Norwich Western Link Environmental Statement Chapter 16: Climate Resilience

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Glossary of Abbreviations and Defined Terms

The definition of key terms used in this report are provided below.

Term	Definition
Climate	The general weather conditions prevailing over a long period of time. Climate change will see trends in the climate conditions changing (seasonal averages and extremes).
Climate change projection	The range of possible climate conditions projected for a range of probability that the conditions will occur for a specific carbon emissions scenario.
Climate resilience	The capacity of a project (or lack thereof) to withstand the adverse effects of climate change
Climate vulnerability	The degree to which a system/asset is exposed and resilient to adverse effects of climate change
DMRB	Design Manual for Roads and Bridges LA 114 Climate is used to assess the likelihood and consequence of potential climate impacts.
IEMA	Institute of Environmental Management and Assessment, guidance used to assess the significance of climate impacts.
In-combination climate change impacts	In-combination climate change impacts is the potential that climate change will exacerbate or ameliorate the potential effects identified within each of the environmental topics
Non-motorised Users (NMU)	A specific group of road users including walkers, cyclists or horse riders.

Term	Definition
RCP	Representative Concentration Pathway are four scenarios to understand the potential impacts from low and high energy intensive scenarios, there impact on the global climate, and how significant the climate hazards will be.
UKCP18	UK Climate Projections 2018 are used as the most up to date climate projections for the UK

16 Climate Resilience

16.1 Introduction

16.1.1 The requirement to consider a project's impact on and vulnerability to climate change results from the 2014 amendment to the EIA Directive (2014/52). The Directive has been fully transposed into UK law in the Town and Country Planning (Environmental Impact Assessment) Regulations 2017 (**'EIA Regulations'**). Paragraph 5(f) of Schedule 4 to the EIA Regulations refers to *"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;".* As such, this chapter reports the outcome of the assessment of likely significant effects arising from climate change upon the Proposed Scheme whereas the Environmental Statement (ES) **Chapter 15: Greenhouse Gases** (Document Reference: 3.15.00) assesses the likely effects of the Proposed Scheme on climate change (i.e. the Proposed Scheme's Green House Gas (GHG) emissions, contributing to climate change).

16.1.2 This chapter describes the assessment methodology and the baseline conditions relevant to the assessment, which have been used to reach these conclusions, as well as a summary of the likely significant effects leading to the additional mitigation measures required to avoid, prevent, reduce or, if possible, offset any likely significant adverse effects, and the likely residual effects and any required monitoring after these measures have been employed. Opportunities for environmental enhancement, where such opportunities exist, are also discussed.

16.1.3 This chapter is intended to be read as part of the wider ES with particular reference to **Chapter 11: Road Drainage and the Water Environment** (Document Reference: 3.11.00) and **Appendix 3.1: Outline Construction Environment Management Plan (OCEMP)** (Document Reference: 3.03.01).

16.2 Legislative Framework, Policy and Guidance

Legislative Framework

16.2.1 The Climate Change Act 2008 (**Ref 16.24)** requires the UK Government to produce a UK Climate Change Risk Assessment (CCRA) every five years. The CCRA assesses current and future risks to and opportunities for the UK from climate change. In response to the CCRA, the Climate Change Act also requires the UK Government to produce a National Adaptation Programme (NAP). The NAP covers England, while the devolved administrations produce their own programmes and policies.

16.2.2 The Climate Change Act 2008 established the creation of the Committee on Climate Change, with a responsibility for:

16.2.3 Advising and scrutinising the UK Government's associated climate change adaptation programmes; and

16.2.4 Producing a NAP for the UK Government to implement.

16.2.5 The climate resilience assessment demonstrates how the Proposed Scheme will be resilient against climate impacts.

Policy

16.2.6 Planning policy applicable to climate resilience assessment includes the following:

- National Planning Policy Framework (NPPF), 2023 (**Ref. 16.15**);
- National Policy Statement for National Networks (NPSNN), 2014 (**Ref. 16.26**)
- Draft National Policy Statement for National Networks, 2023 (**Ref. 16.28**);
- Norfolk County Council Environmental Policy (NCCEP), 2019 (**Ref. 16.25**);
- Norfolk County Council Climate Strategy, 2023 (**Ref 16.29**);

- Norfolk County Council Climate Policy, 2024 (**Ref. 16.33**)
- Norfolk County Council Local Transport Plan 4, 2021 (**Ref 16.30**)
- Norfolk County Council Local Transport Plan 4 Implementation Plan, 2022 (**Ref 16.31**); and
- Transport for Norwich Strategy, 2021 (**Ref 16.32**)

National

National Planning Policy Framework

16.2.7 NPPF, Section 14 “Meeting the challenge of climate change, flooding and coastal change” establishes at paragraph 158 that:

“plans should take a proactive approach to mitigating and adapting to climate change, taking into account the long-term implications for flood risk, coastal change, water supply, biodiversity and landscapes, and the risk of overheating from rising temperatures”.

16.2.8 Paragraph 159 states that:

"*New development should be planned for in ways that*:

a) 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”.

National Policy Statement for National Networks

16.2.9 Whilst the Proposed Scheme is not a Nationally Significant Infrastructure Project (NSIP), the NPSNN contains a section on ‘climate change adaptation’ and sets out how the NPS puts Government policy on climate change adaptation into practice for national networks projects. In particular it sets out how applicants and the Secretary of State should take the effects of climate change into account when developing and consenting infrastructure.

16.2.10 The NPSNN in Chapter 4: Assessment Principles identifies that:

"Climate change is likely to mean that the UK will experience hotter, drier summers and warmer, wetter winters. There is an increased risk of flooding, drought, heatwaves, intense rainfall events and other extreme events such as storms and wildfires, as well as rising sea levels. Adaptation is therefore necessary to deal with the potential impacts of these changes that are already happening. New development should be planned to 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 provision of green infrastructure" (paragraph 4.37).

16.2.11 And paragraph 4.40 states that "*new national networks infrastructure… will need to remain operational over many decades*". Consequently, applicants must consider the impacts of climate change through the application of *"…the UK climate projections*" using the *"…high emissions scenarios…against the 2080 projections at the 50% probability level*".

Draft National Policy Statement for National Networks

16.2.12 Climate change adaptation is discussed from paragraph 4.30 to 4.41 of the Draft NPS NN. Paragraph 4.36 recognises that new network infrastructure is likely to be a long-term and operational over many decades. As such, the impacts of climate change must be considered when *"planning the location, design, build, operation and maintenance".*

Local

16.2.13 The Norfolk County Council Environmental Policy identifies mitigating and adapting to climate change as key to the Environmental Policy through:

- Managing land sustainably – improving soil health, focusing on woodland and reducing risks from flooding and coastal erosion, working to make 'at-risk' properties more resilient to flooding;
- Recovering nature and enhancing the beauty of landscapes - providing support for designated sites, including the Norfolk & Suffolk Broads, and

the Norfolk Coast Area of Outstanding Natural Beauty, Natura 2000 sites and species, and County Wildlife Sites; and

- Connecting people with the environment to improve health and wellbeing - planting more trees to improve biodiversity and as a potential mitigation measure for climate change in appropriate locations.

Norfolk County Council Climate Strategy

16.2.14 Focus area five of NCC's Climate Change Strategy is for climate adaptation, where states *"Part of Norfolk County Council's response to climate change must focus on managing climate risk for Norfolk by building resilience across the local services it provides and adapting our infrastructure through nature-based and engineering solutions".* The strategic policy includes ensuring *"new infrastructure is designed against appropriate assumptions on the future impacts of climate change".* Norfolk County Council's Climate Policy 2024 reflects the main elements of the Strategy, but in a more concise format.

Norfolk County Council Local Transport Plan 4

16.2.15 The Climate Change section of the Plan notes the importance of transport infrastructure to be adapted to climate change to ensure the network is not compromised. It also notes the importance of climate vulnerability assessments to enhance risk understanding and implementing necessary measures.

Norfolk County Council Local Transport Plan 4 Implementation Plan

16.2.16 The implementation plan sets out an action for Norfolk County Council to undertake a vulnerability assessment of transport networks in 2022 and annually as necessary (under Policy 1 as part of Objective 1: Embracing the Future). Under Policy 21 (as part of Objective 7: A Well Managed and Maintained Transport Network), Norfolk County Council is required to review the resilience network assessment (completed as part of Policy 1 action) and maintain an up-to-date flood risk management strategy to manage flood risk due to climate change.

Transport for Norwich Strategy

16.2.17 The strategy is primarily focused on net zero goals, however the link between reducing carbon emission to *"mitigate the damaging effects of climate change"* (paragraph 6.1) are noted.

Guidance

16.2.18 The following guidance documents have been used during the preparation of this chapter:

- Institute of Environmental Management and Assessment (IEMA's) Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation, 2020 (**Ref 16.27**); and
- Design Manual for Roads and Bridges (DMRB) LA 114 Climate, 2019 (**Ref 16.4**).

