Great Yarmouth Third River Crossing

Application for Development Consent Order

Document 6.2: Environmental Statement Volume II: Technical Appendix 13B: Vulnerability Assessment

Planning Act 2008

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

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1 Vulnerability Assessment

1.1 Vulnerability Assessment Findings

1.1.1 The assessment of the vulnerability of the Scheme to the impacts of climate change has been informed by regional scale information on historic and projected change in climate variables. The vulnerability of the Scheme to climate change has been assessed against the UK Climate Projections 2018 (Ref 1.10) (UKCP18) for the 2080s for the East of England region for a high emissions ('worst-case') scenario (termed Representative Concentration pathway (RCP) 8.5).

1.1.2 In line with published guidance (primarily IEMA (2015), Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation (Ref 1.13) and European Commission (2016), Climate Change and Major Projects (Ref 1.14), the assessment of climate vulnerability and risk in the EIA process consists of five steps:

- **Step 1**: Identify receptors and analyse policy context;
- **Step 2**: Climate vulnerability assessment;
- **Step 3**: Risk assessment;
- **Step 4**: Adaptation measures and
- **Step 5:** Determination of significance.

1.1.3 This Appendix presents the detailed assessment and findings of Step 1 (identify receptors) and Step 2 climate vulnerability assessment. The analysis of policy context element (review of relent legislation and policy) of Step 1 is presented in Appendix 13A. The assessment methodology for the assessment can be found in Chapter 13: Climate Change (document reference 6.1), Section 13.6.

Step 1: Identify Receptors and Analyse Policy Context

1.1.4 During this stage, relevant receptors which may be affected by climate change are identified, whilst considering the impact of extreme weather and changes in climate on the Scheme over its lifetime. These receptors may comprise both known (i.e. receptors affected by historic weather events) and unknown (new) receptors. This stage includes a definition of the policy context (presented in Appendix 13A).

Step 2: Climate Vulnerability Assessment

1.1.5 This stage comprises an assessment of the vulnerability of the receptors identified in Step 1 to projected climate change and extreme weather variables. The vulnerability of a receptor to extreme weather and climate change is a function of:

- The typical **sensitivity** of the receptor to climate variables – based on literature review and professional judgement from knowledge of similar schemes; and
- The **exposure** of the receptor to projected change in climate variables, based on information on observed climate and projected climate. UKCP18 provides probabilistic projections of future climate for a range of emissions scenarios. However, future GHG emissions and the resultant effects on climate is uncertain. As such, a precautionary approach has been adopted by selecting the High emissions ('worst-case') scenarios for the longest term timeslice (2080s), which offer the longest-term projections into the Scheme timescale.

1.1.6 For each element of the vulnerability assessment (i.e. sensitivity and exposure), a category is assigned to each climate variable relative to each receptor based on the following scale:

- High: High climate sensitivity or exposure;
- Medium: Moderate climate sensitivity or exposure; and
- Low: No significant climate sensitivity or exposure.

1.1.7 This is a qualitative assessment informed by expert opinion and supporting literature.

1.1.8 The vulnerability of receptors to climate variables is determined from the combination of the sensitivity and exposure categorisation, using the matrix shown in Table 1.1. At this point 'Low' vulnerabilities are scoped out of further assessment, whilst 'High' and 'Medium' vulnerabilities are taken forward to Steps 3 and 4.

Table 1.1: Vulnerability Rating

Sensitivity	Exposure		
	Low	Medium	High
Low	Low Vulnerability	Low Vulnerability	Low Vulnerability
Medium	Low Vulnerability	Medium Vulnerability	Medium Vulnerability
High	Low Vulnerability	Medium Vulnerability	High Vulnerability

Step 1: Identify Receptors

1.1.9 Receptors associated with the Scheme are as follows:

- Dual carriageway road;
- Double-leaf bascule bridge and associated substructure and knuckle walls (design life 120 years);
- Five-arm roundabout;
- Single span bridge over Southtown Road;
- Reinforced earth embankments;
- Signalised junction;
- Cycle and pedestrian provision; and
- Signage.

1.1.10 The Scheme receptors are summarised below in terms of key Scheme elements. The terms 'road', 'bridge' and 'cycle and footway' are used throughout this Appendix, Chapter 13: Climate Change (document reference 6.1) and Appendix 13C:

- The 'road' including the new dual carriageway road, five-arm roundabout signalised junction junctions and reinforced earth embankments;
- 'Bridges' including the new double-leaf bascule bridge and associated substructure and 'knuckle' walls and associated control tower, plant room control equipment, and single span bridge over Southtown Road; and
- The 'cycle and footway' comprising the cycle and pedestrian provision.

Step 2: Climate Vulnerability Assessment

Sensitivity

1.1.11 Based on relevant guidance (Ref 1.1) and professional judgement, the climate variables which the Scheme elements are typically vulnerable to are shown in Table 1.2. Australian guidance (Ref 1.1) is used in lieu of any UK guidance to assess the vulnerability Scheme elements.

1.1.12 'Crossed' grey shaded cells in the table indicate where the climate variable or climate-related hazard is not relevant to the Scheme elements; these climate variables and climate-related hazards have then been excluded from the forthcoming analyses. Further justification is provided in Table 1.3.

Table 1.2: Climate Variables and Climate Related Hazards: Transport

Scheme Element	Variable: Sea				Precipitation			Temperature			Wind		Relative Humidity		Soils			
	Sea level rise	Storm surge and storm tide	Surface temperature	Currents and waves	Change in annual average	Drought	Extreme precipitation events (flooding)	Changes in annual average	Extreme temperature events	Solar radiation	Gales and extreme wind events	Storms (snow, lightning, hail)	Changes in annual average	Evaporation	Soil moisture	Salinity/pH	Runoff	Soil stability
Roads	✓	✓	X	X	✓	✓	✓	X	✓	✓	✓	✓	X	X	✓	✓	✓	✓
Bridges	✓	✓	X	X	X	X	✓	X	✓	✓	✓	✓	X	X	X	✓	X	✓
Cycle and footway	✓	✓	X	X	✓	✓	✓	X	✓	✓	✓	✓	X	X	✓	✓	✓	✓

Table 1.3: Justification for Excluding Climate Variables from Further Analysis

Scheme Element	Climate Variables Excluded from Further Analysis	Justification
Roads, cycle and footway	Sea surface temperature	The roads, cycle and footway elements are sensitive to the presence of water (flooding) rather than water temperature.
	Currents and waves	The main sensitivity of the road, cycle and footway elements is flooding which is picked up through the sea level rise and storm surge variables.
	Changes in annual average temperature	The road, cycle and footway elements are sensitive to extreme temperatures (heatwaves) but not highly sensitive to long term changes in average temperatures.
	Changes in annual average relative humidity	Evaporation has little direct effect on the road, cycle and footway elements
	Evaporation	Evaporation has little direct effect on the road, cycle and footway element
Bridges	Sea surface temperature	Bridges are sensitive to the presence of water (flooding) rather than water temperature
	Currents and waves	The main sensitivity of the bridge element is flooding which is picked up through the sea level rise and storm surge variables.
	Changes in annual average rainfall	Bridges are sensitive to extreme precipitation events but not highly sensitive to long term changes in average precipitation.
	Drought	Bridges are not directly affected by dry conditions. Effects of dry conditions on soil stability which may affect bridges is picked up through the soil stability variable.
	Changes in annual average temperature	Bridges are sensitive to extreme temperatures (heatwaves) but not

Scheme Element	Climate Variables Excluded from Further Analysis	Justification
		highly sensitive to long term changes in average temperatures.
	Changes in annual average relative humidity	Humidity levels have little direct effect on bridges
	Evaporation	Evaporation has little direct effect on bridges
	Soil moisture	Effects of changes to soil stability on bridges is picked up through the soil stability variable.
	Runoff	The bridge element is not thought to be sensitive to changes in soil runoff.

Sea

1.1.13 Road, cycle and footways and bridges located near the coast or in estuarine locations is sensitive to changes in sea level and storm surges. An increase in sea level or increased storm surges could lead to coastal flooding which could cause damage to roads, cycle and footways, bridges and associated structures (e.g. earthworks, control buildings and equipment). Coastal flooding could lead to temporary closure of roads, cycle and footways and bridges as well as deterioration of materials.

Precipitation

1.1.14 Roads, cycle and footways and bridges are sensitive to high rainfall. An average increase in winter rainfall may cause roads, cycle and footways to become flooded due to flooding of local watercourses (fluvial flooding) or surface water flooding (pluvial flooding). Flooding may mean that roads, cycle and footways are impassable. Flooding may also cause damage to paved surfaces (leading to increased maintenance requirements). Roads, bridges, cycle and footways are also sensitive to extreme rainfall events which, in addition to flooding, may also lead to destabilisation of soils and earthworks, potentially leading to temporary or permanent loss of amenity. Any electronic control equipment associated with the bridge will also be sensitive to flooding.

