A1 Birtley to Coal House

Scheme Number: TR010031

6.1 Environmental Statement
Chapter 14 Climate

APFP Regulation 5(2)(a)

Planning Act 2008

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

Volume 6

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Infrastructure Planning

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The Infrastructure Planning (Applications: Prescribed Forms and Procedures) Regulations 2009

A1 Birtley to Coal House

Development Consent Order 20[xx]

Environmental Statement

Regulation Reference:	APFP Regulation 5(2)(a)
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14. CLIMATE

14.1. INTRODUCTION

14.1.1. This chapter reports the outcome of the Climate assessment of the Scheme. The Climate assessment consists of two separate assessments:

a. Greenhouse gases - the likely significant effects of the Scheme on climate, in particular the magnitude and mitigation of the reasonable worst-case scenario Greenhouse Gases (GHGs) emissions associated with construction and operation of the Scheme. The assessment of likely significant effects of the Scheme on climate quantifies and reports GHG emissions as carbon dioxide equivalent (CO_2e), as one normalised measure based on the global warming potential of carbon dioxide (CO_2), in the form of a carbon footprint. This assessment has been carried out following the methodology set out in the Design Manual for Roads and Bridges (DMRB) Volume 11, Section 3, Part 1 Air Quality; HA 207/07 (**Ref 14.1**).

b. Vulnerability - the vulnerability of the Scheme to climate change, in particular impacts on the Scheme from extreme weather and long-term climate change during construction and operation phases over the Scheme lifetime (60 years for roads and 120 years of bridges).

14.1.2. This chapter summarises the legislative and policy framework and describes the methodology followed for the assessments along with the assessment assumptions and limitations. The chapter identifies the potential impacts as a result of the Scheme, details the design, mitigation and enhancement measures that have been identified and reports the assessment of the significant effects of the Scheme. Details of monitoring that should be carried out for the Scheme are also provided.

14.1.3. This chapter is intended to be read as part of the wider Environmental Statement (ES) and in conjunction with its associated figures and appendices.

14.1.4. A full description of the Scheme is provided in **Chapter 2 The Scheme** in this ES (**Application Document Reference: TR010031/APP/6.1)**.

Allerdene Embankment and Viaduct Options

14.1.5. In the assessment of the effects of the Scheme on climate, the differences between Allerdene embankment option and Allerdene viaduct option, as detailed in **paragraphs 2.7.11** to **2.7.18** of this ES, does affect the findings. This is mainly due to impacts associated with the type and quantities of construction materials required and waste generated by the design options. There are also small differences in the transportation of materials and waste to and from site. In the assessment for the Allerdene viaduct option, data on material types and quantities for both the six and seven span options were reviewed and the data with the greatest associated impact used in order to assess the worst-case.

14.1.6. In the assessment of vulnerability of the Scheme to climate change, the differences between Allerdene embankment option and Allerdene viaduct option does not affect the assessment. This is because there is little difference, from a climate resilience perspective, between the proposed options.

14.2. COMPETENT EXPERT EVIDENCE

14.2.1. As detailed in **Table 14-1** the professionals contributing to the production of this ES chapter have sufficient expertise to ensure the completeness and quality of this ES.

Table 14-1 – Climate professional competence

Name	Role	Qualifications and Professional Membership	Experience
Jean-Louis Bartlett	Author (Greenhouse Gas)	BSc (Hons) Biology MSc Environmental Consultancy IEMA Practitioner	– 3 years' experience relevant to EIA – Lead author of the Climate Chapter of the M3 Junction 9 Scoping Report. – Co-author of the Climate Chapter of the A27 Arundel. Bypass Environmental Assessment Report. – Peer review and co-author of the new Highways England DMRB Volume 10 & 11 Climate.
Dr. Paul Munday	Author (Climate resilience)	PhD Climate Change and GIS MSc Climate Change BSc (Hons.) Geography CSci C. WEM/M.CIWEM CGeog (GIS) FRGS	– 12 years' experience – Lead author of the Climate chapter for a major energy project in the north-east. – Lead author of the Climate chapter of M25 junctions: A2B2E, Junction10, Junction 25 and Junction 28 Scoping Reports and PEIRs.
Tom Wood	Reviewer	MSc Environmental Technology Chartered Environmentalist (CEnv) C.WEM/M.CIWEM IEMA Affiliate	– 13 years' experience – Lead author of the (unpublished) Highways England DMRB Volume 10 & 11 Climate. – Contribution to the Highways England (2015) voluntary progress report on climate change adaptation. – Lead author or reviewer of climate chapters for multiple environmental assessments across sectors including

Name	Role	Qualifications and Professional Membership	Experience
			highways, rail, energy, water and industry.
Nikki van Dijk	Reviewer	MSc Climate Change BA(Hons) Geography C.WEM/MCIWEM CEnv FRGS	– 13 years' experience – Lead author of the A27 Arundel Bypass EAR (Climate Vulnerability) – Reviewer for the A1 Morpeth to Felton ES climate chapter – Reviewer for the A1 Alnwick to Ellingham ES climate chapter – Member of working group to update the IEMA EIA Guidance on Climate Resilience

14.3. LEGISLATIVE AND POLICY FRAMEWORK

INTERNATIONAL LEGISLATION

Directive 2014/52/EU on the Assessment of the Effects of Certain Public and Private Projects on the Environment (the EIA Directive)

14.3.1. The EIA Directive provides the overarching legislative framework for assessing the significance of impacts and effects from schemes on the environment.

14.3.2. The Directive requires Environmental Impact Assessment (EIA) to identify, describe and assess the direct and indirect significant effects of a project on climate (Article 3). It also stipulates that the information to be included within the Environmental Impact Assessment report should include *"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"* (Annex IV).

NATIONAL LEGISLATION

UK Climate Change Act

14.3.3. The Climate Change Act 2008 established a legal requirement for an 80% reduction in the GHG of the UK economy by 2050 in comparison to the 1990 baseline. The Act also created the Committee on Climate Change, with responsibility for:

a. Setting five-year carbon budgets, covering successive periods of emissions reduction to 2050.
b. Advising and scrutinising the UK Government's climate change adaptation programmes.
c. Producing a national adaptation plan for the UK Government to implement.

14.3.4. In 2011, Highways England was required to complete a climate change adaptation report (referred to as Adaptation Reporting Power or ARP1 (**Ref 14.2)**) and submit it to the UK Government to inform the national adaptation plan. In 2015, Highways England submitted a voluntary report (ARP2, **Ref 14.3**) on progress since ARP1. Through undertaking this process, Highways England were able to identify the key climate, and weather related risks affecting their network and evidence actions that they are, and will take, to reduce their impacts. Many of the risks identified in these reports are relevant to the Scheme.

Infrastructure Carbon Review

14.3.5. In 2013, the UK government published the Infrastructure Carbon Review (**Ref 14.4**) aiming to *"release the value of lower carbon solutions and to make carbon reduction part of the DNA of infrastructure in the UK."* Major infrastructure owners, operators and developers were invited to endorse, become signatories and make commitments under the review. Highways England was one of these organisations.

14.3.6. The review provided increased emphasis on 'capital carbon' (GHG emissions associated with raw materials, activities and transport for construction, repairs, replacement, refurbishment and de-construction of infrastructure) while acknowledging that 'operational carbon' (associated with energy consumption for the operation and use of infrastructure) will continue to dominate overall emissions to 2050 and beyond.

14.3.7. The Infrastructure Carbon Review highlighted the importance of assessing GHG emissions early in the lifecycle of an infrastructure scheme when there is the greatest carbon reduction potential. It is for this reason that the 'carbon footprint' of the Scheme continues to be assessed and targeted at each stage of the Scheme. The Infrastructure Carbon Review also led to the publication of the Publicly Available Specification on carbon management in infrastructure (PAS 2080:2016) (**Ref 14.5**). The methodology in this chapter aligns with the approach set out in PAS 2018:2016.

NATIONAL POLICY

14.3.8. National policy relevant to the effects on Climate is outlined in **Table 14-2**.

Table 14-2 – National policy

Policy	Relevant Policy Objectives	Significance of impact of the Scheme on policy objective
National Policy Statement for National Networks (NPS NN) (**Ref 14.6**)	Chapter 3 of the NPS NN: Wider Government policy on national networks - Emissions: – Identifies that the transport sector will play an important part in meeting the Government's carbon targets. It is acknowledged that technologies, fuels, and promoting lower carbon transport choices will	The Scheme does not contribute positively to government carbon targets albeit the impacts of construction and operation are not concluded to be significant.

Policy	Relevant Policy Objectives	Significance of impact of the Scheme on policy objective
	make the biggest reductions and that (comparatively) the likely impact from road development is "very small."	
NPS NN (**Ref 14.6**)	Chapter 4 of the NPS NN: Assessment principles Climate Change Adaptation: – Sets out the how the policy statement shall be put into practice with regards to climate change mitigation and adaptation when developing and consenting infrastructure. – With regards to the decision-making process, the policy states that *"the applicant must demonstrate that a full account has been taken of the policy on assessment and mitigation…taking account of the potential effects of climate change on these risks."* Flood Risk: – Acknowledges the fact that climate change will likely lead to an *"increased flood risk in areas susceptible to flooding, and to an increased risk of flooding in some areas which are not currently thought of as being at risk."* It also states that an applicant's assessment should *"identify and assess the risks of all forms of flooding to and from the project and demonstrate how these flood risks will be managed, taking climate change into account"* by taking *"the impacts of climate change into*	The assessment of climate resilience (including flood risk) and the identification and incorporation of adaptation measures aligns the Scheme with these objectives.