16.3 Consultation, Scope, Methodology and Significance Criteria

Consultation Undertaken to Date

16.3.1 No consultation (beyond the scoping opinion responses) has been required in relation to climate resilience, as the methodology has followed published, best practice guidance, and the baseline data is publicly available. Consultation in relation to the scope of the chapter assessment, as part of the Scoping Report, is outlined below.

Scope of the Assessment

16.3.2 The scope of this assessment has been established through an ongoing scoping process. Further information can be found in ES **Chapter 5: Approach to EIA** (Document Reference: 3.05.00).

16.3.3 This section provides the scope of the assessment in this chapter as identified within **Appendix 5.1 Scoping Report 2020** (Document Reference: 3.05.01) and **Appendix 5.2 Scoping Report Addendum 2022** (Document Reference: 3.05.02).

Table 16-1 Scoping Opinion and Scoping Addendum Responses

Consultee	Comments provided in Scoping Response	Response to comments
Norfolk County Council	No comments to make with regards to climate resilience issues within the Scoping Report.	The comment has been noted.
Norfolk County Council – Planning Authority	The England Biodiversity Strategy published by Defra establishes principles for the consideration of the effects of climate change. The ES should reflect these principles and identify how the Proposed Development's effects on the natural environment will be influenced by climate change, the impacts greenhouse gases, climate resilience both during construction and when in operation. In relation to climate resilience, the longer-term impact of climate change, should as is proposed, be addressed together with details of the mitigation measures proposed to reflect the impact probability of the climate variables stated, insofar as they affect the scheme.	The ES **Chapter 10: Biodiversity** (Document Reference: 3.10.00) provides commentary on how the habitats and species assessed within the chapter may be impacted by climate change. Mitigation within the Proposed Scheme includes nature based solutions with climate resilience and biodiversity co-benefits such as use of a variety of species within planting mixes and planting of native tree and shrub species. Refer to **Table 16-14** for embedded mitigation within the Proposed Scheme design.
Natural England	The ES should identify how the development affects the ability of the natural environment (including habitats, species, and natural processes) to adapt to climate change, including its ability to provide adaptation for people. This should include impacts on the vulnerability or resilience of a natural feature (i.e. what's already there and affected) as well as impacts on how the environment can accommodate change for both nature and people, for example whether the development affects species ability to move and adapt. Nature-based solutions, such as providing green infrastructure on-site and in the surrounding area (e.g. to adapt to flooding, drought and heatwave events), habitat creation and peatland restoration, should be considered. The ES should set out the measures that will be adopted to address impacts.	The ES **Chapter 10: Biodiversity** (Document Reference: 3.10.00) provides commentary on how the habitats and species assessed within the chapter may be impacted by climate change. Mitigation within the Proposed Scheme includes nature based solutions with climate resilience and biodiversity co-benefits such as use of a variety of species within planting mixes and planting of native tree and shrub species. Refer to **Table 16-14** for embedded mitigation within the Proposed Scheme design.
Norfolk County Council – Community & Environmental Services	The longer-term impact of climate change is clearly outlined. It is noted that appropriate mitigation measures will be in place to reflect the impact probability of the climate variables stated, insofar as they affect the scheme, so nothing to add to this.	The comment has been noted and the appropriate mitigation as set out in **Table 16-17** and **Table 16-18** will be employed as listed, including as upheld for construction in the OCEMP.

Elements Scoped out of the Assessment

16.3.4 The elements (the climate variables which the Proposed Scheme components have the potential to be vulnerable to) shown in **Table 16-2** are not considered to give rise to likely significant effects and have therefore not been considered within this assessment.

16.3.5 Given the inland location of the Proposed Scheme, variables associated with sea level and sea temperature are not included in the assessment.

16.3.6 A climate vulnerability assessment was undertaken at scoping stage, outlined in the Environmental Impact Assessment Scoping Report 2020 **Appendix 5.1** (Document Reference: 3.05.01. The vulnerability of the Proposed Scheme to climate change was assessed as a function of the sensitivity and exposure of the receptors to climate change.

16.3.7 The Proposed Scheme components listed in **Table 16-2** were identified during scoping to be of low vulnerability to the climate variables and effects. As such, are not considered likely to have significant effects on the components of the Proposed Scheme during the operational phase.

16.3.8 No construction components were identified to be of low vulnerability and therefore no construction components have been scoped out.

Table 16-2 Proposed Scheme operational components scoped out of the assessment

Proposed Scheme component (operational phase)	**Climate variable**	**Climate effect**
Road components (including carriageway, pavements and roundabout)	Sea	Sea level rise Storm surge and storm tide Surface temperature Currents and waves

Proposed Scheme component (operational phase)	**Climate variable**	**Climate effect**
Road components (including carriageway, pavements and roundabout)	Temperature	Changes in annual average
Road components (including carriageway, pavements and roundabout)	Wind	Storms (hail, lightning)
Road components (including carriageway, pavements and roundabout)	Water quality and soils	Runoff
Structural components (including viaduct, overpass and underpass bridges)	Sea	Sea level rise Storm surge and storm tide Surface temperature Currents and waves
Structural components (including viaduct, overpass and underpass bridges)	Precipitation	Drought
Structural components (including viaduct, overpass and underpass bridges)	Temperature	Changes in annual average

Proposed Scheme component (operational phase)	Climate variable	Climate effect
Structural components (including viaduct, overpass and underpass bridges)	Relative humidity	Changes in annual average Evaporation
Structural components (including viaduct, overpass and underpass bridges)	Water quality and soils	Runoff
Ancillary works (including provision for non-motorised users and signage)	Sea	Sea level rise Storm surge and storm tide Surface temperature Currents and waves
Ancillary works (including provision for non-motorised users and signage)	Precipitation	Changes in annual average Drought
Ancillary works (including provision for non-motorised users and signage)	Temperature	Changes in annual average
Ancillary works (including provision for non-motorised users and signage)	Wind	Gales and extreme wind events Storms (hail, lightning)

Proposed Scheme component (operational phase)	Climate variable	Climate effect
Ancillary works (including provision for non-motorised users and signage)	Water quality and soils	Runoff

Elements Scoped into the Assessment

16.3.9 The following elements identified in **Table 16-3** are considered to have the potential to have likely significant effects during construction and operation of the Proposed Scheme and have therefore been considered within this chapter assessment. The climate variables will be the same for the construction and operation of the Proposed Scheme.

Table 16-3 Proposed Scheme construction and operational components scoped into the assessment

Proposed Scheme component (construction and operation)	Climate variable	Climate effect
Construction: Construction site (site compound, plant and equipment; and materials)	Precipitation	Changes in annual average Extreme precipitation events
Construction: Construction site (site compound, plant and equipment; and materials)	Temperature	Extreme temperature events
Construction: Construction site (site compound, plant and equipment; and materials)	Wind	Gales and extreme wind events
Construction: Construction site (site compound, plant and equipment; and materials)	Water quality and soils	Soil moisture Soil stability
Construction: Construction workers	Precipitation	Changes in annual average Extreme precipitation events
Construction: Construction workers	Temperature	Extreme temperature events
Construction: Construction workers	Wind	Gales and extreme wind events
Operation: Road components (including carriageway, pavements and roundabout)	Precipitation	Changes in annual average Drought Extreme precipitation events
Operation: Road components (including carriageway, pavements and roundabout)	Temperature	Extreme temperature events

Proposed Scheme component (construction and operation)	Climate variable	Climate effect
Operation: Road components (including carriageway, pavements and roundabout)	Wind	Gales and extreme wind events
Operation: Road components (including carriageway, pavements and roundabout)	Water quality and soils	Soil moisture Soil stability
Operation: Structural components (including viaduct, overpass and underpass bridges)	Precipitation	Change in annual average Extreme precipitation events
Operation: Structural components (including viaduct, overpass and underpass bridges)	Temperature	Extreme temperature events
Operation: Structural components (including viaduct, overpass and underpass bridges)	Wind	Gales and extreme wind events Storms (hail, lightning)
Operation: Structural components (including viaduct, overpass and underpass bridges)	Water quality and soils	Soil moisture Soil stability
Operation: Ancillary works (including provision for non-motorised users and signage)	Precipitation	Extreme precipitation events
Operation: Ancillary works (including provision for non-motorised users and signage)	Temperature	Extreme temperature events
Operation: Ancillary works (including provision for non-motorised users and signage)	Water quality and soils	Soil moisture Soil stability
Operation: Drainage	Precipitation	Extreme precipitation events Change in annual average

Proposed Scheme component (construction and operation)	Climate variable	Climate effect
Operation: Landscaping and vegetation	Precipitation	Extreme precipitation events Change in annual average
Operation: Landscaping and vegetation	Temperature	Extreme temperature events Change in annual average
Operation: End users (road users)	Precipitation	Extreme precipitation events
Operation: End users (road users)	Wind	Gales and extreme wind events Storms (hail, lightning)

Extent of the Study Area

16.3.10 The focus of the climate resilience assessment is the impact of climate change events on the climate resilience of the Proposed Scheme (rather than the impact of the Proposed Scheme on the environment which is assessed in other chapters). The study area for the assessment is the Red Line Boundary, as set out in **Appendix 2.2 Red Line Boundary Plans** (Document Reference: 2.02.00).