1.1.15 Roads, cycle and footways are also sensitive to low rainfall or drought. Prolonged dry periods may lead to drying out and cracking of earthworks and soils.

Temperature

1.1.16 Roads, bridges, cycle and footways are sensitive to extreme temperatures. High temperatures may cause damage to paved surfaces, including potential melting and deformation. An increase in solar radiation can also cause more rapid deterioration of materials and associated infrastructure such as signage. Bridges are sensitive to high temperatures which affect thermal expansion joints and increase earth pressures.

Wind

1.1.17 Bridges are sensitive to high winds which increase wind loading on the structure. High winds and storms can affect the stability of above-ground infrastructure and hasten material degradation. High winds can also cause wind-driven rain infiltration into building materials and surfaces which can increase maintenance costs and operational disruption. High winds also increase risk to bridge users (particularly high sided vehicles) and may lead to temporary closure. Road, cycle and footway users may also be sensitive to high winds. Associated infrastructure such as signage or signals could also be damaged by high winds.

1.1.18 Bridges are also sensitive to storms, particularly the risk of lightning strike. Electronic control equipment associated with bridges is likely to be highly sensitive to lightning strike.

Soils

1.1.19 Roads, bridges, cycle and footways are all sensitive to soil stability. Soil stability can be reduced as a result of extreme rainfall or prolonged periods of rainfall which can lead to waterlogging, as well as extreme temperatures and drought which can causes soils to dry out and crack. Earthworks and embankments associated with roads, bridges, cycle and footways are particularly sensitive to changes in soil stability. Roads, cycle and footways are also sensitive to an increase in soil runoff, increasing the amount of sediment on paved surfaces and reaching drains, potentially leading to blockages.

1.1.20 Water availability can cause a number of impacts to water quality and soils. For example, greater water volumes can increase the mobilisation of pollutants in soils whilst water scarcity can increase the accumulation of chemicals and pollutants which may cause increased salinity and acidification. Sea level rise could also lead to increasing soil salinity. More acidic soils and/or water will increase the deterioration of building materials. Bridge foundations may be sensitive to changes in soil chemistry

1.1.21 Based on the information described above, literature review and professional opinion, Table 1.4 outlines the climate sensitivity of the Scheme.

Table 1.4: Sensitivity Assessment

Climate Variable		Sensitivity of Scheme Components		
		Road	Bridges	Cycle and Footway
Sea	Sea level rise	Medium	Medium	Medium
	Storm surge and storm tide	High	High	Medium
Precipitation	Changes in annual average	Medium	n/a	Low
	Drought	Medium	n/a	Medium
	Extreme precipitation events	High	High	Medium
Temperature	Extreme temperature events	High	High	Medium
	Solar radiation	Medium	Low	Low
Wind	Gales and high winds	Medium	High	Low
	Storms	Low	High	Low
Soils	Soil moisture	Medium	n/a	Medium
	Soil salinity	Low	Medium	Low
	Runoff	Medium	n/a	Medium
	Soil stability	Medium	High	Medium

Exposure

1.1.22 This section considers the exposure of the Scheme to current climate and climate change/changes in extreme weather.

Current Climate

1.1.23 The Scheme is located in the East of England which has a warm, dry climate, compared to UK average. Information on long term average observed climate variables over the period 1981 – 2010 is presented below. This information is taken from The Climate of the United Kingdom and Observed Trends (Ref 1.2), Met Office regional climate profile for Eastern

England (Ref 1.3) and Met Office Weather Station data (Ref 1.11). The date range (1981-2010) is the most up to date long term average data available.

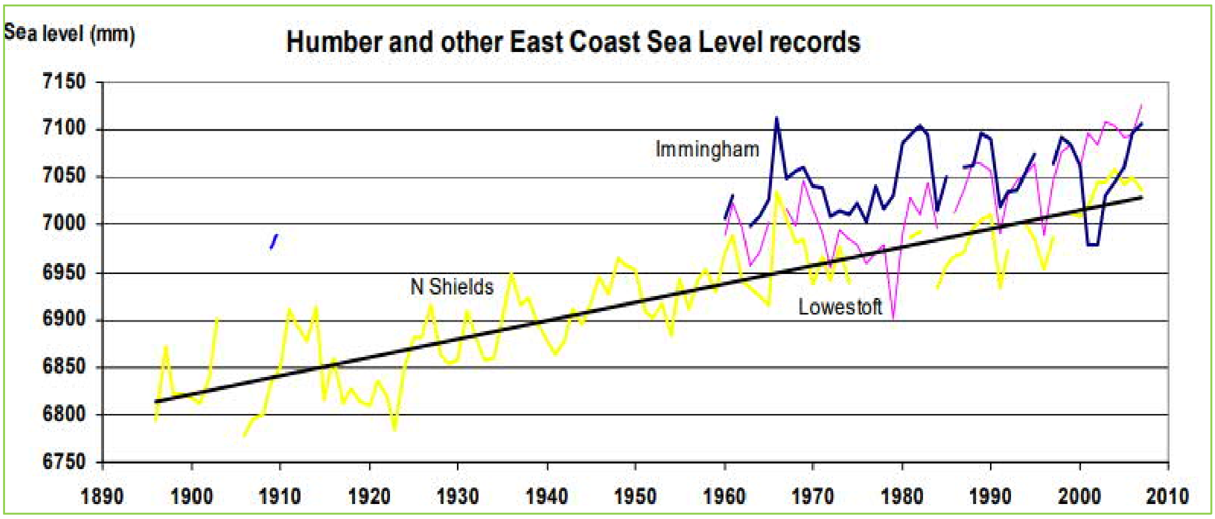
Sea Level

1.1.24 Sea level change is controlled by two main factors: eustatic (changes related to the expansion and contraction of sea water plus changes in the volume of water stored on land as ice sheets/glaciers) and isostatic (changes related to movement of the land in responses to the effect of glaciers on the Earth's crust). Recent and future sea level change in the region is dominated by the eustatic component resulting from global warming. Local changes (i.e. in geomorphology), modify these broader changes and can have a significant effect on the actual sea level rise experienced along the region's coastline.

1.1.25 Sea level around the UK rose by about 1mm/yr in the 20th century, corrected for land movement (Ref 1.2). At Lowestoft (the nearest tide gauge site to the Scheme), mean sea level increased by 2.01 (+/- 0.42) mm per year over the period 1960-1996 (Ref 1.6).