Policy	Relevant Policy Objectives	Significance of impact of the Scheme on policy objective
	account, clearly stating the development lifetime over which the assessment has been made" when preparing the flood risk assessment.	
NPS NN (**Ref 14.6**)	Chapter 5 of the NPS NN: Generic Impacts Applicant's assessment: – Sets out that *"it is very unlikely that the impact of a road project will, in isolation, affect the ability of Government to meet its carbon reduction plan targets."*	The Scheme in isolation will not affect the ability of Government to meet its carbon reduction plan targets.
National Planning Policy Framework (NPPF) (2019) **(Ref 14.7)**	The NPPF (**Ref 14.7**) sets out the core planning principle of supporting *"the transition to a low carbon future in a changing climate…":* Chapter 10 of the NPPF: Meeting the Challenge of Climate Change, Flooding and Coastal Change - establishes that local planning authorities should *"adopt proactive strategies to mitigate and adapt to climate change"* with particular focus on reducing emissions, energy (efficiency and renewables, for example), flood risk and coastal change.	The Climate assessment has identified any significant effects (GHG emissions and climate vulnerability) and identified appropriate mitigation measures which have been incorporated into the design. This helps to deliver the policy objectives of a low carbon future and adaptation to climate change.
Highways England Climate Change Adaptation Strategy and Framework	Highways England's Climate Change Adaptation Strategy and Framework (2009) has led to modifications in existing standards on the national network. Local roads are maintained by upper tier and unitary local authorities in Great Britain. For local roads, the UK Roads Liaison Group Code of Practice for Well Maintained Highways sets out a regularly updated set of recommendations for dealing with climate change by local authorities.	The assessment of climate resilience and the identification and incorporation of adaptation measures aligns the Scheme with these objectives.

LOCAL POLICY

14.3.11. Local policy relevant to the potential effects on Climate is outlined in **Table 14-3**.

Table 14-3 – Local policy

Policy	Relevant Policy Objectives	Significance of impact of the Scheme on policy objective
Gateshead Local Plan Policies (2015) (**Ref 14.8**) and Planning for the Future (2015) (**Ref 14.9**)	These documents set out the vision, the core strategy and urban core plan policies for Gateshead Council and Newcastle City Council that address climate change. The Spatial Vision Statement includes the focus and importance of low carbon economy and sustainable development which will be supported by new developments that are designed to mitigate and adapt to the impacts of climate change. The policies emphasise the need to consider climate change: – CS1 Spatial Strategy for Sustainable Growth: This sets out that all developments need to be *"designed to reduce carbon emissions and adapted to the effects of climate change."* – CS16 Climate Change: This sets out the requirements to ensure that development will be sustainable in regard to functioning effectively in a changing climate and addressing the impacts on climate change emissions. – CS17 Flood Risk and Water Management: This sets out the requirement for developments to consider the impacts of climate change when avoiding and	The assessment of construction and operational GHG emissions as well as climate vulnerability (including flood risk) and the identification and incorporation of adaptation measures aligns the Scheme with these objectives.

Policy	Relevant Policy Objectives	Significance of impact of the Scheme on policy objective
	managing flood risk over its lifetime.	
Planning for the Future - Sustainability Appraisal Adoption Statement (2015) (**Ref 14.9**)	This document identifies the Sustainability Objectives and the Spatial Vision and Strategic Objectives, which include: *"Adapt to and mitigate against the impacts of climate change:* – *Reduce our contribution to the causes of climate change.* – *Make sure we adapt to the effects of climate change and mitigate against its impacts in future development"* *"To reduce CO_2 emissions from new development and future growth while adapting to the issues, mitigating adverse impacts and take advantage of the opportunities presented by climate change."*	The assessment of construction and operational GHG emissions as well as climate vulnerability (including flood risk) and the identification and incorporation of adaptation measures aligns the Scheme with these objectives.

14.4. ASSESSMENT METHODOLOGY

EFFECTS OF THE SCHEME ON CLIMATE

Scope of the Assessment

14.4.1. The scope of the GHG assessment for the construction stage (2020-2023) is set out in **Table 14-4** in terms of the lifecycle stages and the corresponding potential sources of emissions.

Table 14-4 – Construction stage - emissions sources included in the assessment

Lifecycle Stage	Potential Sources of Emissions	Activity Data
Product stage; including raw material supply,	Embodied emissions associated with the required raw materials.	– Available information for construction materials required for this Scheme include: – Bulk materials for earthworks.

Lifecycle Stage	Potential Sources of Emissions	Activity Data
transport and manufacture.		– Road paving materials, including sub-base and bituminous materials. – Steel for structures, reinforcement and signage. – Concrete including pre-cast or prefabricated elements. – Aggregate. – Timber for fencing and formwork. – Aluminium street furniture and signage. – Copper cabling. – Other general construction materials.
Construction process stage; including transport to/from works site and construction/installation processes.	Activities for organisations conducting construction work, including emissions associated with use of heavy good vehicles and construction plant.	Transportation of materials from point of purchase to site, mode/distance. Fuel/electricity consumption and construction activity type/duration.

14.4.2. The scope of the GHG assessment for the operation stage (2023-2083) is set out in **Table 14-5** in terms of the lifecycle stages and the corresponding potential sources of emissions.

Table 14-5 – Operational stage - emissions sources included in the assessment

Lifecycle Stage	Potential Sources of Emissions	Activity Data
Use of the infrastructure by the end-user.	Vehicles using highways infrastructure.	Traffic count/speed by vehicle type for highway links.
Maintenance/refurbishment.	Activities for organisations conducting maintenance/refurbishment, including transportation to site and construction plant for the works. Embodied emissions associated with	Number of replacements/repairs to assets over design life.

Lifecycle Stage	Potential Sources of Emissions	Activity Data
	the required raw materials for the maintenance/refurbishment works.	

Methodology

Emissions Calculations

14.4.3. For the construction and operation lifecycle stages of the Scheme, the assessment involves the following:

a. Collection of available data/information on the scale of GHG emitting activities for the baseline scenario and for the Scheme.
b. Calculation of the GHG emissions using a standard emissions calculation methodology applying a suitable emissions factor.

14.4.4. Emissions calculations have been completed using Highways England's Carbon Tool (**Ref 14.10**) which is an industry recognised carbon calculation tool focusing on emissions throughout the project lifecycle. Values have been reported as tonnes of carbon dioxide equivalents (tCO_2e).

14.4.5. The total operational stage end-user GHG emissions from traffic, have been modelled in accordance with the Design Manual for Roads and Bridges, Volume 11, Section 3, Part 1 Air Quality (HA 207/07) (**Ref 14.1**). The modelling includes the do-minimum and do-something total GHG emissions for all vehicles covered by the traffic model covering the Affected Road Network.

Significance of Effects

14.4.6. In line with the NPS NN (2014) (**Ref 14.6**), significance of effects has been assessed by comparing estimated GHG emissions arising from the Scheme with UK carbon budgets, and the associated reduction targets, outlined in **Table 14-6.**

Table 14-6 - UK carbon budgets and reduction targets

Carbon Budget	Carbon Budget Level	Reduction Below 1990 Levels
Third carbon budget (2018 – 2022)	2,544 $MtCO_2e$	37% by 2020
Fourth carbon budget (2023-2027)	1,950 $MtCO_2e$	51% by 2025
Fifth carbon budget (2028 –2032)	1,725 $MtCO_2e$	57% by 2030

14.4.7. The comparison of the do-minimum and the do-something scenario is presented with and without carbon reduction opportunities realised.

14.4.8. The NPS NN (2014) also sets out that *"it is very unlikely that the impact of a road project will, in isolation, affect the ability of Government to meet its carbon reduction plan targets."*

14.4.9. There are currently no agreed thresholds for what level of GHG emissions is considered significant in an EIA. However, the impact is considered more significant the greater the total emissions and the greater the proportion they represent of the carbon budget.

14.4.10. Professional judgement based on schemes of a similar size and nature has been used to consider and assess the significance of NPS NN (2014) (**Ref 14.6**), by comparing estimated GHG emissions arising from the Scheme with UK carbon budgets, and the associated reduction targets, outlined in **Table 14-6**.

Data Sources

14.4.11. Data on GHG emitting activities during construction and operation (see **Table 14-4** and **Table 14-5**) was sourced from the Scheme design team and buildability support contractor.

Policy and Guidance

14.4.12. The following guidance documents have informed the methodology for this assessment:

a. IEMA (2017) Environmental Impact Assessment Guide to: Assessing Greenhouse Gas Emissions and Evaluating their Significance (**Ref 14.11**).
b. European Commission Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment (European Commission, 2013) (**Ref 14.12)**.
c. NPS NN (2014) (**Ref 14.6**).