Method of Baseline Data Collation

Desk Study

16.3.11 The assessment has been informed by information on existing and projected change in climate variables.

16.3.12 Met Office Regional Climate Profile for the East of England is used to assess the existing baseline (**Ref 16.2**); and

16.3.13 UK Climate Projections 2018 (UKCP18) (**Ref 16.3**) is used to assess the future baseline.

Surveys

16.3.14 No surveys were required to assess the vulnerability of the Proposed Scheme to climate change events.

Assessment Methodology

16.3.15 The significance of effects has been determined by considering the likelihood and the consequence of potential impacts associated with climate change on the Proposed Scheme components occurring. Likelihood and consequence have been qualitatively assessed using the descriptions in **Table 16-4** and **Table 16-5**, informed by the existing and future baseline. These descriptions are in line with DMRB LA 114 (**Ref 16.4**). The likelihood definitions depend on the lifetime of the Proposed Scheme's components and therefore vary. However, this chapter has assessed the maximum climate projections available from the UKCP18 data; 2020s, 2050s and 2080s to provide context of climate changes associated with the whole lifespan of the Proposed

Scheme, including the structural components expected to have a lifespan of 120 years. The 2080s projections have been applied to cover the period from 2070 to 2099 as there are no projections available past this data at this time. 2080 projections therefore are the most relevant for long-term projections. At the time of writing, these represent the most up-to-date representation of future climate in the UK and the east of England. However, the UKCP18 data currently available does not provide data for drought, snow and ice or wind.

16.3.16 **Table 16-4** describes the frequency of climate variables on the Proposed Scheme (120 years) however, on the assessment of the road components or ancillary works, this has been amended to reflect their projected lifespans (20 years).

16.3.17 The assessment of likelihood and consequence (and therefore significance) has taken into account the embedded mitigation. Embedded mitigation (set out in more detail in section 16.5) has been identified through discussions with the design team and Principal Contractor.

16.3.18 The construction phase is anticipated to take place between 2026-2029

16.3.19 The operational phase of the road is expected to be approximately 20 years with the structural components anticipated to have a lifespan of 120 years.

Table 16-4 Likelihood of climate change risk

Measure of likelihood	**Description**
Very high	The event occurs multiple times during the lifetime of the project e.g. approximately annually.
High	The event occurs several times during the lifetime of the project e.g. approximately once every 5 years.
Medium	The event occurs limited times during the lifetime of the project e.g. approximately once every 15 years (for structures) and 10 years (for roads).

Measure of likelihood	Description
Low	The event occurs occasionally during the lifetime of the project e.g. once in 60 years (for structures) 15 years (for roads).
Very low	The event may occur once during the lifetime of the project (120 years for structures, and 20 years for roads).

Table 16-5 Consequence of climate risk

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

Effect Significance

16.3.20 The likelihood and consequence have been combined to assess the significance of effects on the affected receptors, as shown in **Table 16-6**.

16.3.21 The assessment is qualitative and based on the DMRB LA 114 (**Ref 16.4**).

Table 16-6 Significance rating matrix

Significance	Measure of likelihood	Very Low	Low	Medium	High	Very High
Measure of consequence of hazard occurring	Very Large	Not Significant	Significant	Significant	Significant	Significant
Measure of consequence of hazard occurring	Large	Not Significant	Not Significant	Significant	Significant	Significant
Measure of consequence of hazard occurring	Moderate	Not Significant	Not Significant	Significant	Significant	Significant
Measure of consequence of hazard occurring	Minor	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant

Significance	Measure of likelihood	Very Low	Low	Medium	High	Very High
Measure of consequence of hazard occurring	Negligible	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant

16.4 Baseline Conditions

16.4.1 The existing baseline utilises historic climate data extracted from the East of England region using Met Office Regional climate profiles (**Ref 16.2**) and weather station data from Morley St Botolph Weather station (**Ref 16.5)** (approximately 11 miles south-east of the Proposed Scheme) and the closest weather station to the Proposed Scheme. The future baseline utilises future projected climate data interpreted from UK Climate Projection 2018 datasets (**Ref 16.3**).

Existing Baseline

Precipitation

16.4.2 **Plate 16-1** shows the long-term average monthly rainfall for the East of England Region and Morley St Botolph Weather station between 1991 and 2020. It shows that the region is drier than most parts of the UK throughout the year, however, rainfall in the immediate vicinity of the weather station is slightly higher than the average for the East of England.

Plate 16-1 Long-term Average Mean Monthly Rainfall for Morley St Botolph Weather Station and East Anglia, in comparison to the rest of the UK

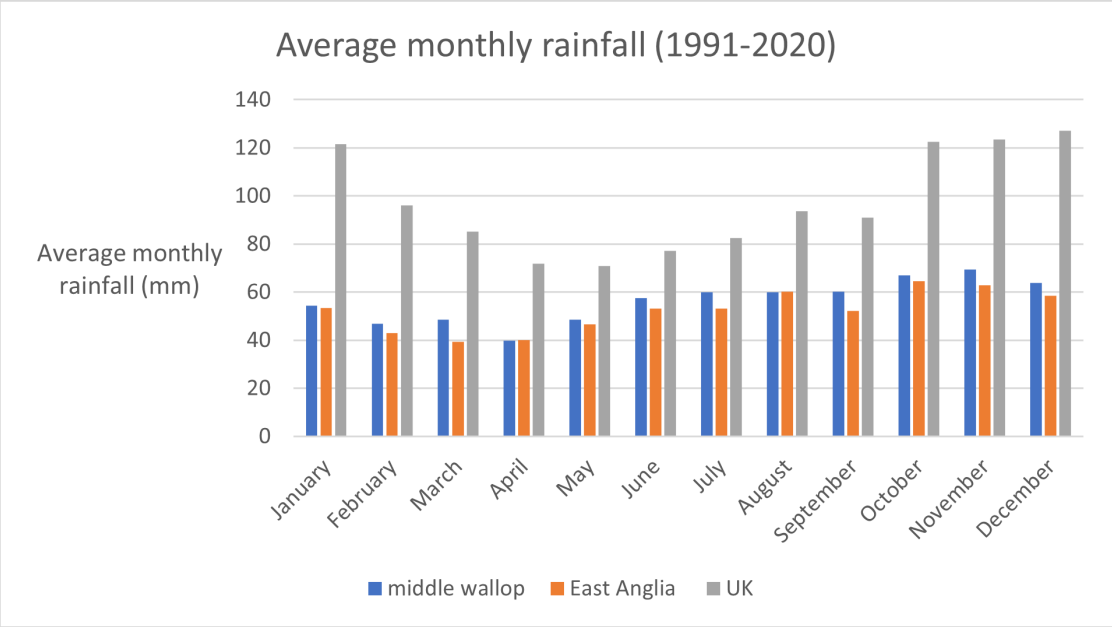


Table 16-7 Long-term Average Monthly Rainfall (1991-2020) for Morley St Botolph Weather Station, East Anglia, and the UK Average

Season	Precipitation (mm) Morley St Botolph Weather Station	Precipitation (mm) East Anglia	Precipitation (mm) UK Average
Summer	178mm	166mm	253mm
Winter	165mm	154mm	345mm
Annual	676mm	627mm	1163mm

Extreme Precipitation

16.4.3 Whilst the region is drier than the UK average, it does experience extreme rainfall events. **Table 16-8** shows the average number of days where rainfall exceeded 10mm per day (a measure of extreme rainfall) (**Ref 16.5**).

Table 16-8 Average of Total Number of Days where Rainfall Exceeded 10mm for the Baseline Period (1991 - 2020)

Period	Average number of days rainfall > 10mm (1981-2010)
Summer	4 to 6 days
Winter	<4 days
Annual	<15 days

16.4.4 Periods of prolonged rainfall are often associated with Atlantic depressions or with convection. The Atlantic lows are more vigorous in autumn and winter. In summer, convection caused by solar surface heating sometimes forms shower clouds and is the driver for a large proportion of rainfalls from showers and thunderstorms at this time of year. Rainfall caused this way is normally more intense than winter rainfall which tends to be more frontal with falls occurring over longer periods. Some noteworthy extreme rainfall, drought and storm events include: **(Ref. 16.6)**

16.4.5 October 2023: Storm Babet brought heavy, persistent and widespread rain affecting much of England, recording the third-wettest independent 3-day period for England and Wales in a series from 1891. Central and eastern parts of England recorded more than twice the October whole-month average rainfall in the first three weeks of the month.