1.1.26 Plate 1.1 shows sea level records on the east coast. Lowestoft is the nearest recording station to the Scheme.

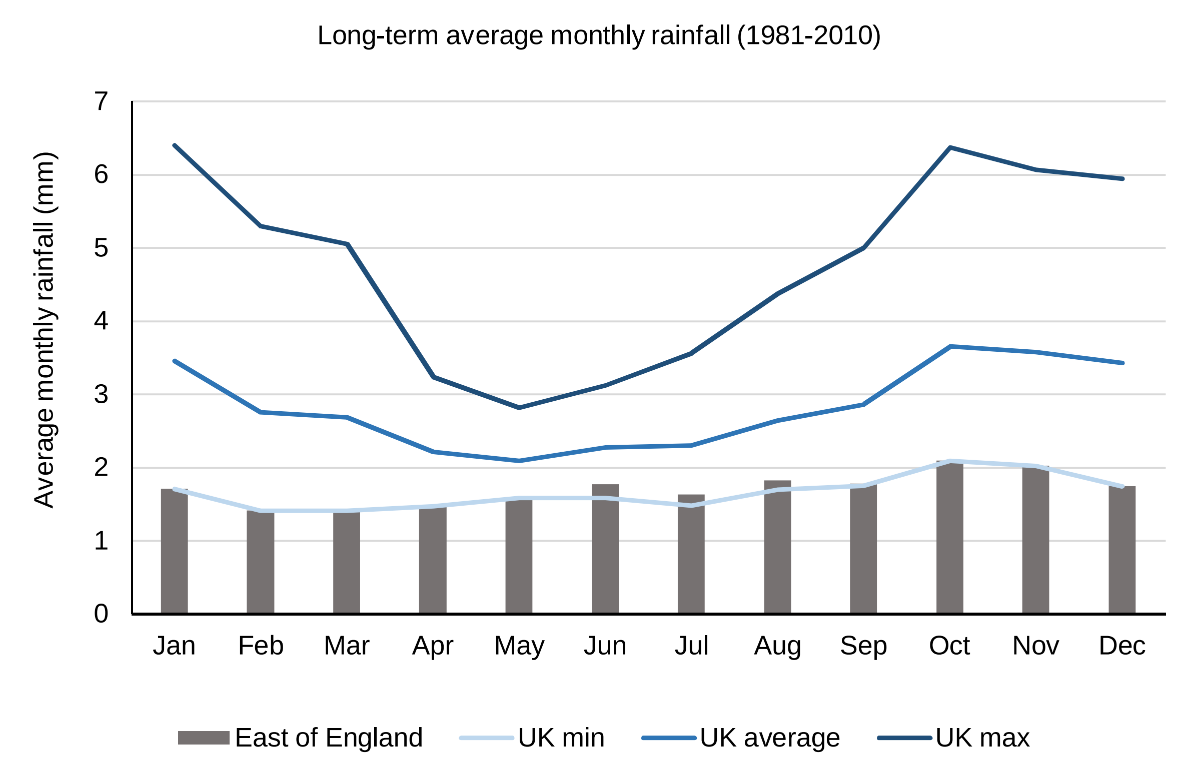
Plate 1.1: East Coast Sea Level Records



Precipitation

1.1.27 Plate 1.2 shows the long-term average monthly rainfall for the East of England region between 1981 and 2010 (Ref 1.2). Across most of the region there are, on average, about 30 rain days (rainfall greater than 1 mm) in winter (December to February) and less than 25 days in summer (June to August) with the highest averages being at the higher altitude of the Lincolnshire Wolds (Ref 1.3).

Plate 1.2: Long Term Average Monthly Mean Rainfall



1.1.28 Average summer (June, July and August) and winter (December, January and February) rainfall at Hemsby Weather Station (the nearest weather station to the Scheme situated approximately 11km to the north east) for the period 1981-2010 is summarised in Table 1.5 (Ref 1.11).

Table 1.5: Long Term Average Mean Rainfall (mm) at Hemsby Weather Station (1981 – 2010)

Period	Mean Rainfall (mm)
Summer	57.7
Winter	58.6
Annual	636.4

1.1.29

1.1.30 Table 1.6 shows the average number of days per year (in the period 1981 – 2010 where rainfall exceeded 10mm per day in the East of England region (Ref 1.2).

Table 1.6: Long Term Average of Total Number of Days where Rainfall Exceeded 10mm for the Baseline Period (1981 – 2010) in the East of England Region

Period	Average Number of Days Rainfall >10mm (1981-2010)
Summer	1.4
Winter	0.9
Annual	1.2

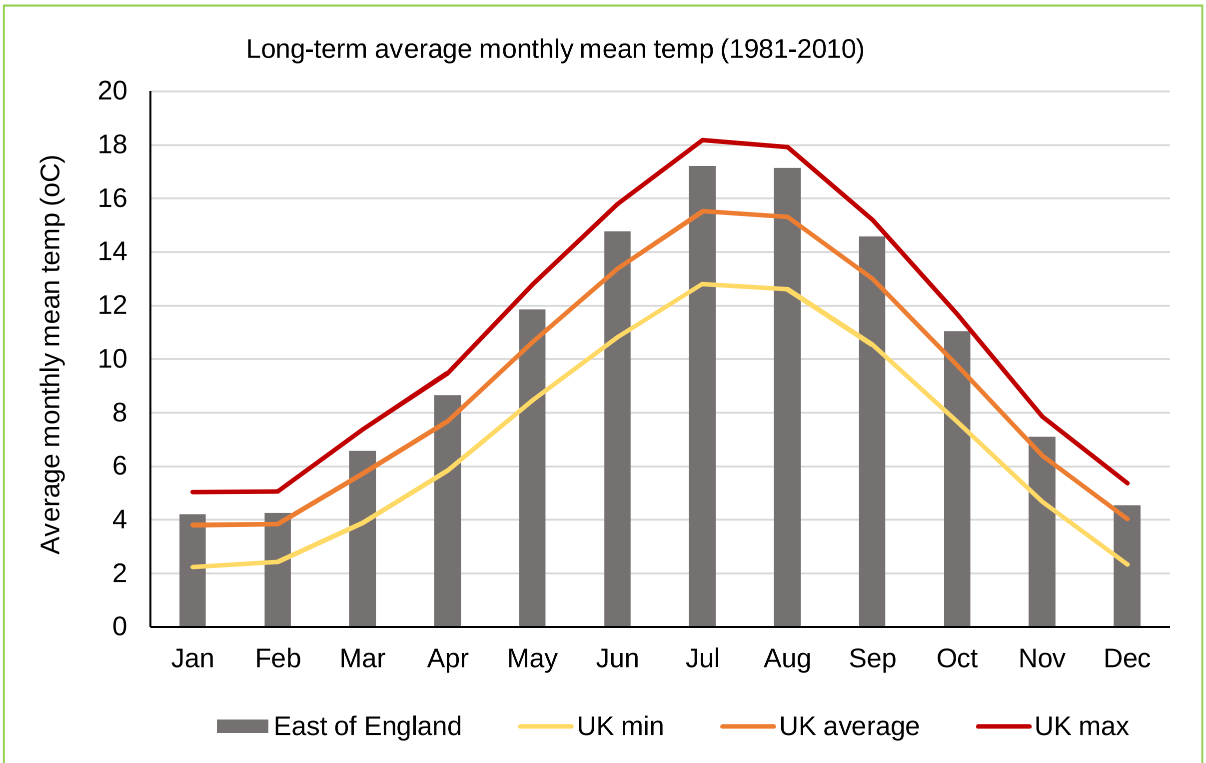
1.1.31 Although rainfall is generally low in the East of England, there have been some noteworthy severe storms. These include (Ref 1.3):

- 25 to 26 August 1912 - over 100 mm was recorded in Norfolk causing damage to roads and bridges
- 1 September 1994 - 147 mm was recorded in only a few hours in Suffolk, causing transport disruption and significant flooding.

Temperature

1.1.32 Plate 1.3 shows the long-term average mean monthly temperature for the East of England region between 1981 and 2010 (Ref 1.2). The mean annual temperature over the region varies from around 9.5°C to just over 10.5°C (Ref 1.3).

Plate 1.3: Long Term Average Monthly Temperature



1.1.33 The long-term average of maximum mean summer (June, July and August) temperature and minimum mean winter (December, January and February) temperature at Hemsby Weather Station for the baseline period is presented in Table 1.7 below (Ref 1.11).

Table 1.7: Long Term Average Mean Monthly Temperature

Variable	Temperature °C
Maximum mean summer temperature (°C) (1981 – 2010)	19.7
Minimum mean winter temperature (°C) (1981 – 2010)	2.1

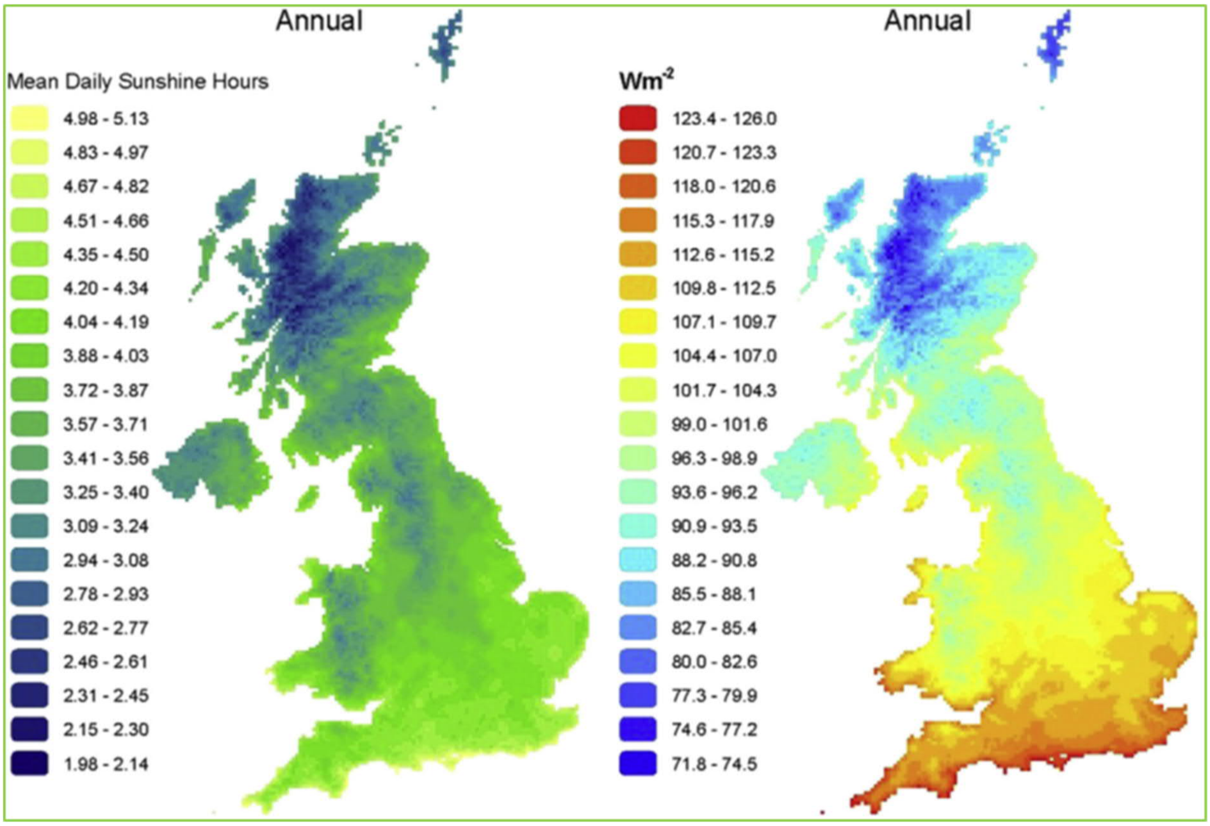
1.1.34 The highest known temperature recorded in the region was 37.3°Cat Cavendish on 10 August 2003 (Ref 1.3).

