution potential of rivers will also make them increasingly vulnerable to adverse impacts from pollution incidents such as accidental spillages, cross connections or other point pollution sources that are connected to the surface water drainage system. The consequence with and without the Scheme is considered to be similar.	**Not significant**

15.2.11 Monitoring

15.2.11.1 No significant vulnerabilities of the Scheme to climate change are identified and accordingly no further mitigation or enhancement measures are required beyond the embedded mitigation identified in the above tables.

15.2.11.2 It is recommended that monitoring and evaluation of the Scheme's major assets resilience to climate shall be part of regular asset inspections to inform climate change adaptation decision-making in the future.

15.2.12 Cumulative effects

15.2.12.1 Cumulative effects can be intra-Scheme, for example the combined impact of multiple effects on a single receptor and also inter-Scheme, where more than one scheme is under construction that has potential to effect the same receptor. They are discussed further in the Cumulative Effects Chapter.

15.2.12.2 There are no inter-Scheme cumulative effects relevant to climate vulnerability. However, intra- scheme effects are important. These are considered in section 15.2.10, they include combined effects from climate change projections of:

- Heavy rain and wetter winters;
- Drier summers and hotter summers; and
- Warmer winters and reduced snow.

15.2.13 NPSNN compliance

15.2.13.1 Paragraph 4.40 of the NPSNN (Department for Transport, 2014) 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 NPSNN requirement this chapter therefore considers how projected climate changes in the project area (section 15.2.7) could alter the design and operation of the Scheme (section 15.2.10).

15.2.14 Summary

15.2.14.1 This sub section has presented the climate change vulnerability assessment. The assessment has been undertaken in compliance with Highways England Guidance. The impact of future climatic conditions on the Scheme during construction and during operation have been considered.

15.2.14.2 The assessment of the vulnerability of the Scheme to climate change has shown that climate in the study area is projected to change in the future and that the Scheme will be vulnerable to the impacts of this change during its operation. However, the detailed assessment has found that none of these vulnerabilities are significant as embedded mitigation sufficiently adapts the design and operational processes to remove and reduce all adverse climate vulnerability impacts.

15.2.14.3 It is noted that climate change may create more dangerous driving conditions in the future, for example causing more heavy rainfall events. When considered at the regional level, these impacts could be considered to have a significant adverse effect on end users by increasing accident rates. However, at the Scheme level, since drivers would be exposed to the same risks on the existing road regardless of whether or not the Scheme was constructed, the significance of the effect with and without the Scheme are considered to be the same. The impact is therefore assessed as being not significant. 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. The Scheme will not change the existing significant high baseline risk of driving in dangerous conditions.

15.2.14.4 The Scheme would not increase the significance of any of the impacts identified beyond those that would occur without the Scheme in place. In most cases, the climatic vulnerabilities in the study area would be the same with or without the Scheme. In several instances potential impacts on assets would be reduced by the Scheme which will replace and upgrade older infrastructure that would be less resilient to the projected future climate.

15.3 References

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