VULNERABILITY OF THE SCHEME TO CLIMATE CHANGE

Scope of the Assessment

14.4.13. The scope of the vulnerability assessment is limited to the construction and operational phases of the Scheme. The following climate variables are considered in this assessment.

a. Precipitation:
  i. Changes in seasonal average
  ii. Drought
  iii. Extreme precipitation events
  iv. Snow

b. Temperature:
  i. Changes in seasonal average
  ii. Extreme temperature events
  iii. Solar radiation

c. Wind:
  i. Gales and extreme wind events
  ii. Storms (lightning, hail)

d. Relative Humidity:
  i. Changes in annual average

e. Water quality and soils:
   i. Soil moisture
   ii. Salinity/pH
   iii. Runoff
   iv. Soil stability

Methodology

14.4.14. The climate vulnerability assessment focusses on identifying the risks for receptors to relevant climate variables and climate-related hazards, such as those outlined in **Table 14-7.** The level of exposure of the Scheme receptors is then determined based on an analysis of observed climate, scenarios for projected future climate and a literature review of associated climate hazards.

Table 14-7 - Typical climate variables and related hazards

Climate Variable	Climate-Related Hazard
Average (air) temperature change (annual, seasonal, monthly)	Sea level rise (plus local land movements), storm surge/tide
Extreme (air) temperature (frequency and magnitude)	Water availability/drought
Average precipitation (annual, seasonal, monthly)	Flood (coastal and fluvial)
Extreme rainfall (frequency and magnitude)	Subsidence and ground stability
Average wind speed change (annual, seasonal, monthly)	Fog
Gales and extreme winds (frequency and magnitude)	Storms (tracks and intensity), including storm surge
Humidity	Snow, ice and hail
Solar radiation	Storms and lightning

14.4.15. The significance of effects depends on the likelihood of them occurring and the consequence if they do occur. Likelihood and consequence can be qualitatively assessed using the descriptions in **Table 14-8** and **Table 14-9**. Note, the latter considers both the potential extent and severity of disruption associated with the effects, whilst likelihood takes account of the rate of climate change. The assessment of likelihood is informed by observed climate and projections of future climate.

Table 14-8 – Qualitative description of consequence

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

Table 14-9 – Qualitative description of likelihood

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

14.4.16. These determinants are then combined to develop a significance rating (**Table 14-10**).

Table 14-10 – Significance rating matrix

Likelihood	Consequence				
	Negligible	Minor adverse	Moderate adverse	Large adverse	Very large adverse
Very high	NS	S	S	S	S
High	NS	S	S	S	S
Medium	NS	NS	S	S	S
Low	NS	NS	NS	S	S
Very low	NS	NS	NS	NS	NS
N.B: NS = not significant and S = significant.					

14.4.17. In the final step, adaptation measures are identified for 'significant' climate risks, through consultation with the Scheme design team and using professional judgement. Taking account of the contribution of the incorporated measures to climate resilience, a summary of the level of climate resilience of the Scheme elements to significant climate variable/hazards is applied, based on the following rankings:

a. **High** - a strong degree of climate resilience, remedial action or adaptation may be required but is not a priority.
b. **Moderate** - a moderate degree of climate resilience, remedial action or adaptation is suggested.
c. **Low** – a low level of climate resilience, remedial action or adaptation is required as a priority.

Data Sources

14.4.18. The following data sources have been used in this assessment:

a. UK Climate Projections (2018) (UKCP18) – for projections of UK climate change projections
b. UK Climate Projections (2009) (UKCP09) – for projections of UK climate change
c. Centre for Environmental Data Analysis (CEDA) – for observed climate data
d. **Chapter 13 Road Drainage and the Water Environment** of this ES **(Application Document Reference: TR010031/APP/6.1)** – for drainage inputs

Policy and Guidance

14.4.19. The following policy and guidance documents have been used to inform the methodology detailed in this section:

a. NPS NN (2014) **(Ref 14.6).**
b. IEMA (2015) Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation **(Ref 14.13)**.
c. European Commission (2013) Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment **(Ref 14.12).**

d. European Commission (2016) Climate change and major projects **(Ref 14.14).**
e. European Commission Non-paper Guidelines for Project Managers: Making vulnerable investments climate resilient (2013) **(Ref 14.15).**
f. Highways England (2016) Climate adaptation risk assessment progress update **(Ref 14.16).**

Consultation

14.4.20. Through dialogue with the Scheme design team, a range of adaptation measures were identified (see **Table 14-13**) to reduce the vulnerability of the Scheme to the climate and weather related risks identified in this assessment.

14.5. ASSESSMENT ASSUMPTIONS AND LIMITATIONS

14.5.1. The draft Development Consent Order (DCO) contains powers of lateral and vertical deviation. The EIA has taken the Limits of Deviation (LoD) into account and the approach taken is described in **Chapter 4 Environmental Assessment Methodology, paragraph 4.5.4** of this ES (**Application Document Reference: TR010031/APP/6.1**). The outputs of the assessment are not considered likely to change materially as a result of the power of deviation.

EFFECTS OF THE SCHEME ON CLIMATE

14.5.2. There is currently no specific guidance or carbon emissions thresholds, which, if exceeded, are considered significant.

14.5.3. Type and quantities of material and waste provided at this stage are indicative and will be refined as the design of the Scheme progresses.

14.5.4. Data has been provided by the Buildability Support contractor, based on the current design for the Scheme. The data included the anticipated source of construction materials, anticipated waste disposal method and anticipated waste management facilities.

VULNERABILITY OF THE SCHEME TO CLIMATE CHANGE

14.5.5. The assessment undertaken here provides a broad indication of the potential impacts of climate change on the Scheme based on a qualitative and quantitative assessment and professional judgement.

14.5.6. There is currently no agreed methodology that should be applied for assessing the vulnerability of major schemes, including road infrastructure, under the new EIA regulations. Therefore, an approach has been developed and applied in this assessment based on existing best practice in collaboration with the Applicant and the team climate specialists.

14.5.7. The UKCP18 projections **(Ref 14.17)** have been used to infer future changes in a range of climate variables that may affect the vulnerability of the Scheme to climate change. At the time of writing, these represent the most up-to-date representation of future climate in the UK. However, the UKCP18 data currently available does not provide data for extreme precipitation, drought, snow and ice, extreme temperature, solar radiation, wind or relative humidity. Data for these aspects has been taken from UKCP09 **(Ref 14.17)**.

14.5.8. There are inherent uncertainties associated with climate projections and they are not predictions of the future. It is possible that future climate will differ from the baseline climate against which the resilience of the Scheme has been assessed depending on global emissions over the next century. A ‘high’ emissions scenario (Representative Concentration

Pathways (RCP) 8.5) using the 2080s timeslice (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) and is in-line with the design life of the Scheme.

14.5.9. Broadly speaking, the UKCP09 scenarios cover a similar range of future climate change forcings as the RCP4.5 to RCP8.5 scenarios used in UKCP18. There is considerable overlap between the two sets of projections over land, with uncertainty ranges being broad in both cases. The differences between UKCP18 and UKCP09 at any particular percentile level appears much smaller than the 5th to the 95th percentile spread for the season and variable being assessed. Therefore, there is expected to be minimal difference between the UKCP18 and UKCP09 projections adopted in this study.

14.5.10. Any further research, analysis or decision-making should take account of 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.

14.5.11. The determination of resilience has been undertaken under the assumption that robust design standards will be adhered to where detailed information is unavailable.

14.6. STUDY AREA

EFFECTS OF THE SCHEME ON CLIMATE

14.6.1. The GHG assessment is not restricted by geographical area but instead includes any increase or decrease in emissions as a result of the Scheme.

14.6.2. The Study Area can therefore be split up to include the following:

a. Primary: construction emissions within the Scheme Footprint.
b. Secondary: regional emissions associated with the operation of the new Scheme infrastructure but also emissions (or reduction in emissions) which result from the end-use of the Scheme and any shifts in transport modes/patterns which may occur.
c. Tertiary: the emissions associated with the manufacturing of construction materials, transportation of materials to and from the Scheme, and from the disposal of materials in the UK/globally.

VULNERABILITY OF THE SCHEME TO CLIMATE CHANGE

14.6.3. The Study Area for the vulnerability assessment is the Scheme itself as it is the receptor.

14.6.4. The choice of climate projections to use in the assessment also informs the Study Area. UKCP18 provides probabilistic projections for the whole of the UK at 25km^2 resolution. The Study Area of the assessment is limited to the 25km^2 UKCP18 grid square (437500.00, 562500.00) which encompasses the Scheme (**Figure 14-1,** below), and supplemented by the 25km^2 UKCP09 grid square (ID: 1004) where data under UKCP18 is not available (

14.6.5. **Figure** 14-2).

14.6.6. In addition, it is likely that changes in climate and extreme weather events may be influenced by regional characteristics, therefore, reference is also made to the geographical

region in which the Scheme is located, the north-east region (**Figure 14-2**), where appropriate.