1.1.35 Sea temperatures off the coast of eastern England vary from 5-6°C in February and early March to 15-16°C in August (Ref 1.3). The temperature is governed by the influx of warm water associated with the Gulf Stream.

Solar Radiation

1.1.36 The Met Office has developed UK gridded observed sunshine duration data sets which are based on observations from weather stations. Sunshine duration data can be converted to solar radiation data. Plate 1.4 shows average daily annual sunshine hours and converted solar irradiance over the period 1961 – 1990 across the UK (Ref 1.4). Average daily solar irradiance at Great Yarmouth over this period is in the region of 110 watts per meter squared (Wm^{-2}).

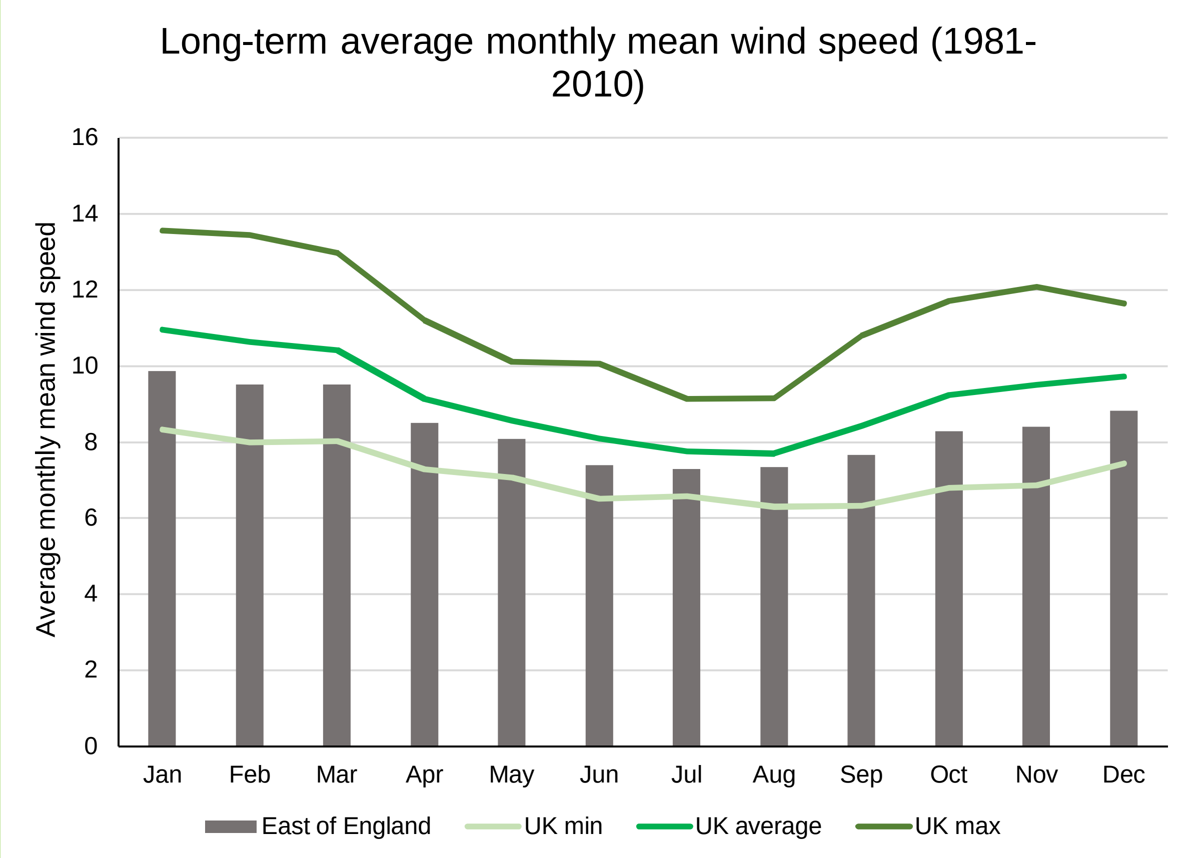
Plate 1.4: Long Term Average Daily Solar Irradiance



Wind

1.1.37 Plate 1.5 shows the long-term average monthly mean wind speed in the East of England region between 1981 and 2010 (Ref 1.2). Eastern England is one of the more sheltered parts of the UK and the strongest winds are associated with the passage of deep depressions across or close to the UK. In coastal areas sea breezes are an important feature of the weather in late spring and summer when the land is warming up and the sea still relatively cool (Ref 1.3).

Plate 1.5: Long Term Average Monthly Mean Windspeed



1.1.38 The long-term average of mean summer and winter wind speed at 10m at the Hemsby Weather Station (Ref 1.11) for the baseline period is presented in Table 1.8 below.

Table 1.8: Long Term Average of Mean Summer and Winter Wind Speed for the Baseline Period (1981 – 2010), Hemsby Weather Station

Variable	Wind speed (knots)
Mean summer wind speed (knots) (1981 – 2010)	8.6
Mean winter wind speed (knots) (1981 – 2010)	11.7
Annual	10.2

1.1.39 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. Much of East Anglia and Lincolnshire has no more than two days of gale each year, but exposed coasts average about five gales each year. Two particularly noteworthy gale events have occurred in the region (Ref 1.3):

- 2 January 1976 - a depression moved across Scotland to the North Sea causing storm force winds that particularly affected the north, east and Midland areas of England. Gusts exceeding 90 knots were reported in East Anglia and sea walls were breached at Walcott in Norfolk and Cleethorpes on Humberside causing extensive damage.
- The 'Great Storm' of 15-16 October 1987 caused widespread damage across south-east England. The strongest gust recorded in Eastern England was 87 knots at Shoeburyness (Landwick) in Essex.

Projected Climate

1.1.40 Information on projected climate is taken from the UK Climate Projections 2018 (UKCP18) (Ref 1.10). 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 (Representative Concentration Pathways RCPs[1]) and for a range of timeslices[2] to the end of the 21st Century. The projections are presented using a central estimate (50th percentile) projections for the 2080s high emissions scenarios (RCP8.5) for the East of England administrative region.

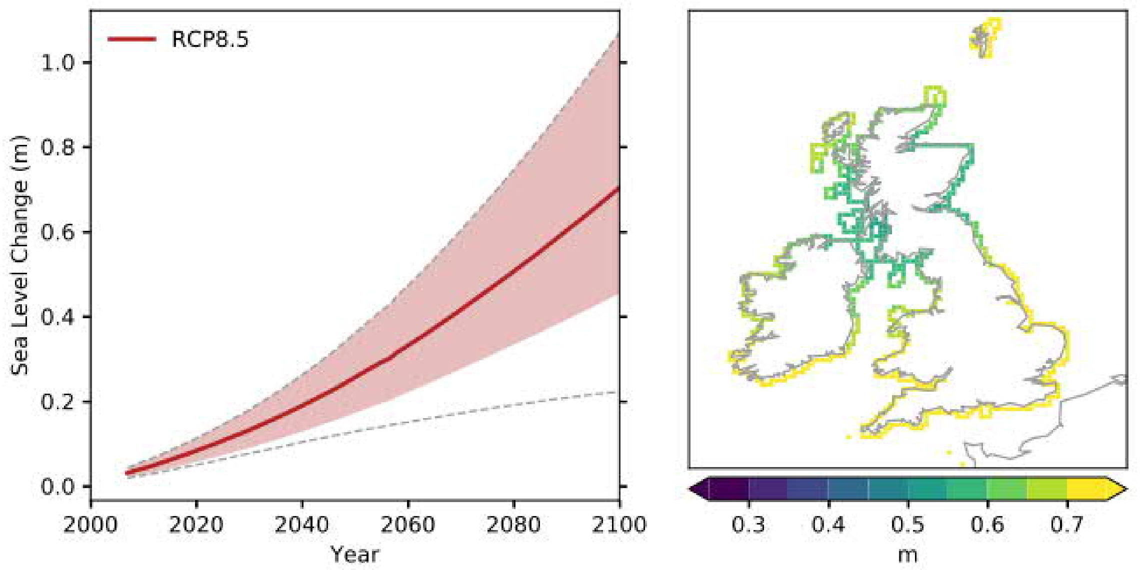
Sea Level

1.1.41 UKCP18 projections provide predictions for four cities across the UK of which London is the most applicable here. Under RCP8.5, UKCP18 suggests that seal level change will be between 0.53m (5th percentile) and 1.15 (95th percentile). Plate 1.6, shows the UK average sea level change under the RCP8.5 emission scenario and the pattern of change around the UK coastline in the year 2100 (Ref 1.15).