16.4.6 July and August 2022: Driest July for England since 1935, and the driest July on record for East Anglia, southeast and southern England. Only 10.5mm of rain was recorded, which is just 17% of its average rainfall. Following the prolonged dry period, the Environment Agency confirmed Drought status in 8 of its 14 areas, including East Anglia.

16.4.7 August 2020: Norfolk experienced extreme rainfall, where a remarkable daily total of 239.9mm daily rainfall was recorded. The torrential rainfall caused localised flash-flooding with several properties affected, and there were other flooding problems more widely across Norfolk from thunderstorms and torrential downpours.

16.4.8 June 2019: The UK experienced a spell of very wet weather in mid-June as a low-pressure system and associated fronts brought widespread and slow-moving heavy rainfall. In Eastern England, approximately 60mm of rain fell in three days. This is the average rainfall expected for the month of June.

16.4.9 Winter 2009/2010 to March 2012 - Much of central, eastern and southern England and Wales experienced a prolonged period of below average rainfall due to a sequence of dry months from winter 2009/10 to March 2012, particularly in the spring, autumn and winter seasons. For England and Wales, this was one of the ten most significant droughts of one to two years' duration in the last 100 years.

Snow and ice

16.4.10 Snowfall is closely linked with temperature, with falls rarely occurring if the temperature is higher than 4°C. For snow to lie for any length of time, the temperature normally must be lower than this. Over most of the area, snowfall is normally confined to the months between November and April, but upland areas may have brief falls in October and May. Snow rarely lies outside the period from December to March. The region has experienced snow events in:

16.4.11 February to March 2018 - the most significant spell of snow and low temperatures for the UK overall since December 2010 (**Ref 16.7**).

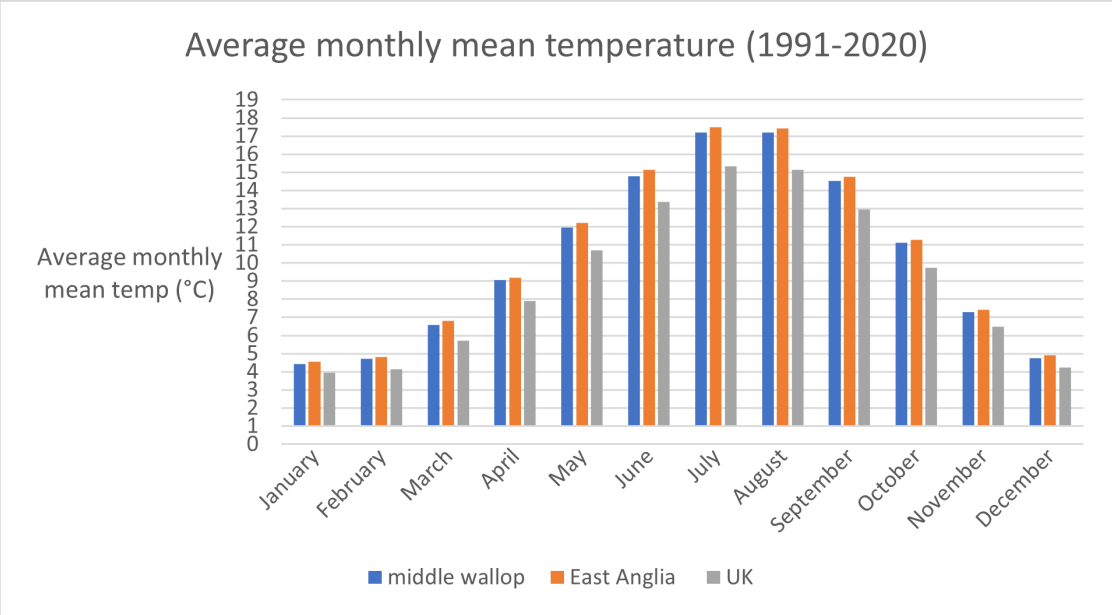
16.4.12 March 2013 – where winds from the east or north, drew bitterly cold air from northern Europe and Siberia (**Ref 16.8**).

16.4.13 December 2010 – There were two spells of snowfall lasting for around a month (**Ref 16.9)**.

Temperature

16.4.14 **Plate 16-2** shows the long-term average mean monthly temperature for the East of England Region and Morley St Botolph Weather station between 1991 and 2020. It shows that the region is warmer than the UK average, though the area within Morley St Botolph Weather station is slightly cooler than the average for the East Anglia region.

Plate 16-2 Long-term Average Mean Monthly Temperature for Morley St Botolph Weather Station and East Anglia, in comparison to the rest of the UK



Extreme Temperature

16.4.15 Mean maximum and minimum temperatures recorded at the Middle Wallop weather station are used to demonstrate extreme temperatures. **Table 16-9** shows the average maximum and minimum summer (June, July and August) and winter (December, January and February) temperatures recorded.

Table 16-9 Summer and Winter Mean maximum Temperature at Middle Wallop weather station, 1991 - 2020

Period	Mean Maximum Temperature (°C)	Mean Minimum Temperature (°C)
Summer	21.3	11.4
Winter	7.4	1.8

16.4.16 The hottest day in the UK on record was experienced during record heatwave conditions in July 2022 with temperatures exceeding 40°C and reaching a record 40.3°C at Coningsby in Lincoln. This led to national disruption to

transport infrastructure with temperatures causing restriction to all public transport (**Ref 16.10**).

16.4.17 The second hottest day in the UK on record was experienced during record heatwave conditions in July 2019 with temperatures widely exceeding 30°C and reaching a record 38.7°C in Cambridge (**Ref 16.11**) (approximately 50 miles south-west of the Proposed Scheme). This led to national disruption to transport infrastructure with temperatures causing traffic lights to fail and vehicles to breakdown (**Ref 16.12**).

Wind

16.4.18 Eastern England is one of the more sheltered parts of the UK, since the windiest areas are to the north and west, closer to the track of Atlantic storms. The strongest winds are associated with the passage of deep depressions across or close to the UK. The frequency of depressions is greatest during the winter months, and this is when the strongest winds normally occur.

16.4.19 A day of gale is defined as a day on which the wind speed attains a mean value of 34 knots or more over any period of 10 minutes. In 2022 alone, the UK has seen three storms with two rare red warnings issued:

16.4.20 Storm Dudley (16 – 17 February 2022)

16.4.21 Storm Eunice (18 February 2022)

16.4.22 Storm Franklin (20 - 21 February 2022)

16.4.23 Other notable gales affecting the east of England include:

16.4.24 March 2019 ‘Storm Gareth’ - The UK experienced a turbulent week of weather in March 2019 as a succession of Atlantic low-pressure systems brought strong winds and heavy rain, driven by a powerful jet stream. Falling on already saturated ground, the persistent wet weather resulted in widespread flooding from rivers during March 2019. This spell included Storm Gareth, the seventh named storm of the 2018/2019 winter. The East of England experienced maximum gusts of 40 to 50Kt (46 to 58 mph) (**Ref 16.13**).

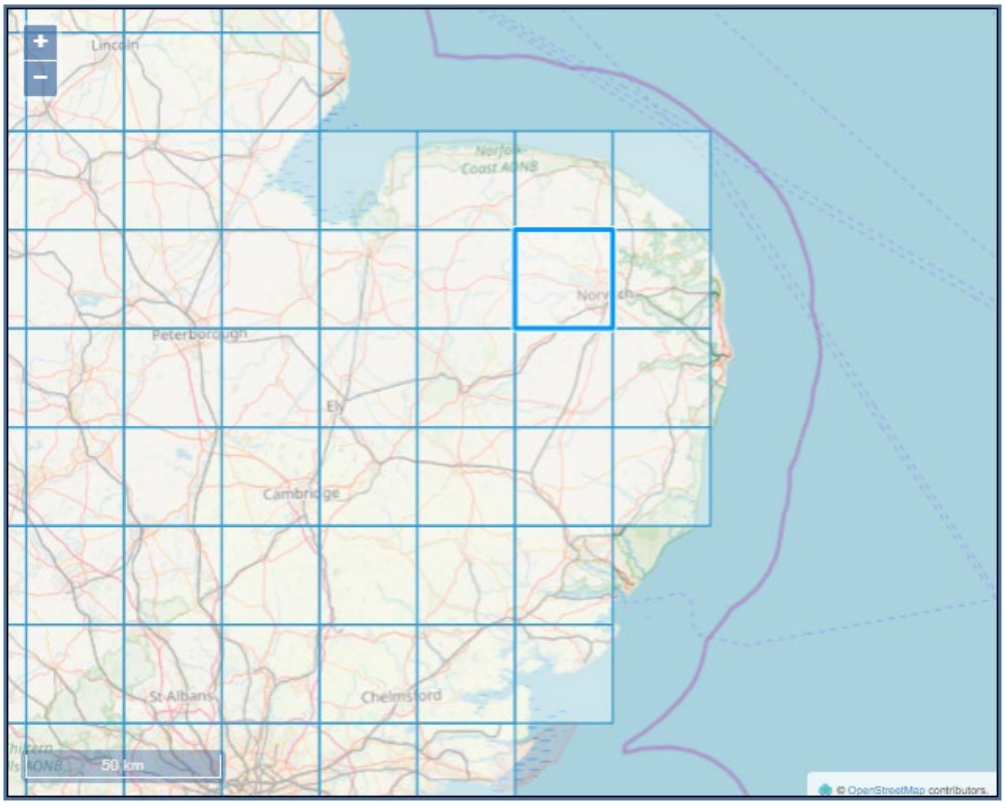
16.4.25 October 2013 – due to a fast-moving, vigorous Atlantic depression, bringing both very strong winds and heavy rain. The East of England experienced maximum gusts around 70 to 80Kt (80 to 92 mph). St Jude Storm winds caused death and destruction to south-east England leaving up to 850,000 homes without electricity (**Ref 16.14**).