Figure 14-1 - Location of 25km^2 grid box used for UKCP18 (437500.00, 562500.00)

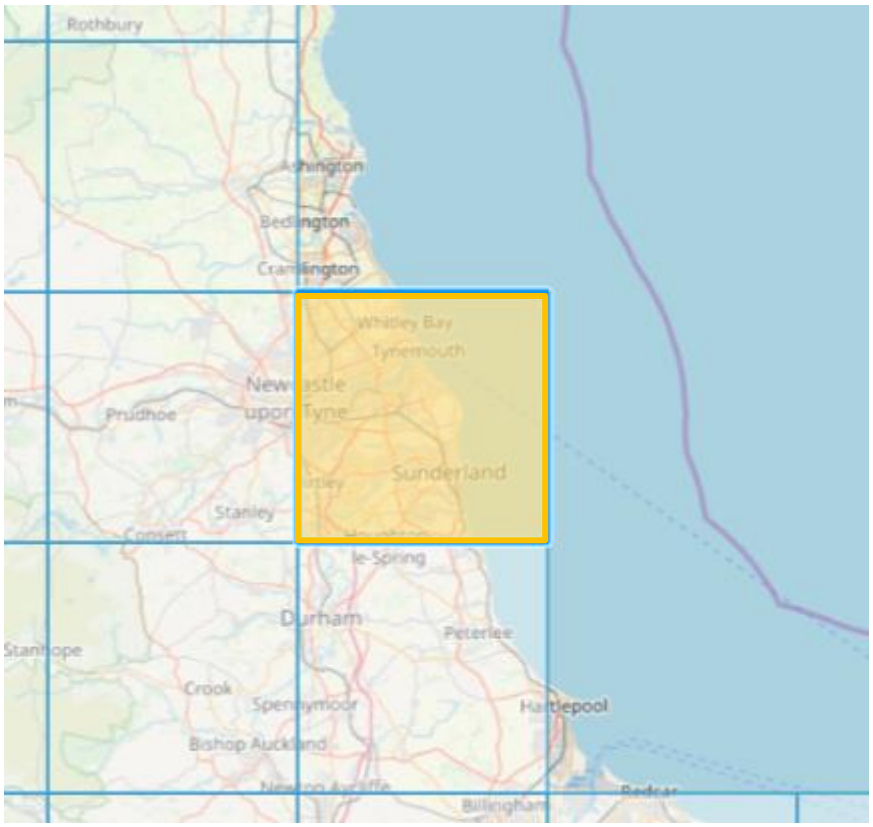


Figure 14-2 – Location of 25km^2 grid square for UKCP09 (ID: 1004)

Figure 14-3 – Location of north-east region in both UKCP18 and UKCP09

14.7. BASELINE CONDITIONS

EFFECTS OF THE SCHEME ON CLIMATE

14.7.1. In the baseline (do-minimum) scenario, GHG emissions occur constantly and widely as a result of human and natural activity including energy consumption (fuel, power), industrial processes, land use and land use change. The GHG assessment only considers where the Scheme results in additional or avoided emissions in comparison to the baseline scenario and its assumed evolution.

14.7.2. One of the drivers for the Scheme is to reduce the amount of minor maintenance works required on the Allerdene Bridge. As such, emissions associated with the day-to-day (routine) works have been considered as part of the baseline conditions.

14.7.3. The operation and management of the current Scheme assets is likely to require a small amount of specialist components (for example, light bulbs, signage; and for the bridge: cement; steelwork) as well as some bulk material (cement, concrete, sand and gravel) for minor maintenance and refurbishment works. These materials have embodied emissions associated with them. Due to the small materials quantities required, however, emissions are minor.

14.7.4. The do-minimum scenario (i.e. the Scheme is not pursued) would be unlikely to change the current consumption of materials within the current land boundary of the Scheme, though it

has been noted that the regular maintenance works required on the Allerdene Bridge is likely to consume more materials per unit time than comparable (but newer) structures.

14.7.5. In terms of user emissions from road vehicles, the Scheme currently suffers congestion, particularly during peak hours, which can result in unreliable journey times. Traffic is also expected to grow with new housing and employment developments planned for the area.

14.7.6. The total end-user GHG emissions from traffic flows in the 'do-minimum' (baseline) scenario are presented in **Table 14-11.** The emissions have been modelled in accordance with the Design Manual for Roads and Bridges, Volume 11, Section 3, Part 1 Air Quality (HA 207/07) (**Ref 14.1**). The modelling includes the total GHG for all vehicles covered by the traffic model covering the Affected Road Network.

14.7.7. Total CO_2 emissions are expected to increase by 11% between 2023 (opening year) and 2038 (following 15 years' operation). This is because of increased vehicles (traffic growth) dominating over improvements in vehicle emission rates, in terms of the overall mass of CO_2 emissions.

Table 14-11 - Baseline GHG emissions data for end user traffic in the region of the Scheme

Scenario	Total GHG emissions for all traffic in the traffic model area (thousand tonnes of carbon dioxide equivalent; $kTCO_2e$)			
	2023	2038	Average per year (2023 – 2082)	Total (2023-2082)
Baseline (do minimum)	1,466	1,624	1606	97,960

VULNERABILITY OF THE SCHEME TO CLIMATE CHANGE

14.7.8. **Appendix 14.1** of this ES (**Application Document Reference: TR010031/APP/6.3**) provides details of local climate, past weather events and projected changes in climate using the UKCP09 and UKCP18 probabilistic projections for the Study Area.

14.7.9. The vulnerability of the Scheme to climate change depends on the level of exposure of the receptors to changes in different climate variables. Due to the lag in the climate system and given past emissions of GHGs, some degree of climate change is inevitable in the near-term (<20-30 years). In the short-term, natural variability will dominate the weather-related risks that we experience, including extreme events (such as storms and heatwaves). Over the long term, the climate we experience will be influenced by levels of GHG emissions. The RCPs (from UKCP18) specify the concentrations of GHGs 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. RCP8.5 broadly corresponds to a high emissions scenario.

14.7.10. Climate change and extreme weather events will bring challenges for the UK's infrastructure over time, including in the short (2030s), medium (2050s) and long-term (2080s). The

design life of the Scheme (60 years for roads and 120 years for bridges) has been used to identify the temporal boundary for the climate vulnerability assessment. In light of the above, the assessment presented here considers the 2030s, 2050s and 2080s time slices and focusses on the RCP8.5 (UKCP18) or High emissions scenario (UKCP09).

14.7.11. The projections provided by UKCP09 and UKCP18 are probabilistic, which means that rather than a single 'best-guess' of the impact of climate change they provide a range of outcomes based on an 'ensemble' of multiple climate model runs. This better represents the uncertainty of climate prediction science. To help demonstrate consideration of uncertainty inherent within climate modelling, projections for the 10th, 50th (central) and 90th percentiles are stated, where possible. The 10th percentile describes the value at which 10% of the model runs fall at or below, the 50th percentile is the value at which half the climate scenarios fell below the figure and half fell above it, and the 90th percentile described the value at which 10% of the model runs fall at or above.

14.7.12. The Scheme receptors are:

a. Built structures (including gantries and other related overhead structures), including Allerdene Bridge.
b. Geotechnics (including earthworks, embankments and foundations).
c. Hard surfaces e.g. pavements.
d. Roadside infrastructure (including signs and signals).
e. Soft estate (including vegetation).
f. Health and Safety of users (operators and customers).

14.8. POTENTIAL IMPACTS

EFFECTS OF THE SCHEME ON CLIMATE

14.8.1. The Scheme with both Allerdene embankment option and Allerdene viaduct option have been considered. The impacts are the same for both options, but the significance of the effects may vary depending on the option.

14.8.2. The impacts of GHGs relate to their contribution to global warming and climate change. These impacts are global and cumulative in nature, with every tonne of GHG contributing to impacts upon natural and human systems.

14.8.3. GHG are natural and man-made gases occurring in the atmosphere, which absorb and emit infrared radiation thereby maintaining the Sun's energy within the Earth's atmosphere. There is an overwhelming scientific consensus that the major increase in the concentration of greenhouse gases from man-made sources is contributing to global warming and climate change.

14.8.4. The seven main GHGs defined by the Kyoto Protocol are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride. In combination, these GHG emissions are commonly expressed in terms of carbon dioxide equivalents according to their relative global warming potential. For this reason, the shorthand 'carbon' may be used to refer to GHGs.

14.8.5. GHG emissions will occur as a result of human activities with or without the Scheme. The baseline data shows that, in the absence of the Scheme, end-user traffic emissions will increase. However, the Scheme has the potential to result in further increases in GHG emissions associated with construction activities (such as manufacturing of materials and

construction processes). Furthermore, the Scheme may result in changes to end-user traffic emissions throughout its operational life, which could be an increase or decrease, depending on the effect on traffic flows and speeds. Any increase in emissions and the corresponding concentrations of GHGs present in the atmosphere would contribute to global warming and climate change.

14.8.6. The Scheme is designed to increase capacity which may result in a reduction in emissions per vehicle where congestion is relieved. Furthermore, speed restrictions along sections of the A1 may result in a reduction in emissions per vehicle, particularly during inter-peak and off-peak hours in current high-speed areas. However, the benefits of reduced emissions per vehicle may be offset by increases in vehicle flows and, on some sections, by an increase in vehicle emissions due to an increase in vehicle speeds.