[1] Representative Concentration Pathways specify the concentrations of greenhouse gases that would result in target amounts of radiative forcing at the top of the atmosphere by 2100, relative to preindustrial levels. Four forcing levels have been set: 2.6, 4.5, 6.0 and 8.5 W/m^2. These create four RCPs that are used in UKCP18; RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5.

[2] UKCP18 projections are given for seven overlapping 30-year time periods. Each period steps forward by a decade, with the first-time period being 2010-2039. For simplicity, these time periods are referred to by the middle decade, starting with the 2020s (2010-2039) and ending with the 2080s (2070-2099).

Plate 1.6: UK Average Sea Level Change under the RCP8.5 Emission Scenario and the Pattern of Change around the UK Coastline in the Year 2100



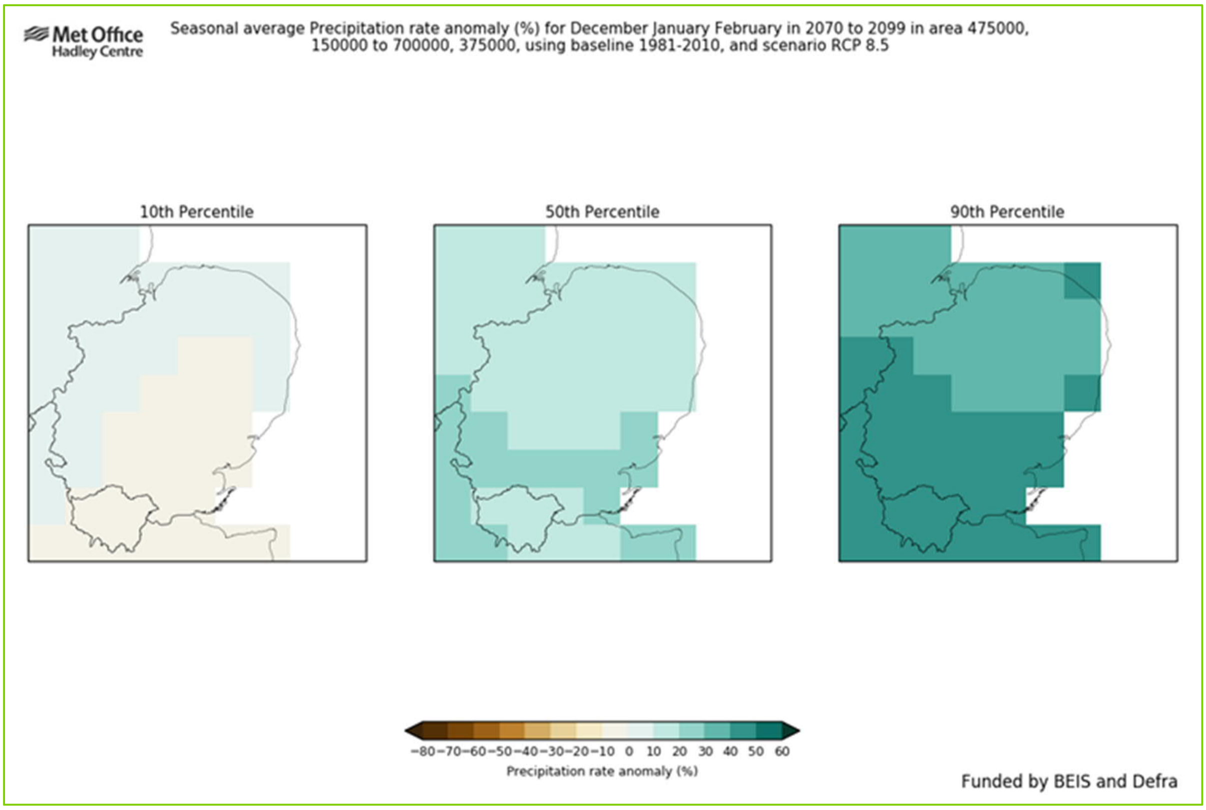
Precipitation

1.1.42 Over land, UKCP18 projects that general trends of climate changes in the 21st century will move towards warmer, wetter winters and hotter, drier summers. However, natural variations mean that some cold winters, some dry winters, some cool summers and some wet summers will still occur.

1.1.43 UKCP18 suggests that by the 2080s in the East of England region, mean winter precipitation is expected to increase by up to 20% in the north and central areas of the region and up to 20% in the south of the region (50th percentile) under RCP 8.5.

1.1.44 Plate 1.7 summarises changes in mean winter precipitation for the 2080s under UKCP18 emission scenarios RCP8.5 (Ref 1.10).

Plate 1.7: Mean Winter Precipitation in the East of England Region for the 2080s under UKCP18 RCP8.5 Emission Scenario

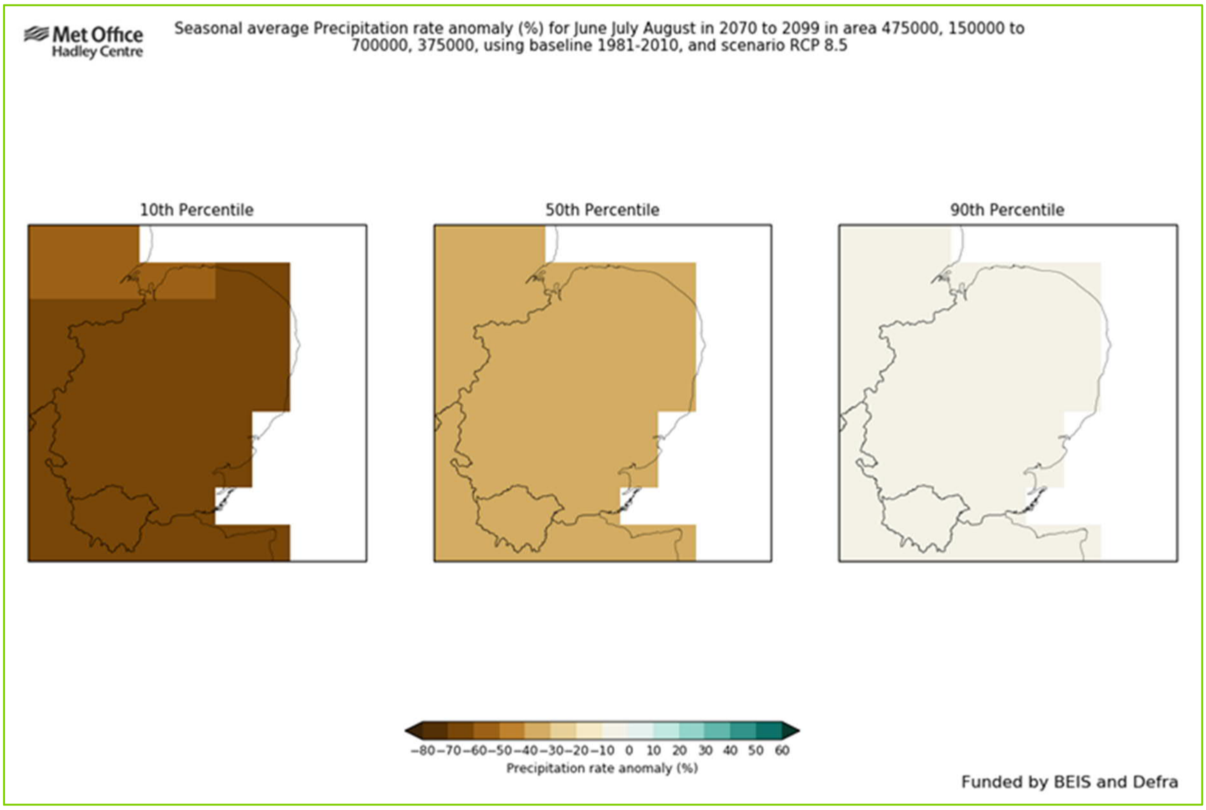


1.1.45 Snowfall is closely linked with temperature, with falls rarely occurring if the temperature is higher than 4 °C. For snow to lie for any length of time, the temperature normally has to be lower than this. With regards to future changes, rising winter temperatures are likely to reduce the amount of precipitation that falls as snow in winter. UKCP18 data (at time of writing) does not have data on snowfall, however UKCP09 (Ref 1.12) projects 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.