Future Baseline

16.4.26 The UK Climate Projections 2018 (UKCP18) (**Ref 16.3**) provide data on projected change in climate variables for the UK.

16.4.27 The UKCP18 breaks the UK down into 25 kilometres grid squares to provide area specific probabilistic projections. Probabilistic projections for the 25 kilometres grid square (612500.00, 312500.00) where the Proposed Scheme is located have been used and is shown in **Plate 16-3**.

Plate 16-3 25km grid square used for the probabilistic projections



16.4.28 The UKCP18 are the most up-to-date projections of climate change for the UK. UKCP18 includes probabilistic projections of a range of climate variables

for different emissions scenarios (termed Representative Concentration Pathway (RCP)) and for a range of future years to the end of the 21st century. The IEMA guidance identifies that "*the recommended approach is to use a high emissions scenario, in the UK this would be RCP 8.5*". RCP8.5 is a high emissions scenario which combines assumptions about high population and relatively slow income growth with modest rates of technological change and energy intensity improvements. The projections for RCP8.5 are presented for the 50th percentile (the 10th and the 90th percentile are provided to give the full range of model uncertainty) against baseline levels of 1981- 2010s.

16.4.29 The future baseline has been presented for the 2020s, 2050s and 2080s to identify the anticipated climate conditions over the life of the Proposed Scheme elements:

16.4.30 Road elements (including carriageway, pavements and roundabout): 20 years;

16.4.31 Bridge elements (including viaduct, overpass and underpass bridges): 120 years;

16.4.32 Ancillary works (including provision for non-motorised users): 20 years; and

16.4.33 End users (road and NMU users): 120 years.

Precipitation

16.4.34 Climate change is projected to lead to wetter winters and drier summers although natural variation, including extreme events such as storms and heat waves, will continue to punctuate these trends. The projected changes to average summer (June, July and August) and winter (December, January and February) rainfall amounts for the 2020s, 2050s and 2080s, based on the RCP8.5 are summarised in **Table 16-10** below.

Table 16-10 Projected Change in Mean Summer and Winter Precipitation (%) for the 2020s, 2050s and 2080s, RCP8.5

Season	Duration years, precipitation change (%) 2020s	Duration years, precipitation change (%) 2050s	Duration years, precipitation change (%) 2080s
Summer	-5.0 (-20 to 9.8)	-17.5 (-41.4 to 5.1)	-34.3 (-60.1 to 4.4)
Winter	2.0 (-4.7 to 9.7)	6.3 (-4.2 to 18.1)	16.1 (-0.7 to 35.9)

16.4.35 The first number depicts the 50th percentile, the numbers in the brackets denote the 10th-90th percentile values to show the range of possible projections.

16.4.36 The central estimate predicts that there will be a decrease in summer rainfall by approximately 17.5% for the 2050s and a further decrease of 34.3% for the 2080s. In contrast, winter precipitation is predicted to increase by 6.3% for the 2050s and 16.1% for the 2080s (central estimate). The climate projection data is modelled on the 1981-2010 baseline where average summer rainfall recorded at the Middle Wallop weather station was 172mm, and winter rainfall was 157mm.

Extreme Precipitation

16.4.37 Climate change means that more rainfall will fall during 'intense' events, particularly in winter. Projections for extreme precipitation are only available at the 2.2 kilometres scale from UKCP18 (**Ref 16.3**) for the time periods of 2021-2040 and 2061-2080. Projections for summer and winter changes in extreme precipitation amounts are presented in **Table 16-11** for the RCP8.5.

Table 16-11 Projected Change in Mean Extreme Summer and Winter Precipitation (%) for the 2030s and 2070s, RCP8.5

Season / Duration years	Precipitation change (%)
Summer 2021-2040	-4%
Summer 2061-2080	-37%
Winter 2021-2040	7%
Winter 2061-2080	25%

Temperature

16.4.38 Climate change is projected to lead to hotter summers and warmer winters. **Table 16-12** summarises the UKCP18 (**Ref 16-3)** projections for changes in mean temperature for the 25 kilometres grid square where the Proposed Scheme is located (**Plate16-3**) in the 2020s, 2050s and 2080s based on the RCP 8.5.

Table 16-12 Projected Change in Mean Summer and Winter Temperature (ºC) for the 2060s and 2080s, RCP8.5

Season	Duration years, temperature change (ºC) 2020s	Duration years, temperature change (ºC) 2050s	Duration years, temperature change (ºC) 2080s
Summer	0.9 (0.3 - 1.8)	2.3 (1.0 - 4.2)	4.5 (2.2 - 7.8)
Winter	0.7 (0.0 - 1.3)	1.7 (0.4 - 2.7)	3.1 (1.1 - 4.8)

16.4.39 The 10th and 90th percentile (in parenthesis) provide the lower and upper estimates of projected warming. For example, for the summer in the 2050s,

temperature increase is very unlikely to be less than a 1.0°C increase, or more than a 4.2°C increase. The central estimate predicts that there will be an increase in summer temperature by approximately 2.3°C for the 2050s and a further increase by 4.5°C for the 2080s. Winter temperature is also predicted to increase by 1.7°C for the 2050s and 3.1°C for the 2080s (central estimate). The climate projection data is modelled on the 1981-2010 baseline where average summer temperature recorded at the Middle Wallop weather station was 16°C, and winter temperature was 4°C.

Extreme Temperature

16.4.40 **Table 16-13** summarises the UKCP18 projections for maximum temperature for summer and winter in the 2020s, 2050s and 2080s in the RCP8.5 emissions scenario. Note, the values below represent mean maximum temperatures therefore, individual days and heatwave events may exceed these values.

Table 16-13 Projected Maximum Summer and Winter Air Temperatures (ºC) for the 2020s, 2050s and 2080s RCP8.5

Season	**Duration years, Maximum air temperature °C 2020s**	**Duration years, Maximum air temperature °C 2050s**	**Duration years, Maximum air temperature °C 2080s**
Summer	32.7	34.2	36.4
Winter	17.4	18.4	19.8

Snow and Ice

16.4.41 Climate Change is likely to result in rising winter temperatures, which are likely to reduce the amount of precipitation that falls as snow in winter. UKCP18 does not have data on snowfall, although the earlier UKCP09 projections show a reduction of mean snowfall, the number of days when

snow falls and heavy snow events by the end of the 21st century. UKCP09 does not provide projections for the nearer term for snow. While there is less certainty in the magnitude of projected change, there is confidence in the negative sign of the change (i.e. snow fall is generally expected to decrease compared with the baseline **(Ref 16.16)**). Projections indicate substantial reductions in snowfall days for all regions in winter (**Ref 16.17).**

Wind

16.4.42 UKCP18 depicts 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 (**Ref 16.18**). It is therefore difficult to represent regional wind extreme winds and gusts within regional climate models (**Ref 16.19**).

16.4.43 Central estimates of change in mean wind speed for the 2060s are low (<0.2ms-1). A wind speed of 0.2ms−1 (approximately 0.4 knots) is small compared with the typical magnitude of summer mean wind speed of about 3.6–5.1ms-1 (7–10 knots) over much of England (**Ref 16.20**). Seasonal changes at individual locations across the UK lie within the range of –15% to +10% differences in wind speeds.

16.4.44 With regards to storms, the analysis presented here is a summary of expected changes in storm patterns under a changing climate. 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 24.5m/s or 55mph).

16.4.45 Thunderstorms are most likely to occur from May to September, reaching their peak in July and August, but are less frequent than in areas further south, and the north of the region can expect only five to eight days with thunder each year. The heaviest rainfall events in the UK are often associated with these summer thunderstorms.