VULNERABILITY OF THE SCHEME TO CLIMATE CHANGE

14.8.7. The Scheme with both Allerdene embankment option and Allerdene viaduct option have been considered. The impacts are the same for both options.

14.8.8. Potential climate and weather-related impacts affecting the Scheme receptors over the construction and operational phases are described in **Table 14-12**.

Table 14-12 – Climate variables and potential impacts for the Scheme

Climate variable	Associated hazards	Potential impact (construction and operational phase)					
		Structural stability	Structural robustness	Weather proofing and detailing	Material durability	Site contents and business continuity	Health and Safety of users (operators and customers)
Precipitation	**Extreme rainfall events**	– Damage to carriageway structures between junction 65 (Birtley) to junction 67 (Coal House) due to increased run-off. – Soil saturation and water damage. – Undercutting of Kingsway Viaduct. – Increased slope instability. – Damage to unpaved shoulders. – Erosion, silting and sedimentation.	-	– Guttering and drainage becoming overwhelmed – Blockages of drainage assets – Greater mobilisation of pollutants in soil/ground causing premature deterioration of materials	– Softening of subsurface materials on the carriageways between junction 65 (Birtley) to junction 67 (Coal House)	– Water accumulation causing disruption to construction and operation. – Stopping of services due to asset failure. – Scour of embankments leading to increased maintenance, in particular of the Kingsway Viaduct. – Traffic disruption and congestion. – Excessive vegetation growth. – Operational disruption. – Reduced opportunities for maintenance.	– Difficult working conditions. – Movement of debris causing slip, trip and fall hazards. – Health and safety risks to road users
	Drought	– Loss of vegetation across the Scheme leading to greater erosion risk.	– Drying out of construction materials and cracking on carriageway between junction 65 (Birtley) to junction 67 (Coal House). – Deformation of rigid structures.	– Damage and disruption from fires.	– Enhanced reactions during curing of cement and concrete. – Increased rate of deterioration of materials, potentially leading to need for early replacement on carriageways and bridges such as the Allerdene Bridge	– Evaporation of construction water.	– More dust.

Climate variable	Associated hazards	Potential impact (construction and operational phase)					
		Structural stability	Structural robustness	Weather proofing and detailing	Material durability	Site contents and business continuity	Health and Safety of users (operators and customers)
					and the Longbank Bridleway Underpass. – Shrinking and cracking.		
	Drier summers	– Subsidence – Failure of earthworks due to desiccation affecting carriageways and bridges. – Shrinking and cracking of soils.		– Increased dust and windborne materials affecting site construction, operation and maintenance, including silting and sedimentation. – Damage and disruption from fires.	– Enhanced reactions when cement stabilising and drying of concrete		
	Wetter winters (including flooding and/or repeated wet cycles)	– Damage due to increased run-off – Soil softening and erosion leading to collapse and settlement of soil structures – Increased slope instability, particularly in past coal mining areas – Soil saturation – Damage to unpaved shoulders	– Deformation of rigid structures – Undercutting of Kingsway Viaduct	– Blockage of drains and associated assets – Water accumulation in low spots and/or on impermeable surfaces – Excessive vegetation growth – Softening of subsurface materials	– Greater mobilisation of pollutants in the soil/ground	– Increasingly difficult working conditions, including time available to undertake works – Reduced opportunities for maintenance	– Movement of debris causing slip, trip and fall hazards
Temperature	**Extreme temperature events**	– Cracking and expansion affecting bridges such as Allerdene Bridge, North Dene. Footbridge and Smithy Lane Overbridge. – Overheating of equipment.	– Risks to stored equipment, including waste. – Damage and disruption (e.g. fires). – Risks to stored equipment, including waste.	– Damage to external weather proofing and detailing at ground level. – Higher day and night-time temperatures.	– Enhanced reactions during curing of cement and concrete on carriageway. between junction 65 (Birtley) to junction 67 (Coal House).	– Reduced working periods and delays. – Reduced opportunities for maintenance. – Operational disruption	– Difficult working conditions. – Increased fire risk. – Hot surfaces which may cause injury. – Failure of temperature controls

Climate variable	Associated hazards	Potential impact (construction and operational phase)					
		Structural stability	Structural robustness	Weather proofing and detailing	Material durability	Site contents and business continuity	Health and Safety of users (operators and customers)
		– Increased risk of erosion.			– UV degradation of exposed equipment e.g. cabling.		– Health and safety risks to road users.
	Hotter summers	– Overheating of equipment			– Enhanced reactions during curing of cement and concrete.	– Reduced opportunities for maintenance. – Greater demand for cooling. – Higher summer river temperatures. – Risks to gas distribution at compressor stations due to high temperatures (leading to lower delivery pressures).	– Difficult working conditions. – More dust. – Evaporation of construction water.
	Changes in solar radiation			– Increased solar gain (i.e. glare and warming of exposed surfaces)	– Deformation of materials		
Wind	**Gales and extreme wind events**	– Risk of damage to structures such as gantries and foundations, including from flood scour and/or run-off, affecting the Kingsway Viaduct. – Damage to signage and site structures. – Erosion of banks and exposed surfaces.		– Damage from high winds and rain-infiltration into surfaces and materials.	– Increased rate of deterioration of materials on carriageways from junction 65 (Birtley) to junction 67 (Coal House), potentially leading to need for early replacement.		– Difficult working conditions. – Health and safety risks to road users.

Climate variable	Associated hazards	Potential impact (construction and operational phase)					
		Structural stability	Structural robustness	Weather proofing and detailing	Material durability	Site contents and business continuity	Health and Safety of users (operators and customers)
	Storms (snow, hail, lighting)	– Destabilisation due to lighting strike.				– Risk to power sources – Risk to operation and loss of power. – Electrical surges. – Fire risk.	– Difficult working conditions – Health and safety risks to road users.
Relative humidity	**Humidity**			– Damage to external weather proofing and detailing at ground level (i.e. from condensation, mould growth and/or mildew).	– Excessive moisture in building materials. – Excessive moisture in sheltered (i.e. north-facing) surfaces.		– Uncomfortable working conditions.
Water quality	**Soil stability**	– Subsidence. – Failure of earthworks due to desiccation, particularly in already at-risk coal mining areas. – Shrinking and cracking of soils.				– Increased maintenance costs and risks to operation.	

14.9. DESIGN, MITIGATION AND ENHANCEMENT MEASURES

EFFECTS OF THE SCHEME ON CLIMATE

Construction and Operation

14.9.1. The effects on climate from the construction of the Scheme are inherently linked to the consumption of materials resources (including any site arisings that can be recovered and diverted from landfill), the generation and disposal of waste, and the transport of these to/from site. There are also effects on climate associated with the construction process stage.

14.9.2. The following mitigation measures would be implemented:

- **a.** As far as possible, material resource efficiency and waste minimisation good practice would be incorporated into detailed design.
- **b.** Material resources would, as far as possible, be designed and specified to minimise the amount of embedded carbon to minimise environmental impact.
- **c.** Measures associated with the minimisation of waste and maximising re-use of materials on site would be incorporated into the Construction Environmental Management Plan (CEMP), Site Waste Management Plan (SWMP) and Materials Management Plan (MMP) for the Scheme.
- **d.** Re-use of material resources from Scheme demolition activities in the construction of the new road.
- **e.** Maximise off site construction to minimise waste.
- **f.** Deconstruct North Dene Footbridge so that it can be re-used elsewhere on the highway network (the feasibility of which will be explored and confirmed as the design progresses).
- **g.** Reduce the GHG emissions intensity of raw materials by specifying best-in-class products with reference to information published in Environmental Product Declarations (EPDs).
- **h.** Adoption of vehicles with best-in-class efficiency for construction, delivery, maintenance and de-construction.
- **i.** Adoption of efficient logistics management for transport of construction materials and excavated material.
- **j.** Adoption of plant and processes with best-in-class efficiency for construction, maintenance and refurbishment activities.
- **k.** Specification of best-in-class energy efficient systems for operations e.g. lighting and signage.

VULNERABILITY OF THE SCHEME TO CLIMATE CHANGE

14.9.3. This section outlines the adaptation measures that would be integrated into the Scheme in response to the potential impacts that have been identified. Note, Scheme phases (construction and operation) are differentiated where appropriate.

Identification of Planned Adaptation Measures

14.9.4. In consultation with the project team, a range of adaptation measures have been identified in **Table 14-13** to reduce the vulnerability of the Scheme to the identified climate- and weather-related risks.