1.1.46 For the summer, by the 2080s in the East of England region, mean summer precipitation is expected to decrease by up to 40% (50th percentiles) under RCP8.5.

1.1.47 Plate 1.8 summarises changes in mean summer precipitation for the 2080s under UKCP18 emission scenario RCP8.5 (Ref 1.10).

Plate 1.8: Mean Summer Precipitation in the East of England Region for the 2080s under UKCP18 RCP8.5 Emission Scenario



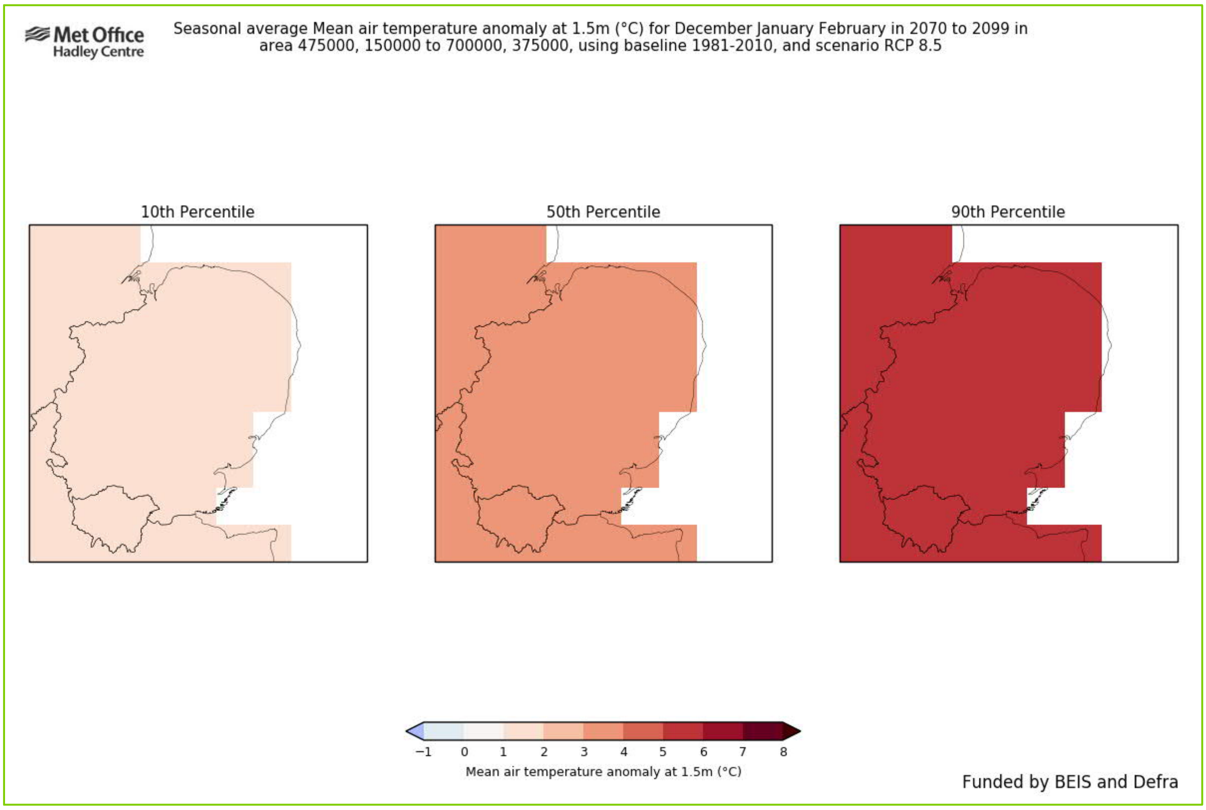
Temperature

1.1.48 Climate change is projected to lead to hotter summers and warmer winters. The probabilistic projections show that there is more warming in the summer than in the winter. Additionally, in summer there is a pronounced north / south contrast at the scale of the UK, with greater increases in maximum summer temperatures over the southern UK compared to northern Scotland.

1.1.49 UKCP18 suggests that by the 2080s, mean winter temperature in the region is expected to increase by up to 4°C (50th percentile) under RCP8.5.

1.1.50 Plate 1.9 summarises changes in mean winter temperature for the 2080s under UKCP18 emission scenario RCP8.5 (Ref 1.10).

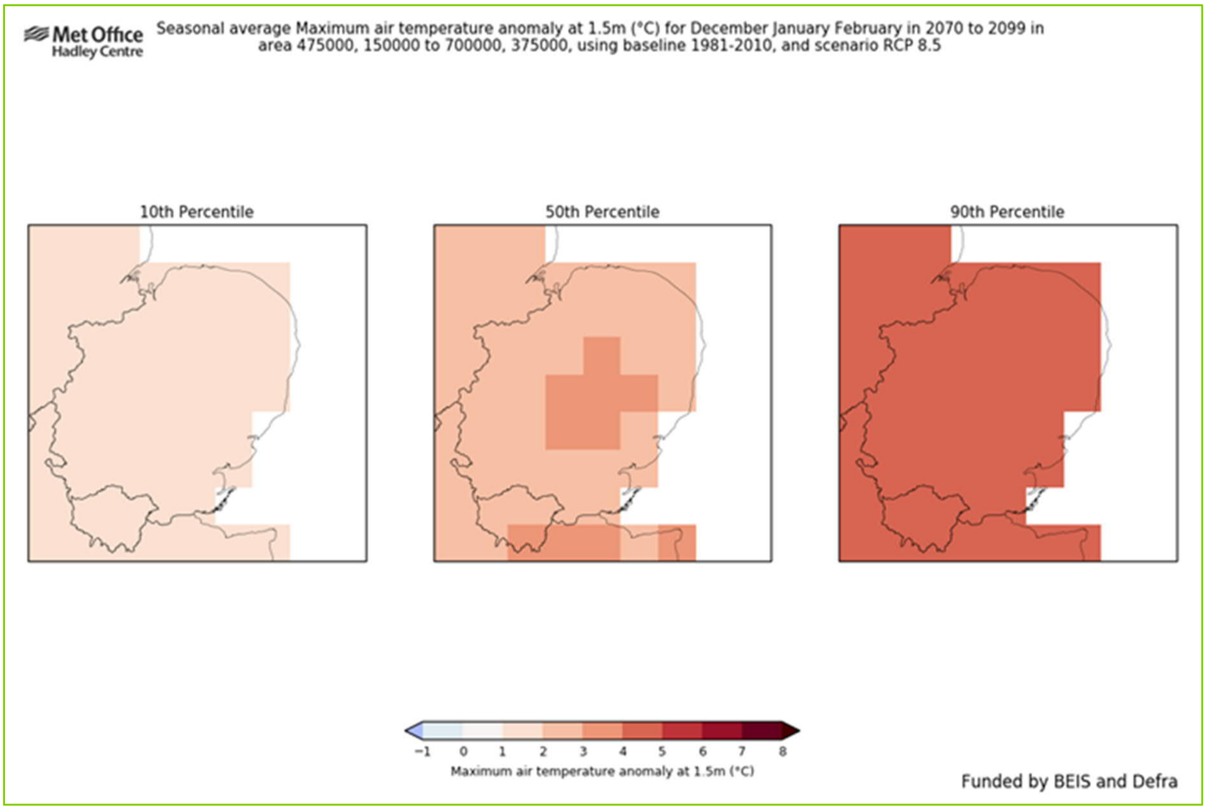
Plate 1.9: Mean Winter Temperature in the East of England Region for the 2080s under UKCP18 RCP8.5 Emission Scenario



1.1.51 UKCP18 suggests that by the 2080s, mean daily maximum winter temperature in the region is expected to increase by up to 3°C in the coastal and western area of the region and up to 4°C in the central areas of the region (50th percentile) under RCP8.5.

1.1.52 Plate 1.10 summarises change in mean daily maximum temperature in the winter for the 2080s under RCP8.5 (Ref 1.10).