16.4.46 With regard to future projections of storms, studies suggest that climate-driven storm changes are less distinct in the Northern than the Southern Hemisphere (**Ref 16.21**). 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.

Solar Radiation

16.4.47 A recent (regional) study (**Ref 16-22**) suggests that the East of England is likely to see an increase in annual solar radiation by the 2060s of 5.1 watts per square metre (Wm-2) and by the 2080s of 6.5Wm-2 (central estimate), under RCP8.5.

16.4.48 As a result of increasing temperatures, higher summer temperatures may increase exposure to ultraviolet radiation, if the higher temperatures lead to a decrease in cloud coverage. During winter months there is likely to be an increase in cloud cover in winter leading to more rainfall and wetter winters.

16.4.49 National Highways' guidance section 2.5.2 (**Ref 16.23**) highlights the following:

"*Climate projections suggest that the UK is likely to receive more solar radiation and less cloud cover, and therefore more UV radiation, due to climate change, particularly during summer*".

16.5 Sensitive Receptors

16.5.1 The following sensitive receptors have been assessed for the construction and operation phases of the assessment.

Construction

- Construction site (site compound, plant and equipment; and materials); and
- Construction workers.

Operation

- Road components (including carriageway, pavements and roundabout);

- Structural components (including viaduct, overpass and underpass bridges);
- Ancillary works (including provision for non-motorised users and signage);
- Drainage;
- Landscaping and vegetation and other environmental mitigation; and
- End users (road users).

16.6 Assessment of Potential Effects, Mitigation and Residual Effects

16.6.1 The assessment of effects takes into account mitigation embedded in the Proposed Scheme's design that has been discussed with the design team and Principal Contractor. The embedded mitigation identified has been used to inform the assessment of potential significant effects. Where this assessment has identified significant effects, additional mitigation has been identified to reduce the potential for significant effects. The residual effects following implementation of the additional mitigation have been reported on.

Construction embedded mitigation

16.6.2 For the construction phase assessment, mitigation measures included in **Appendix 3.1 Outline Construction Environment Management Plan (OCEMP)** (Document Reference: 3.03.01) are considered embedded measures and have been taken into account when assessing potential effects.

Operation embedded mitigation

16.6.3 For each of the climate variables and effects identified for further assessment (**Table 16-3**), **Table 16-14** sets out the corresponding embedded mitigation measures in the design which consider climate resilience during the operation of the Proposed Scheme. The assessment in **Table 16-14** considers the embedded mitigation in the design as outlined. As part of an iterative assessment process, where significant effects are identified, additional

mitigation has been identified and the residual effects report later in this assessment.

16.6.4 For the operation phase assessment, mitigation measures included in **Appendix 3.10.32 Ecological Mitigation Strategy** (Document Reference: 3.10.32) are considered embedded measures and have been taken into account when assessing potential effects.

Table 16-14 Embedded mitigation in the Proposed Scheme design during operation

Climate Variable	Associated climate effect	Potential and effects	Receptor affected	Embedded mitigation
Precipitation	Changes in annual average Extreme precipitation events	Increase in volume of water from the River Wensum leading to flooding Flooding of the carriageway Drainage infrastructure overwhelmed leading to surface water flooding	Road components (including carriageway, pavement, roundabout) Drainage Landscape and vegetation Earthworks End users	The drainage design (detailed in **Appendix 4.4 Drainage Strategy Report** (Document Reference: 4.04.00)), includes Sustainable Drainage Systems (SuDS) for attenuating / infiltrating the surface water runoff during operation. The SuDS systems are designed to attenuate / infiltrate highway drainage from the 1 in 2-year event to the 1 in 100-year rainfall event with a 40% allowance for climate change. The drainage system is designed to attenuate/infiltrate highway drainage from the 1 in 2-year event to the 1 in 100-year rainfall event with a 45% allowance for climate change. Following flooding events or heavy rainfall, debris removal and channel clearing would be carried out. This would be the responsibility of the principal contractor during construction and Norfolk County Council during operation.

Climate Variable	Associated climate effect	Potential and effects	Receptor affected	Embedded mitigation
Precipitation	Changes in annual average Extreme precipitation events	Waterlogging and erosion leading to destabilisation Soil erosion from precipitation leading to destabilisation Greater mobilisation of pollutants in soil / ground causing premature deterioration of materials	Road components (including carriageway, pavement, roundabout) Earthworks Structures	The geotechnical specialist will undertake an analysis (include conservative parameters) to model both waterlogging of earthworks and where applicable shallow slope failures. Embankments would be topsoiled and seeded as required which improves soil stability and resists erosion. **Appendix 10.32 Ecological Mitigation Strategy** (Document reference 3.10.32) confirms that a Landscape and Ecological Management Plan (LEMP) will be produced by the Contractor, and will ensure correct planting and sowing seasons, correct soil conditions for species and habitats, sufficient spacing of trees and viabilities of trees, bulbs and grassland. **Appendix 10.32 Ecological Mitigation Strategy** (Document Reference: 3.10.32), also makes reference to limiting bare soil, increasing soil fertility and seeding which will maintain stability and avoid soil erosion. Wensum Viaduct pier columns are founded on piles, located in the floodplain. **Appendix 12.2 Flood Risk Assessment** (Document Reference 3.12.02) modelling includes a 100yr +44% climate chance upper allowance modelled on the 2080s projections in line with the climate scenarios in section 14.3. River Tud tributary culvert to have scour protection aprons in front of the wingwalls. Retaining walls to be backfilled with free draining fill. Back of wall drainage to be provided.

Climate Variable	Associated climate effect	Potential and effects	Receptor affected	Embedded mitigation
Precipitation	Changes in annual average Extreme precipitation events	Damage to structures due to increased runoff Scour of embankments leading to increased maintenance Increased precipitation resulting in flooding of the NMU routes and Wensum Viaduct.	Structures (including viaduct, overpass and underpass bridges) Earthworks Ancillary works	If there is a risk of erosion to an embankment, the embankment slopes will be strengthened with a granular fill together with a geotextile separator. Ground investigation works will be complete prior to construction to inform suitable design and construction. Flood risk to the Proposed Scheme is detailed in **Appendix 12.2 Flood Risk Assessment** (Document Reference 3.12.02) and will be incorporated into the design. All bridge deck runoff water is to be intercepted by a deck drainage system or by the highway drainage system for short / medium span structures, such as Greenbridges and Ringland Lane Underbridge.

Climate Variable	Associated climate effect	Potential and effects	Receptor affected	Embedded mitigation
Precipitation	Changes in annual average Extreme precipitation events	Loss of vegetation due to extreme rainfall or flooding	Landscaping and vegetation and other environmental mitigation	**Appendix 10.32 Ecological Mitigation Strategy** (Document Reference: 3.10.32), confirms that a Landscape and Ecological Management Plan (LEMP) will be produced by the Contractor, and will ensure correct planting and sowing seasons, correct soil conditions for species and habitats, sufficient spacing of trees and viabilities of trees, bulbs and grassland. **Appendix 10.32 Ecological Mitigation Strategy** (Document Reference: 3.10.32), also makes reference to limiting bare soil, increasing soil fertility and seeding which will maintain stability and avoid soil erosion. Species to be planted in locations where full size would not cause a safety issue. Development of a management plan to include pruning where required e.g. near structures or carriageway. Planting mixes and densities will be considered across site to respond to longer growing season. DMRB LD117 provides guidance on planting distances from carriageway edge, these are to be adhered to as a minimum to ensure planting does not encroach on visibility sight lines for drivers.
Precipitation	Changes in annual average Extreme precipitation events	Electrical failure caused by flooding	Ancillary works (including provision for non-motorised users and signage)	The carriageway is not expected to be illuminated and therefore no cabling is anticipated beyond the connection to the short stretch of illuminated road on the approach to the A47 roundabout. Therefore the risk is mitigated.

Climate Variable	Associated climate effect	Potential and effects	Receptor affected	Embedded mitigation
Precipitation	Changes in annual average Extreme precipitation events	Difficult driving conditions and risk of aquaplaning	End users	The drainage strategy includes measures to significantly reduce the amount of standing water on the road including SuDS measures and a deck drainage system and the highway drainage system to intercept run-off.
Temperature	Extreme temperature events	Increase in thermal expansion of bridge joints	Structures (including viaduct, overpass and underpass bridges)	Thermal expansion and contraction has been considered in accordance with approach 2 of BS EN 1991-1-5 as modified by the National Annex. The appropriate standard in design has been met to accommodate thermal expansion. Proprietary bearings and expansion joints are used to accommodate thermal movements on the Wensum Viaduct. In accordance with CD 350, structures would be made integral where possible. Greenbridges and the Ringland Lane Underbridge are to be designed as integral structures, without bearings and expansion joints. This is because the thermal action can be accommodated by flexure of the structure (Greenbridges) and sliding of the superstructure (Ringland Lane Underbridge). Earth pressure behind integral abutments and bankseats will be considered as per PD 6694-1:2011. The design of the structures aligns with the relevant Eurocodes and associated UK National Annexes, as well as being in accordance with the Design Manual for Roads and Bridges.