Table 14-13 – Potential impacts and planned adaptation measures for the Scheme

Component	Potential impacts	Adaptation measure(s)
Structural stability	Damage to structures due to increased runoff and changes to soil stability (construction and operation).	A 20% increase to allow for climate change has been included in the design. Further details are provided in **Chapter 13 Road Drainage and the Water Environment** of this ES (**Application Document Reference: TR010031/APP/6.1)**. Allowance for climate change is also to be applied for the entire catchment area inclusive of the new paved areas. Flows exceeding the revised discharge rate are to be attenuated and released at a rate which is identical to the existing. This will be facilitated with the Allerdene attenuation pond which will be developed to manage the flow of water. This is to be made permanent during operation to manage surface water from the carriageway. Concrete exposure classes (relating to the environmental/ground conditions at the structure location) have been selected to ensure all structures have a design life of at least 120 years with minimal maintenance. The following structures on the Scheme are considered to have piled foundations (into bedrock): Kingsway Viaduct, Allerdene Bridge (both the embankment and viaduct option), Longbank Bridleway Underpass extension and all ADS Gantries. Ground improvement works in the form of rigid inclusions will be also carried out to the embankment around Allerdene Bridge. This will ensure that any soil related settlement is reduced as much as practically possible.
	Loss of vegetation leading to greater erosion risk (operation).	Regular maintenance and preventative action through landscaping. Vegetation management. Where vegetation is cleared for earthworks, replanting of woodland/woodland edge/linear tree belts/hedges would occur to tie in with adjacent planting.
	Overheating of equipment (during construction and operation e.g. gantries).	General inspections and Principal inspections of each structure would be carried out at minimum two and six-year intervals respectively. The inspections would determine condition of the structure and identify any potential maintenance requirements. There are currently no technology gantries (which would include electronic signage) proposed as part of the Scheme. All the proposed Advanced Directional Sign (ADS) gantries shall be maintained by the maintaining agent and be subject to the same inspection requirements as stated above.
	Risk of damage to structures and foundations, including flood scour and/or runoff (construction and operation).	A 20% increase to allow for climate change has been included in the design. Further details are provided in **Chapter 13 Road Drainage and the Water Environment** of this ES (**Application Document Reference: TR010031/APP/6.1)**. Where there is no increase to paved area, the additional runoff (generated by application of the 20% increase to rainfall intensities for climate change) is to be attenuated, so that the proposed discharge rate does not exceed the existing. The Allerdene viaduct option will include the proposal to expose the existing section of Allerdene Culvert to an open channel. The Allerdene embankment option will include the proposal to entirely replace the existing Allerdene Culvert with a new larger culvert (increasing flow capacity). A small section of the existing culvert (underneath the existing A1 southbound carriageway) is proposed to become an open channel. Both bridge options above will introduce opportunities to reduce flows by energy reduction methods.

Component	Potential impacts	Adaptation measure(s)
		Where structures are located next to watercourses, the effects of scour undermining foundations have been significantly reduced by using piled foundations (into bedrock), such as Kingsway Viaduct. Consideration for scour protection is to be reviewed further at detailed design stage.
	Damage to signage and site structures (operation).	Weep holes have been proposed to ensure reduction in the build of pore water pressures behind wall faces in retaining walls one to six. They are considered to be good practice and will be shown on drawings at the detailed design stage. General inspections and Principal inspections of each structure such as the carriageways, slip roads and bridges such as Allerdene Bridge and North Side Overbridge would be carried out at minimum two and six-year intervals respectively. The inspections would determine condition of the structure and identify any potential maintenance requirements. All structures have been designed for the effects of vehicular loadings which are considered to be significantly higher than the effects of wind loading.
Weather proofing and detailing	Water accumulation (construction and operation).	Structure drainage systems would have maintenance access built in to ensure blockages are reduced as much as practically possible to eliminate build-up of water. All structures have been designed with their own system of waterproofing. Above ground structures would have spray applied waterproofing and below ground structures would have bituminous paint to ensure a barrier against water seepage.
	Excessive vegetation growth (operation).	General inspections and Principal inspections of each structure would be carried out at minimum two and six year intervals respectively. The inspections would determine condition of structures and identify any potential maintenance requirements. Schedules for landscape maintenance would be used to manage excessive vegetation growth.
	Higher day and night-time temperatures (operation).	Steel structures would be designed to meet the limit stipulated in the standard at a maximum design temperature of 35°C and a minimum temperature of -35°C. Steelwork protection in accordance with the requirements of series 1900 of the Manual of Contract Documents for Highway Works (**Ref 14.18**) shall be adopted. Aluminium members would be protected by galvanised coatings.
Material durability	Water accumulation (construction and operation).	Structure drainage systems would have maintenance access built in to ensure blockages are reduced as much as practically possible to eliminate build-up of water.
	Excessive vegetation growth (operation).	General inspections and Principal inspections of each structure would be carried out at minimum two and six year intervals respectively. The inspections would determine condition of the structure and identify any potential maintenance requirements.
	Increased rate of deterioration of materials, potentially leading to early replacement (operation).	Steelwork protection in accordance with the requirements of series 1900 of the MCHW (**Ref 14.18**) shall be adopted. Aluminium members would be protected by galvanised coatings.

Component	Potential impacts	Adaptation measure(s)
Site contents and business continuity	Water accumulation in low areas causing disruption (during construction and operation).	General inspections and Principal inspections of each structure would be carried out at minimum two- and six-year intervals respectively. The inspections would determine condition of the structure and identify any potential maintenance requirements. The attenuation pond will be developed to manage flow of water during construction and operation.
	Stopping of services due to asset failure from climate (operation).	Weep holes have been proposed to ensure reduction in the build of pore water pressures behind wall faces in retaining walls one to six. Where structures are located next to watercourses, the effects of scour undermining foundations have been significantly reduced by using piled foundations (into bedrock), such as Kingsway Viaduct. General inspections and Principal inspections of each structure such as the carriageways, slip roads and bridges such as Allerdene Bridge and North Side Overbridge would be carried out at minimum two six year intervals respectively. The inspections would determine condition of the structure and identify any potential maintenance requirements. All structures have been designed for the effects of vehicular loadings which are considered to be significantly higher than the effects of wind loading. The proposal to expose the existing section of Allerdene Culvert (Allerdene viaduct option) to an open channel will provide opportunities to reduce flows by energy reduction methods. Where structures are located next to watercourses, the effects of scour undermining foundations have been significantly reduced by using piled foundations (into bedrock), such as Kingsway Viaduct.
	Scour of embankments/shoulders leading to increased maintenance (operation).	General inspections and Principal inspections of each structure would be carried out at minimum two and six-year intervals respectively. The inspections would determine condition of the structure and identify any potential maintenance requirements.
	Excessive vegetation growth (operation).	General inspections and Principal inspections of each structure would be carried out at minimum two and year-year intervals respectively. The inspections would determine condition of the structure and identify any potential maintenance requirements.
	Increasingly difficult working conditions due to climate (construction).	Load construction effort in low-risk periods (i.e. outside of summer).
	Reduced opportunities for maintenance (operation).	Concrete exposure classes (and corresponding allowable crack widths) have been selected to ensure the structure has a design life of at least 120 years with minimal maintenance to adapt to possible reduced opportunities. This applies to the Allerdene viaduct option and the Allerdene embankment option. Structure drainage systems would have maintenance access built in to ensure blockages are reduced as much as practically possible to eliminate build-up of water.
H&S of users (operators and customers)	Difficult working conditions owing to extreme precipitation, temperatures, wind and relative humidity (construction and operation).	Load construction effort in low-risk periods (i.e. outside of summer) and ensure that the structure has a design life of at least 120 years with minimal maintenance to adapt to possible reduced opportunities.
	Movement of debris causing slip, trip and fall hazards, caused by excess water (construction).	

Component	Potential impacts	Adaptation measure(s)
	Skid and accident risk (operation)	General inspections and Principal inspections of each structure, including the carriageways between junction 65 (Birtley) to junction 67 (Coal House) and bridges such as Allerdene Bridge and North Dene Footbridge, would be carried out at minimum two and six-year intervals respectively. Use of masks and adequate safety equipment during times of high dust risk. The inspections would determine condition of structures and identify any potential maintenance requirements to reduce fire risk.
	More dust and particulates (construction).	
	Increased fire risk (operation).	
	Hot surfaces may cause injury (operation).	
	Health and safety risks to road users (e.g. from falling trees and vegetation) (operation).	General inspections and Principal inspections of roadside vegetation.

14.10. ASSESSMENT OF LIKELY SIGNIFICANT EFFECTS

EFFECTS OF THE SCHEME ON CLIMATE

Construction Phase Estimated GHG Emissions

14.10.1. During construction, the main source of emissions is anticipated to be embedded carbon in construction materials. Another important source of GHG emissions during construction is the transport of materials to and waste from site.

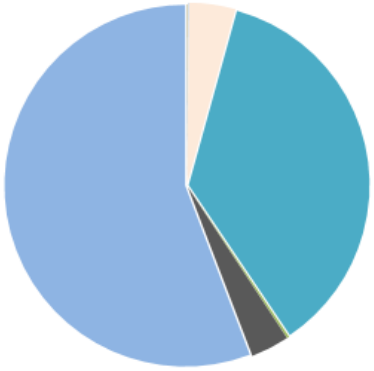
14.10.2. The total GHG emissions (tonnes of carbon dioxide equivalent) arising from material supply, the manufacturing of materials, waste generation and disposal, and transportation of materials and waste to and from site from the construction of the Scheme are presented in the Carbon Tool outputs below (**Figures 14-4 and 14-5**). The figures show the GHG emissions associated with the Scheme with the Allerdene embankment option and Allerdene viaduct option respectively.