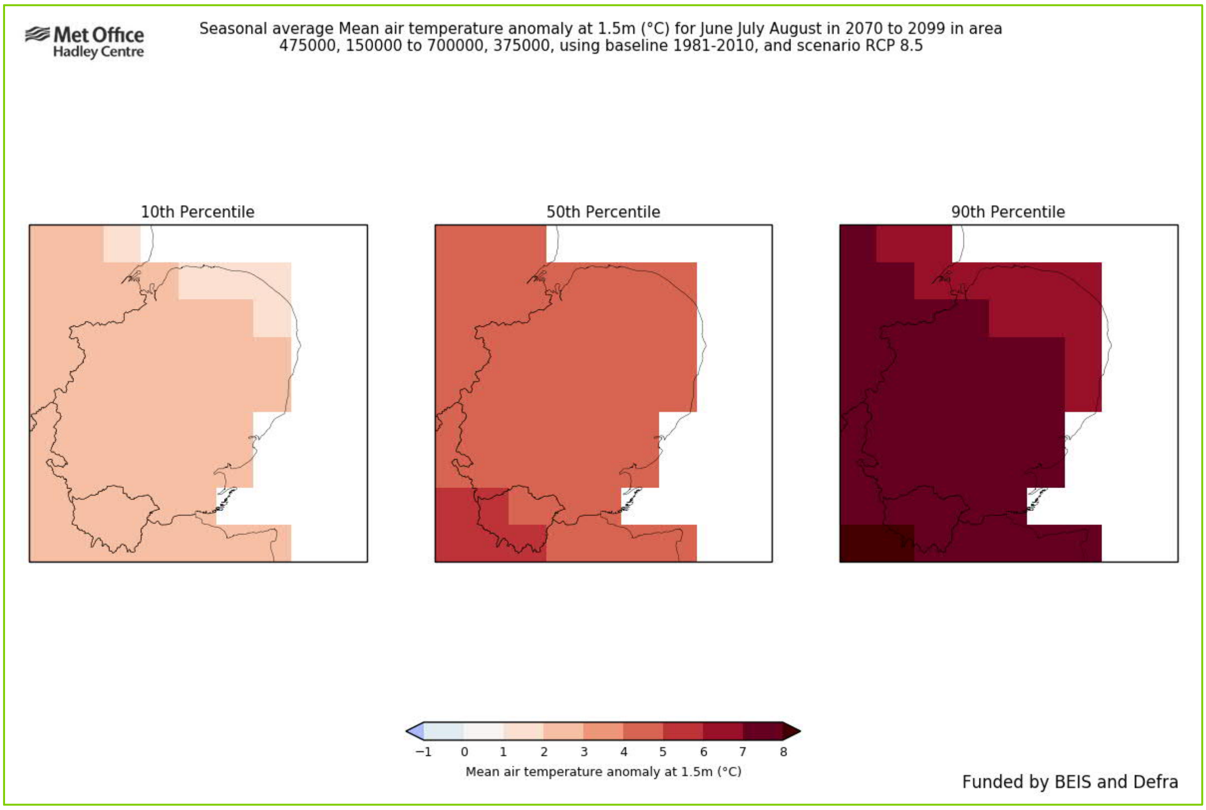
Plate 1.10: Mean Daily Maximum Winter Temperature in the East of England Region for the 2080s under UKCP18 RCP8.5 Emission Scenario



1.1.53 For the summer, by the 2080s, mean summer temperature is expected to increase by up to 5°C (50th percentile) under RCP8.5.

1.1.54 Plate 1.11 Summarises changes in mean summer temperature for the 2080s under RCP8.5 (Ref 1.10).

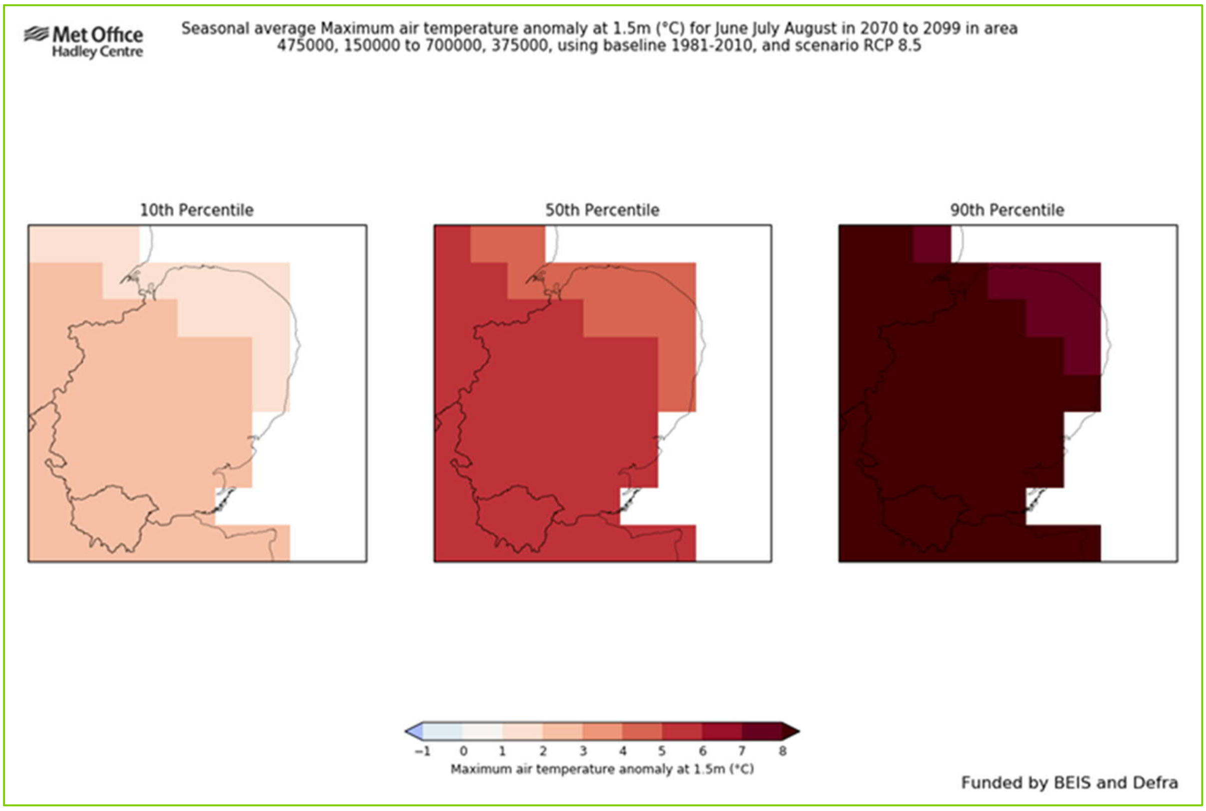
Plate 1.11: Mean Summer Temperature in the East of England Region for the 2080s under UKCP18 RCP8.5 Emission Scenario



1.1.55 For the summer by the 2080s, mean daily maximum summer temperature is expected to increase by up to 6°C in the majority of the region and by 5°C in the north east of the region (50th percentile) under RCP 8.5.

1.1.56 Plate 1.12 summarises changes in the mean daily maximum temperature in the summer for the 2080s under RCP8.5 (Ref 1.10).

Plate 1.12: Mean Daily Maximum Summer Temperature in the East of England Region for the 2080s under UKCP18 RCP8.5 Emission Scenario



1.1.57 In addition to changes in seasonal average temperatures, it is likely that there will be more extreme temperature events. With regard to heat waves, research published by the Met Office Hadley Centre suggests the European summer heat wave in 2003 could become a normal event by the 2040s. By the 2060s, such a summer would be considered cool according to some climate models. It is very likely (confidence level >90%) that human influence has at least doubled the risk of a heatwave exceeding mean summer temperatures experienced in 2003 (Ref 1.4).

Solar Radiation

1.1.58 A recent (regional) study suggests that the England South region (including the East of England administrative region), is likely to see an increase in annual solar radiation by the 2050s of 5.6 Watts per square meter (Wm-2) (Low), 5.3Wm-2 (Medium) or 6.2Wm-2 (High) under the central (50th percentile) estimate. By the 2080s, increases of 6.2 Wm-2 (Low), 6.8 Wm-2 (Medium) or 8.0 Wm-2 (High) under the central (50th percentile) estimate are projected (Ref 1.4). All regions of the UK are likely to have increased cloud cover (although there is large uncertainty around future projections of cloud cover) and therefore slightly less solar radiation during the winter.