Climate Variable	Associated climate effect	Potential and effects	Receptor affected	Embedded mitigation
Temperature	Extreme temperature events	Loss of vegetation cover due to scorching leading to destabilisation	Earthworks Landscaping and vegetation and other environmental mitigation	Earthworks embankments and cuttings would be graded at between 1 in 2 and 1 in 3. These embankments would be topsoiled and seeded as required. **Appendix 10.32 Ecological Mitigation Strategy** (Document Reference: 3.10.32), confirms that a Landscape and Ecological Management Plan (LEMP) will be produced by the Contractor, and will ensure correct planting and sowing seasons, correct soil conditions for species and habitats, sufficient spacing of trees and viabilities of trees, bulbs and grassland. Use of a variety of species within planting mixes and groups will reduce vulnerability to extreme events / enable quicker recovery.

Climate Variable	Associated climate effect	Potential and effects	Receptor affected	Embedded mitigation
Temperature	Extreme temperature events	Longer growing season, more vigorous vegetation growth in spring and autumn	Landscaping and vegetation and other environmental mitigation	**Appendix 10.32 Ecological Mitigation Strategy** (Document Reference: 3.10.32) confirms that a Landscape and Ecological Management Plan (LEMP) will be produced by the Contractor. Maintenance activities include timely cutting of grass and pruning activities. Use of diverse mix of plant species in groups at suitable density that species competition reduces excessive growth. Species to be planted in locations where full size would not cause a safety issue. Development of a management plan to include pruning where required e.g. near structures or carriageway. Planting mixes and densities will be considered across site to respond to longer growing season. DMRB LD117 provides guidance on planting distances from carriageway edge, these are to be adhered to as a minimum to ensure planting does not encroach on visibility sight lines for drivers.
Temperature	Extreme temperature events	Overheating of electronic equipment and fire Faster rate of deterioration of materials from increase in UV radiation e.g. fading, brittleness	Ancillary works (including provision for non-motorised users and signage)	Civil Structures are not prone to such risks. Their design life is 120 years and durability requirements of construction materials are set accordingly.

Climate Variable	Associated climate effect	Potential and effects	Receptor affected	Embedded mitigation
Wind	Gales and extreme wind events	Increase in wind loading on bridges Damage from high winds and rain-infiltration into surfaces and materials	Structures (including viaduct, overpass and underpass bridges)	The wind forces on the bridges will be in accordance with the Clauses 8.2 and 8.3 of BS EN 1991-1-4 and the associated National Annex (National Annex). Provisions within PD6688-1-4 shall be applied as required by the National Annex. All bridge deck runoff water is to be intercepted by a deck drainage system or by the highway drainage system for short / medium span structures, such as Greenbridges and Ringland Lane Underbridge.
Wind	Gales and extreme wind events	Windborne dust and debris clogging drainage channels and requiring clearing	Drainage	Land drains designed with a conservative Mannings coefficient (The Mannings coefficient represents the roughness / friction applied to the flow by the channel) to take into consideration some debris collection. Operations & Maintenance Manual to be produced as part of Health and Safety File.

Climate Variable	Associated climate effect	Potential and effects	Receptor affected	Embedded mitigation
Wind	Gales and extreme wind events	Trees blown down and increase in debris on the carriageway	End users	Tree and shrubs would be planted in groups to reduce vulnerability to wind. Existing trees vulnerable to exposure with shallow roots will be removed. Development of a management plan to ensure trees are pruned where required to increase stability. Trees would be planted at suitable offset to carriageway to reduce risk if appropriate. Planting mix specification will be considered across site to withstand gales and extreme wind events where possible. DMRB LD117 provides guidance on planting distances from carriageway edge, these are to be adhered to as a minimum to ensure planting does not encroach on visibility sight lines for drivers. **Appendix 10.32 Ecological Mitigation Strategy** (Document Reference: 3.10.32) confirms that a Landscape and Ecological Management Plan (LEMP) will be produced by the Contractor. Maintenance activities include pruning activities.
Wind	Gales and extreme wind events	Poor visibility	End users	Remove or reduce any visibility departures and relaxations as far as reasonably practical. A road safety audit has been undertaken for the Proposed Scheme. Operations & Maintenance Manual to be produced as part of Health and Safety File.

Climate Variable	Associated climate effect	Potential and effects	Receptor affected	Embedded mitigation
Water quality and soils	Soil moisture	Shrinking and cracking of soils Subsidence	Earthworks	Given poor ground quality, piled foundations are likely to be relatively deep and therefore unaffected by drying to surface soils. Slope stability assessments would include asset specific analysis and an accompanying geotechnical risk register would ensure all associated risks are communicated and suitably mitigated. Embankments would be topsoiled and seeded as required. Native tree and shrub species would be planted to encourage species to withstand changes in climate conditions and deal with a range of climatic conditions. Use of variety of species within planting mixes and groups to reduce vulnerability to extreme events / enable quicker recovery and provide some slope integrity with a properly developed root system. Planting mix specification will be considered across site to withstand more extreme climate conditions. Where appropriate species selected for root systems to aid in binding slope.

Construction effects

16.6.5 **Table 16-15** utilises the methodology as identified in section 16.3 and shows the potential impacts and effects from climate change on the construction of the Proposed Scheme. The assessment takes into account the narrative provided earlier in section 16.5 around embedded mitigation within the construction phase but does not include any additional mitigation.

Table 16-15 Assessment of potential effects during construction without additional mitigation

Receptor	Potential impacts and effects	Likelihood	Consequence	Significance
Site compound	Flooding of site resulting in damage to site compound	Low	Minor adverse	*Not Significant*
Site compound	Overwhelming of drainage system preventing construction works	Low	Minor adverse	*Not Significant*
Site compound	Waterlogging of site and excavations preventing works	Low	Minor adverse	*Not Significant*

Receptor	Potential impacts and effects	Likelihood	Consequence	Significance
Site compound	Increased surface runoff leading to surface water flooding and siltation	Low	Minor adverse	*Not Significant*
Materials	Increased runoff from material piles	Medium	Minor adverse	*Not Significant*
Materials	Excessive moisture in materials	Medium	Minor adverse	*Not Significant*
Materials	Destabilisation of material, including topsoil and spoil heaps	Low	Minor adverse	*Not Significant*
Materials	Deformation and melting of materials	Low	Moderate adverse	*Not Significant*
Materials	Shorter drying times in summer	Medium	Minor adverse	*Not Significant*

Receptor	Potential impacts and effects	Likelihood	Consequence	Significance
Materials	Enhanced reactions when cement stabilising and drying of concrete	Medium	Minor adverse	*Not Significant*
Materials	Drying out of materials	Medium	Minor adverse	*Not Significant*
Plant and equipment	Overheating of machinery	Medium	Minor adverse	*Not Significant*
Plant and equipment	Plant and equipment failure or disruption	Low	Minor adverse	*Not Significant*
Workforce	Increase in dust	Medium	Minor adverse	*Not Significant*
Workforce	Unsafe working conditions (heatstroke, UV levels)	Medium	Minor adverse	*Not Significant*
Workforce	Unsafe working conditions at height	Low	Moderate adverse	*Not Significant*

Operation effects

16.6.6 Utilising the methodology as identified in section 16.3 and taking into account the embedded mitigation identified in **Table 16-14**, **Table 16-16** shows the potential impacts and effects from climate change on the operation of the Proposed Scheme prior to additional mitigation.