14.10.3. This does not include operational stage emissions from traffic or maintenance, repair or replacement.

Figure 14-4 – Scheme with Allerdene embankment option - total GHG emissions breakdown associated with materials

Materials

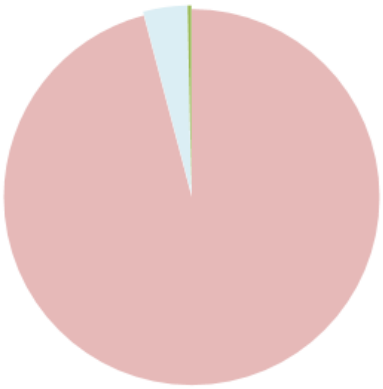
The table and pie chart displayed below show the total CO_2e emissions associated with materials purchased for the contract.



Category	CO_2e Emissions
Fencing / RRS / barriers	156.055
Drainage	128.947
Earthworks	7,099.200
Pavements	62,244.991
Street furniture	335.586
Civil Structures	5,897.250
Bulk Materials	95,847.816
Total	**171,709.844**

Materials, Transport, Energy and Waste Emissions

This table and pie chart show the total CO_2e emissions associated with materials compared to materials transport, energy use, business and employee transport and waste



Category	CO_2e Emissions
Materials Total	171,709.844
Materials Transport	6,771.889
Energy Use	0.000
Business and Employee transport	0.000
Waste	593.130
Total	**179,074.863**

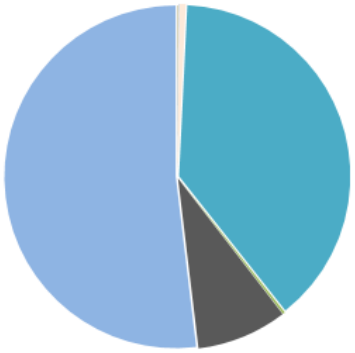
14.10.4. For the Scheme with the Allerdene embankment option, the majority (95.9%) of GHG emissions are associated with materials (product stage 'cradle to grave or 'embodied' emissions) with 0.3% from waste generation and disposal and 3.8% from transport of those materials and wastes.

14.10.5. Of the emissions for materials, the majority (56%) relate to the bulk materials required for the Scheme which are predominantly from aggregates and concrete. Other significant contributions relate to pavements (36%), with minimal emissions from earthworks (4%) and civil structures (3%).

Figure 14-5 – Scheme with Allerdene viaduct option - Total GHG emissions breakdown associated with materials

Materials

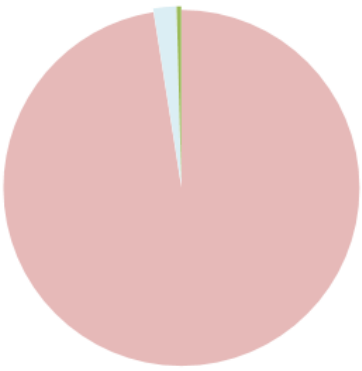
The table and pie chart displayed below show the total CO_2e emissions associated with materials purchased for the contract.



Category	CO_2e Emissions
Fencing / RRS / barriers	156.055
Drainage	128.947
Earthworks	960.000
Pavements	62,244.991
Street furniture	335.586
Civil Structures	13,798.286
Bulk Materials	83,771.189
Total	**161,395.053**

Materials, Transport, Energy and Waste Emissions

This table and pie chart show the total CO_2e emissions associated with materials compared to materials transport, energy use, business and employee transport and waste



Category	CO_2e Emissions
Materials Total	161,395.053
Materials Transport	3,460.262
Energy Use	0.000
Business and Employee transport	0.000
Waste	703.727
Total	**165,559.042**

14.10.6. For the Scheme with the Allerdene viaduct option, the majority (97.5%) of GHG emissions are associated with materials (product stage 'cradle to gate' or 'embodied' emissions) with 0.4% from waste generation and disposal and 2.1% from transport of those materials and wastes.

14.10.7. Of the emissions for materials, the majority (52%) relate to the bulk materials required for the Scheme which are predominantly from concrete. Other significant contributions relate to pavements (39%), civil structures (9%) and earthworks (1%).

Operation Phase Estimated GHG Emissions

14.10.8. During operation, the main GHG emissions sources would be from end-users (traffic) and those associated with the maintenance, repair and refurbishment (resurfacing) of the Scheme over its operational life cycle.

14.10.9. GHG emissions during operation would be primarily generated through end-users (traffic emissions). GHG arising from traffic emissions from the Scheme (with both the Allerdene embankment option and Allerdene viaduct option being the same) are presented in **Table 14-14**.

Table 14-14 - End user GHG Emissions data for the traffic in the region of the Scheme

Scenario	Total GHG emissions for all traffic in the traffic model area (thousand tonnes of carbon dioxide equivalent; $kTCO_2e$)			
	2023	2038	Average per year (2023 – 2082)	Total (2023-2082)
Baseline (do minimum)	1,466	1,624	1,606	97,960
Scheme (do something)	1,469	1,628	1,610	98,217

14.10.10. When considering road resurfacing (operational phase maintenance, repair and refurbishment), the primary GHG emissions would be from the replacement of bituminous materials. The Scheme resurfacing schedule provides for renewal of surface course every five years commencing in 2028 (year 5 of the Scheme). Material quantity data for the Scheme, provided by the Scheme design team and buildability support contractor, indicated that 39,732 tonnes of bituminous materials would be required, which equates to 20 $ktCO_2e$. Of that, 99% relates to the bituminous material, and 1% is for transport of the material.

Total Estimated GHG Emissions

14.10.11. The total estimated GHG emissions arising from the Scheme (with both the Allerdene embankment option and Allerdene viaduct option) are presented in **Table 14-15**. The results are presented for the construction stage (winter 20/21 - winter 23/24), the operation stage (2024-2083) and the overall total for the whole lifecycle (2020-2083).

14.10.12. The total emissions during each of the UK National Carbon Budget periods is presented and compared in percentage terms to the respective National budget. The Third Carbon Budget covering 2018 to 2022 is 2,544 million tCO_2e. The Fourth Carbon Budget covering 2023 to 2027 is 1,950 million tCO_2e. The Fifth Carbon Budget covering 2028 to 2032 is 1,725 million tCO2e (the latest carbon budget agreed by the government).

Table 14-15 – Key information on GHG sources

Stage/timing	Total GHG emissions *(thousand tonnes of carbon dioxide equivalent; $kTCO_2e$)*	
	Scheme with Allerdene embankment option	**Scheme with Allerdene viaduct option**
Construction phase * (2020-23)	179	166
Operation phase (2023-2083)	276	276
Total for lifecycle (2020-2083)	**455**	**442**
Total contribution from the Scheme during the third Carbon Budget period ** (2018-2022) *[% of budget]*	119 *[0.00469%]*	110 *[0.00434%]*
Total contribution from the Scheme during the fourth Carbon Budget period (2023-2027) *[% of budget]*	75 *[0.00386%]*	71 *[0.00363%]*
Total contribution from the Scheme during the fifth Carbon Budget period (2028-2032) *[% of budget]*	20 *[0.00117%]*	20 *[0.00117%]*

* Construction phase (and therefore total lifecycle) emissions take into account the mitigation measure of reuse of certain anticipated arisings generated onsite. This measure has reduced the associated emissions by approximately 482 tCO_2e for the Allerdene embankment option and 561 tCO_2e for the Allerdene viaduct option.

** Only considering construction emissions as asset will not be operational until 2023.

14.10.13. GHG emissions result in the same global climate change effects wherever and whenever they occur and therefore the sensitivity of different human and natural receptors is not considered.

14.10.14. In line with the methodology for assessing significance of effects set out in the NPS NN (2014) (**Ref 14.6**), and in the absence of agreed thresholds for what level of GHG emissions is considered significant in an EIA, professional judgement, based on schemes of a similar

size and nature, has been used to assess the significance of effects. Furthermore, in line with Paragraph 5.17 if the NPS NN (2014) (**Ref 14.6**) the Scheme GHG emissions have been provided against the UK National Carbon Budgets to provide context.

Allerdene Embankment Option

14.10.15. The GHG emissions from the construction and operation of the Scheme with the Allerdene embankment option is likely to have an adverse impact.

14.10.16. Based on professional judgement, the magnitude of change in GHG emissions is considered to be **negligible**.

14.10.17. The Scheme with the Allerdene embankment option is therefore expected to have a **slight adverse** effect (not significant) on climate.

Allerdene Viaduct Option

14.10.18. The GHG emissions from the construction and operation of the Scheme with the Allerdene viaduct option is likely to have an adverse impact.

14.10.19. Based on professional judgement, the magnitude of change in GHG emissions is considered to be **negligible**.

14.10.20. The Scheme with the Allerdene viaduct option is therefore expected to have a **slight adverse** effect (not significant) on climate.

VULNERABILITY OF THE SCHEME TO CLIMATE CHANGE

14.10.21. The results of the assessment of the vulnerability of the Scheme to climate change are presented in **Table 14-16.** The consequence and likelihood of the effects are shown leading to the significance rating, in the absence of adaptation measures, the effects are the same for the Allerdene embankment option and Allerdene viaduct option.