Wind

1.1.59 The UKCP18 global projections over the UK show an increase in near surface wind speeds over the UK for the second half of the 21st century for the winter season when more significant impacts of wind are experienced. This is accompanied by an increase in frequency of winter storms over the UK.

1.1.60 There is large uncertainty in projected changes in circulation over the UK and natural climate variability contributes much of this uncertainty (Ref 1.7). It is therefore difficult to represent regional wind extreme winds and gusts within regional climate models (Ref 1.8).

1.1.61 Central estimates of change in mean wind speed for the 2050s are small in all ensemble runs (<0.2ms-1). A wind speed of 0.2 ms−1 (~0.4 knots) is small compared with the typical magnitude of summer mean wind speed of about 3.6–5.1 ms-1 (7–10 knots) over much of England (Ref 1.2). Seasonal changes at individual locations across the UK lie within the range of –15% to +10%. Results suggest that there could be a future reduction in the summer westerly wind flows over the southern half of the UK. There may be an increase in westerly flows in the north during summer and also an increase in southerly flows over the UK in winter (Ref 1.11).

Relative Humidity

1.1.62 Relative Humidity is the most common measure of humidity. It measures how close the air is to being saturated. UKCP18 does not currently have projections for humidity, therefore data from UKCO09 has been used.

1.1.63 By the 2050s, projections for winter mean relative humidity in the East of England region suggest a decrease of up to 5% under the high emissions scenario (central estimate). By the 2080s, winter mean relative humidity could increase by up to 5% (high emissions scenario, central estimate). The projection for summer mean humidity in the 2050s under the high emissions scenario is a decrease of up to 5% (central estimate). By the 2080s the decrease could be as much as 10% (high emissions scenario, central estimate) (Ref 1.12).

Extreme Climate Change Scenarios

1.1.64 A range of ‘extreme’ climate change scenarios (produced by Wade et al., 2015 (Ref 1.9) have also been reviewed. These scenarios provide a high-impact, low-likelihood event to compare against more likely outcomes. Wade et al., (2015) considered a range of climate variables including heatwaves, cold snaps, low and high rainfall, droughts, floods and windstorms. The H++ scenarios fall outside the ‘likely’ range of UK climate projections and represent scenarios beyond the lower and upper (10th to

90th) percentile range of the 2080s UKCP09 High emissions scenario as presented in the UKCP09 projections and reported here.

1.1.65 The H++ scenarios suggest that average summer maximum temperatures will exceed 30°C across most of the UK, with temperatures of the hottest days are also likely to exceed 40°C (Ref 1.9). The H++ scenarios for heavy daily and sub-daily rainfall suggest that, for the same period, there is a 60% to 80% increase in rainfall for summer or winter events based on a consideration of new high-resolution modelling and physical processes. This is within the UKCP09 distribution range for the 2080s High emissions “wettest day of the winter” variable but higher than uplifts previously considered for summer.

Exposure Rating

1.1.66 As detailed under paragraphs 1.1.5 to 1.1.8, the exposure of the receptor to projected change in climate variables (base in information on observed climate and projected climate) is assessed. Based on the climate change projections for the East of England region, Table 1.9 indicates the level of exposure of the Scheme to changes in climate variables.

Table 1.9: Exposure Assessment

Climate Variable		Scheme Element Exposure Rating		
		Road	Bridges	Cycle and Footway
Sea	Sea Level Rise	High		
	Storm Surge and Storm Tide	High		
Precipitation	Changes in Annual Average	Medium		
	Drought	High		
	Extreme Precipitation Events	High		
Temperature	Extreme Temperature Events	High		
	Solar Radiation	Medium		
Wind	Gales and High Winds	Medium		

Climate Variable		Scheme Element Exposure Rating		
		Road	Bridges	Cycle and Footway
	Storms	Medium		
Soils	Soil Moisture	High		
	Soil Salinity	High		
	Runoff	Medium		
	Soil Stability	High		

Vulnerability Rating

1.1.67 As described under paragraphs 1.1.5 to 1.1.8, the sensitivity and exposure analyses are combined to provide an overall assessment of vulnerability of the Scheme. Table 1.10, Table 1.11, Table 1.12 present the overall assessment of vulnerability for the road, bridge and cycle and footway elements of the Scheme respectively.

Table 1.10: Vulnerability Rating Assessment for Road Elements of the Scheme

Climate Variable		Sensitivity	Exposure	Vulnerability
Sea	Sea Level Rise	Medium	High	Medium
	Storm Surge	High	High	High
Precipitation	Changes in Annual Average	Medium	Medium	Medium
	Drought	Medium	High	Medium
	Extreme Events	High	High	High
Temperature	Extreme Temperature Events	High	High	High
	Solar Radiation	Medium	Medium	Medium
Wind	Gales and High Winds	Medium	Medium	Medium

Climate Variable		Sensitivity	Exposure	Vulnerability
	Storms	Low	Medium	Low
Soils	Soil Moisture	Medium	High	Medium
	Soil Salinity	Low	High	Low
	Runoff	Medium	Medium	Medium
	Soil Stability	Medium	High	Medium

Table 1.11: Vulnerability Rating Assessment for Bridge Elements of the Scheme

Climate Variable		Sensitivity	Exposure	Vulnerability
Sea	Sea Level Rise	Medium	High	Medium
	Storm Surge	High	High	High
Precipitation	Extreme Events	High	High	High
Temperature	Extreme Temperature Events	High	High	High
	Solar Radiation	Low	Medium	Low
Wind	Gales and High Winds	High	Medium	Medium
	Storms	High	Medium	Medium
Soils	Soil Stability	High	High	High
	Soil Salinity	Medium	High	Medium

Table 1.12: Vulnerability Rating Assessment for Cycle and Footway Elements of the Scheme

Climate Variable		Sensitivity	Exposure	Vulnerability
Sea	Sea Level Rise	Medium	High	Medium
	Storm Surge	Medium	High	Medium
Precipitation	Changes in Annual Average	Low	Medium	Low

Climate Variable		Sensitivity	Exposure	Vulnerability
	Drought	Medium	High	Medium
	Extreme Events	Medium	High	Medium
Temperature	Extreme Temperature Events	Medium	High	Medium
	Solar Radiation	Low	Medium	Low
Wind	Gales and High Winds	Low	Medium	Low
	Storms	Low	Medium	Low
Soils	Soil Moisture	Medium	High	Medium
	Soil Salinity	Low	High	Low
	Runoff	Medium	Medium	Medium
	Soil Stability	Medium	High	Medium

1.2 References

Ref 1.1: Standards Australia (2013) Climate Change Adaptation for settlements and infrastructure – a risk-based approach. SAI Global Limited.

Ref 1.2: Jenkins, G.J., Perry, M.C., and Prior, M.J. (2008). The climate of the United Kingdom and recent trends. Met Office Hadley Centre, Exeter, UK.

Ref 1.3: Eastern England Climate, Met Office (accessed 2019). https://www.metoffice.gov.uk/climate/uk/regional-climates/ee

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Ref 1.5: Jenkins, G.J., Perry, M.C., and Prior, M.J. (2008). The climate of the United Kingdom and recent trends. Met Office Hadley Centre, Exeter, UK.

Ref 1.6: Review of UK climate indicators, Defra. http://www.ecn.ac.uk/iccuk/indicators/9.htm.

Ref 1.7: 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.

Ref 1.8: Brown, S., Boorman, P., Buonomo, E., Burke, E., Caesar, J., Clark, R., McDonald, R. and Perry, M. (2008) A climatology of extremes for the UK: A baseline for UKCP09. Met Office Hadley Centre, Exeter.

Ref 1.9: Wade, S., Sanderson, M., Golding, N., Lowe, J., Betts, R., Reynard, N., Kay, A., Stewart, L., Prudhomme, C., Shaffrey, L., Lloyd-Hughes, B., Harvey, B. (2015). Developing H++ climate change scenarios for heat waves, droughts, floods, windstorms and cold snaps. Met Office Hadley Centre, Exeter, UK. Crown copyright.

Ref 1.10: UK Climate Projections 2018, produced by Department for Environment and Rural Affairs, Department for Business, Energy and Industrial Strategy, Met Office and Environment Agency.

Ref 1.11: Met Office Hemsby Climate https://www.metoffice.gov.uk/public/weather/climate/u135wx0y1

Ref 1.12: UK Climate Projections 2009, produced by British Atmospheric Data Centre, Environment Agency, Marine Climate Change Impacts Partnership, Met

Office, National Oceanography Centre, Newcastle University, Tyndall Centre, University of East Anglia.

Ref 1.13: IEMA (2015), Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation.

Ref 1.14: European Commission (2016), Climate Change and Major Projects.

Ref 1.15: Met Office (2018) UKCP18 Factsheet: Sea level risk and storm surge