Table 16-16 Assessment of potential effects during operation without additional mitigation

Receptor	Potential impacts and effects	Likelihood	Consequence	Significance
Road	Flooding of the carriageway	High	Minor adverse	*Not significant*
Road	Greater mobilisation of pollutants in soil / ground causing premature deterioration of materials	Medium	Minor adverse	*Not significant*
Road	Deformation and melting of paved surfaces	Medium	Moderate adverse	**Significant**
Bridges	Damage to structures due to increased run-off	High	Minor adverse	*Not significant*
Bridges	Increase in thermal expansion of bridge joints	High	Minor adverse	*Not significant*
Bridges	Increase in wind loading on bridges	Medium	Minor adverse	*Not significant*
Bridges	Damage from high winds and rain infiltration into surfaces and materials	Medium	Minor adverse	*Not significant*
Drainage	Drainage infrastructure overwhelmed leading to surface water flooding	High	Minor adverse	*Not significant*
Drainage	Windborne dust and debris clogging drainage channels and requiring clearing	Medium	Minor adverse	*Not significant*
Landscaping and vegetation	Longer growing season, more vigorous vegetation growth in spring and autumn due to increased temperatures	Medium	Minor adverse	*Not significant*

Receptor	Potential impacts and effects	Likelihood	Consequence	Significance
Landscaping and vegetation	Loss of vegetation cover due to scorching leading to destabilisation	Medium	Minor adverse	*Not significant*
Ancillary equipment	Overheating of electronic equipment and fire	Medium	Minor adverse	*Not significant*
Ancillary equipment	Faster rate of deterioration of materials from increase in UV radiation e.g. fading, brittleness	Medium	Minor adverse	*Not significant*
Ancillary equipment	Electrical failure caused by flooding	Medium	Minor adverse	*Not significant*
Ancillary equipment	Increased precipitation resulting in flooding of the NMU routes	Medium	Minor	*Not significant*
Earthworks & embankments	Waterlogging and erosion leading to destabilisation	Medium	Minor adverse	*Not significant*
Earthworks & embankments	Scour of embankments leading to increased maintenance	Medium	Minor adverse	*Not significant*
Earthworks & embankments	Soil erosion leading to destabilisation	Medium	Minor adverse	*Not significant*
Earthworks & embankments	Shrinking and cracking of soils	Medium	Minor adverse	*Not significant*
Earthworks & embankments	Subsidence	Medium	Minor adverse	*Not significant*
End users	Increase in water volume from the River Wensum leading to flooding	Medium	Minor adverse	*Not significant*
End users	Difficult driving conditions and risk of aquaplaning	High	Moderate adverse	**Significant**
End users	Trees blown down, increase in debris on road	Medium	Minor adverse	*Not significant*
End users	Poor visibility	Medium	Minor adverse	*Not significant*

Additional Mitigation and Enhancement

16.6.7 This section sets out the additional mitigation measures which are likely to be required to address the significant effects as identified in **Table 16-16** above. No significant effects were identified for the construction phase, and therefore, no additional mitigation is required.

Operation Phase

Table 16-17 Additional mitigation required in the Operation phase of the Proposed Scheme

Climate Hazard	Associated Hazard	Potential impact and effect	Receptor Affected	Additional Mitigation Recommendations
Temperature	**Extreme temperature events**	**Deformation and melting of paved surfaces**	**Road components**	**Pavement surface courses should be composed of materials which offer greater flexibility of extreme temperature ranges.**
Precipitation	Extreme precipitation events	**Difficult driving conditions and risk of aquaplaning**	End users	There is adequate drainage to ensure the risk of aquaplaning will be reduced. This will also work to mitigate difficult driving conditions (i.e visual impairment) via reducing spray from tyres. The surrounding proposed vegetation may act as a barrier for large storm events.

16.7 Residual Effects

Operation

Table 16-18 Assessment of residual effects during operation

Receptor	Potential impacts and effects	Likelihood	Consequence	Significance
Road components	Deformation and melting of paved surfaces	Low	Minor adverse	*Not significant*
End users	Difficult driving conditions and risk of aquaplaning	High	Minor adverse	*Not significant*

16.7.1 There are no residual significant effects expected for operation with the additional mitigation described above being implemented.

Monitoring

16.7.2 Given the uncertainties inherent in climate science and projections, the impacts and effects identified should be monitored throughout the construction and operational phase. The monitoring would be undertaken by the Applicant to assess the appropriateness of the mitigation measures.

16.7.3 A schedule of general inspections and principal inspections of each structure should be carried out by the Applicant during their road maintenance regimes and under their bridge works programme to determine condition of the structure and identify any potential maintenance requirements. Inspections would be in accordance with DMRB CS 450 (**Ref. 16.1**) and would also occur following an intense climatic event such as a high rainfall event or heatwave to monitor any damage and implement appropriate mitigation as necessary.

16.7.4 In addition, extreme weather-related incidents (for example, road surface deformations from temperature, heavy rainfall, snow and ice, etc.) would be monitored by NCC as County Highway Authority to assist in identifying thresholds which, when exceeded, require maintenance.

Cumulative Effects

16.7.5 The climate resilience assessment looks at the potential impacts of environmental change on the Proposed Scheme, rather than impacts of the Proposed Scheme on the environment: the receptor for the resilience assessment is the Proposed Scheme.

16.7.6 An assessment of intra-project combined effects and inter-project cumulative effects for the Proposed Scheme has been carried out and is presented in ES **Chapter 21: Cumulative Effects** (Document Reference: 3.21.00).

16.7.7 From a climate resilience perspective another scheme could not increase the vulnerability of the Proposed Scheme to climate change directly. However, if there are multiple developments within a region which reduce green infrastructure to absorb increased runoff during extreme precipitation events, this may result in adverse cumulative effects. However in this instance **Appendix 12.2 Flood Risk Assessment** (Document reference: 3.12.02) considers the cumulative effects of other developments where relevant.

In-combination climate change impacts

16.7.8 In-combination climate change impacts is the potential that climate change will exacerbate or ameliorate the potential effects identified within each of the environmental topics.

16.7.9 Individual environmental topics have carried out and reported on, where appropriate, in-combination assessments which consider the extent to which Climate Change may alter the effects that have been identified during the EIA. Refer to individual topic Chapters:

- **Chapter 6: Air Quality** (Document Reference: 3.06.00)
- **Chapter 7: Noise and Vibration** (Document Reference: 3.07.00)

- **Chapter 8: Cultural Heritage** (Document Reference: 3.08.00)
- **Chapter 9: Landscape and Visual Effects** (Document Reference: 3.09.00)
- **Chapter 10: Biodiversity** (Document Reference: 3.10.00)
- **Chapter 11: Bats** (Document Reference: 3.11.00)
- **Chapter 12: Road Drainage and Water Environment** (Document Reference: 3.12.00)
- **Chapter 13: Geology and Soils** (Document Reference: 3.13.00)
- **Chapter 14: Material Assets and Waste** (Document Reference: 3.14.00)
- **Chapter 15: Climate Greenhouse Gases** (Document Reference: 3.15.00)
- **Chapter 17: Population & Human Health** (Document Reference: 3.17.00)
- **Chapter 18: Major Accidents and Disasters** (Document Reference: 3.18.00
- **Chapter 19: Traffic and Transport** (Document Reference: 3.19.00)
- **Chapter 20: Cumulative Effects** (Document Reference: 3.20.00)

16.8 Opportunities for Environmental Enhancement

16.8.1 There are no opportunities for enhancement measures for climate resilience.

16.9 Difficulties and Uncertainties

16.9.1 As part of the assessment the following limitations and assumptions have been identified:

16.9.2 There is currently no agreed methodology that should be applied for assessing the vulnerability of major schemes, including road infrastructure,

under the EIA regulations. Therefore, an approach has been developed and applied in this assessment based on existing best practice.

16.9.3 The UKCP18 projections have been used to identify future changes in a range of climate variables that may affect the vulnerability of the Proposed Scheme to climate change. At the time of writing, these represent the most up-to-date representation of future climate in the UK and the east of England. However, the UKCP18 data currently available does not provide data for drought, snow and ice or wind.

16.9.4 There are inherent uncertainties associated with climate projections. As they are projections, they cannot be considered as predictions of the future. It is possible that future climate will differ from the future baseline climate against which the resilience of the Proposed Scheme has been assessed, depending on global emissions over the next century. A 'high' emissions scenario (RCP 8.5) using the 2080s duration years (2070 – 2099 - the longest temporal scale available through UKCP18) has been used to develop the baseline against which resilience has been assessed. This is consistent with the precautionary principle (i.e. 'worst case' scenario).

16.9.5 Any further research, analysis or decision-making should take account of the accuracies and uncertainties associated with climate projections. It is also important to note that the analysis is based on selected observational data, the results of climate model ensembles and a selected range of existing climate change research and literature available at the time of assessment. Any future decision-making based on this analysis should consider the range of literature, evidence and research available at that time and any changes to this.

16.10 Summary

16.10.1 **Table 16-22** provides a summary of the findings of the assessment.

Table 16-19 Summary of climate resilience effects - operational phase

Key to table:

P / T = Permanent or Temporary, D / I = Direct or Indirect, ST / MT / LT = Short Term, Medium Term or Long Term, N/A = Not Applicable

Receptor	Potential Effects	Additional Mitigation	Residual Effects	Monitoring
Road	**Deformation and melting of paved surfaces**	**Pavement surface courses should be composed of materials which offer greater flexibility of extreme temperature ranges.**	Low likelihood / Minor adverse consequence *(Not significant)* **P / I / LT**	**n/a**
End users	Difficult driving conditions and risk of aquaplaning	Adequate drainage will reduce aquaplaning via reducing spray from tyres. Road lighting should be maintained for visuality.	High likelihood / Minor Adverse consequence (*Not significant*) P / I / LT	Norfolk County Council during operation have a channel to be notified of disruptions from weather on the road (storm events leading to debris needing clearing etc). The road lighting will also be monitored for maintenance.

16.11 References

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