14.10.22. The significant effects associated with climate and weather-related risks are:

a. Damage to carriageway structures due to increased runoff due to extreme rainfall events.
b. Loss of vegetation leading to greater erosion risk due to drought/long periods of dry conditions.
c. Damage of carriageways and bridges due to increased runoff and increased slope instability from wetter winters (including flooding and/or repeated wet cycles).
d. Cracking and expansion, affecting the stability of structures due to extreme temperatures, including hotter summers.
e. Risk of damage to structures and foundations, including flood scour and/or runoff from gales and extreme wind events.
f. Drying out of construction materials and cracking from drought and prolonged dry spells.
g. Damage and disruption to structural robustness from fires due to extreme temperatures, including hotter summers.
h. Water accumulation, excessive vegetation growth and softening of subsurface materials due to wetter winters (including flooding and/or repeated wet cycles) affecting weather proofing and detailing and material durability.
i. Higher day and night-time temperatures due to extreme temperatures, including hotter summers.
j. Softening of subsurface materials from extreme rainfall events.

k. Water accumulation causing disruption to construction and operation, stopping of services due to asset failure, scour of embankments leading to increased maintenance and excessive vegetation growth due to extreme rainfall events.
l. Operational disruption due to extreme temperatures, including hotter summers.
m. Skid and accident risk from extreme rainfall events, including wetter winters.
n. Increased fire risk from extreme temperatures, including hotter summers.
o. Health and safety risks to road users (e.g. from falling trees and vegetation) from gales and extreme winds.

14.10.23. Effects which have been assessed as not significant are not considered further in this assessment although it is recommended that a watching brief is maintained to ensure that these risks are addressed in the future if their risk status changes and/or new information might affect their risk status. Watching brief refers to ongoing efforts to monitor unknown and/or uncertain risks, owing to lack of data and/or lack of scientific understanding regarding how the risk might manifest, as used elsewhere (e.g. UK Climate Change Risk Assessment 2017).

Table 14-16 – Significance evaluation

Component	Description of potential impacts		Consequence	Likelihood	Significance of effect (without adaptation)
	Climate hazard	Potential impacts			
Structural stability	Extreme rainfall events	Damage to carriageway structures between junction 65 (Birtley) to junction 67 (Coal House) due to increased runoff	Moderate adverse	Medium	Significant
		Soil saturation and water damage	Minor adverse	Medium. The Scheme is located within Flood Zone 2 and 3 although risk could change over time due to climate change.	Not Significant
		Undercutting and scour of Kingsway Viaduct	Minor adverse		
		Increased slope instability	Moderate adverse		
		Damage to unpaved shoulders	Minor adverse	Medium	Not Significant
		Erosion, silting and sedimentation	Minor adverse	Medium	Not Significant
	Drought/Long periods of dry conditions	Loss of vegetation leading to greater erosion risk	Minor adverse	High	Significant
		Subsidence	Moderate adverse	Low	Not Significant

Component	Description of potential impacts		Consequence	Likelihood	Significance of effect (without adaptation)
	Climate hazard	Potential impacts			
	Drier summers	Failure of earthworks due to desiccation, particularly in at risk unstable coal mining areas	Moderate adverse	Low	Not Significant
		Shrinking and cracking of soils	Moderate adverse	Low	Not Significant
	Wetter winters (including flooding and/or repeated wet cycles)	Damage of carriageways and bridges due to increased runoff	Moderate adverse	Medium	Significant
		Soil softening and erosion leading to collapse and settlement of soil structures	Moderate adverse	Low	Not Significant
		Increased slope instability	Moderate adverse	Medium	Significant
		Soil saturation	Minor adverse	Medium	Not Significant
		Damage to unpaved shoulders	Minor adverse	Medium	Not Significant
	Extreme temperatures, including hotter summers	Cracking and expansion, affecting the stability of structures such as the carriageway between junction 65 (Birtley) to junction 67 (Coal House).	Moderate adverse	Medium	Significant
		Overheating of equipment, including during construction and operation (e.g. gantries and electronic signage)	Minor adverse	Medium	Not Significant
		Increased risk of erosion	Minor adverse	Medium	Not Significant

Component	Description of potential impacts		Consequence	Likelihood	Significance of effect (without adaptation)
	Climate hazard	Potential impacts			
	Gales and extreme wind events	Risk of damage to structures and foundations, including flood scour and/or runoff, affecting the Kingsway Viaduct	Moderate adverse	Medium	Significant
		Damage to signage and site structures	Minor adverse	Medium	Not Significant
		Erosion of banks and exposed surfaces	Minor adverse	Medium	Not Significant
	Storms (snow, hail and lightning)	Destabilisation due to lightning strike	Moderate adverse	Very low	Not Significant
	Water quality	Soil stability and subsidence	Minor adverse	Low	Not Significant
Structural robustness	Drought and prolonged dry spells	Drying out of construction materials and cracking, particularly of the carriageway between junction 65 (Birtley) to junction 67 (Coal House)	Moderate adverse	Medium	Significant
		Deformation of rigid structures, such as Allerdene Bridge and Longbank Bridleway Underpass	Moderate adverse	Low	Not Significant
	Wetter winters (including flooding and/or repeated wet cycles)	Deformation of rigid structures	Moderate adverse	Low	Not Significant
		Undercutting and scour	Minor adverse	Medium	Not Significant

Component	Description of potential impacts		Consequence	Likelihood	Significance of effect (without adaptation)
	Climate hazard	Potential impacts			
	Extreme temperatures, including hotter summers	Risks to stored equipment, including waste	Minor adverse	Medium	Not Significant
		Damage and disruption from fires	Moderate adverse	Medium	Significant
Weather proofing and detailing	Extreme rainfall events	Greater mobilisation of pollutants in soil/ground causing premature deterioration of materials	Minor adverse	Medium	Not Significant
	Drought and prolonged dry spells	Drying out of construction materials and cracking	Minor adverse	Medium	Not Significant
		Deformation of rigid structures such as Allerdene Bridge and Longbank Bridleway Underpass	Moderate adverse	Low	Not Significant
	Wetter winters (including flooding and/or repeated wet cycles)	Water accumulation	Minor adverse	High	Significant
		Excessive vegetation growth	Minor adverse	High	Significant
		Softening of subsurface materials	Moderate adverse	Medium	Significant
	Extreme temperatures, including	Damage to external weather proofing and detailing at ground level	Minor adverse	Medium	Not Significant
		Higher day and night-time temperatures	Minor adverse	High	Significant

Component	Description of potential impacts		Consequence	Likelihood	Significance of effect (without adaptation)
	Climate hazard	Potential impacts			
	hotter summers				
	Changes in solar radiation	Increased solar gain (i.e. glare and warming of exposed surfaces)	Minor adverse	Medium	Not Significant
	Gales and extreme wind events	Damage from high winds and rain-infiltration into surfaces and materials, affecting gantries in particular	Minor adverse	Medium	Not Significant
	Humidity	Damage to external weather proofing and detailing at ground-level (i.e. from condensation, mould growth and mildew)	Minor adverse	Medium	Not Significant
Material durability	Extreme rainfall events	Softening of subsurface materials	Moderate adverse	Medium	Significant
	Drought and prolonged dry spells, including drier summers	Enhanced reactions when cement stabilising and drying of concrete on carriageway between junction 65 (Birtley) to junction 67 (Coal House)	Minor adverse	Medium	Not Significant
		Increased rate of deterioration of materials, potentially leading to need for early replacement	Minor adverse	Medium	Not Significant
		Shrinking and cracking	Minor adverse	Medium	Not Significant
		Water accumulation	Minor adverse	High	Significant

Component	Description of potential impacts		Consequence	Likelihood	Significance of effect (without adaptation)
	Climate hazard	Potential impacts			
	Wetter winters (including flooding and/or repeated wet cycles)	Excessive vegetation growth	Minor adverse	High	Significant
		Softening of subsurface materials	Moderate adverse	Medium	Significant
	Extreme temperatures, including hotter summers	Enhanced reactions when cement is stabilising and drying of concrete on carriageway between junction 65 (Birtley) to junction 67 (Coal House)	Minor adverse	Medium	Not Significant
		UV degradation of exposed equipment e.g. cabling	Minor adverse	Medium	Not Significant
	Changes in solar radiation	Deformation of materials on carriageways and bridges	Moderate adverse	Very low	Not Significant
	Gales and extreme wind events	Increased rate of deterioration of materials, potentially leading to early replacement	Minor adverse	Medium	Not Significant
	Relative humidity	Excessive moisture in building materials	Minor adverse	Medium	Not Significant
		Excessive moisture in sheltered surfaces (i.e. north-facing)	Minor adverse	Medium	Not Significant

Component	Description of potential impacts		Consequence	Likelihood	Significance of effect (without adaptation)
	Climate hazard	Potential impacts			
Site contents and business continuity	Extreme rainfall events	Water accumulation causing disruption to construction and operation	Moderate adverse	Medium	Significant
		Stopping of services due to asset failure	Moderate adverse	Medium	Significant
		Scour of embankments leading to increased maintenance, particularly in the Kingsway Viaduct	Moderate adverse	Medium	Significant
		Traffic disruption and congestion	Minor adverse	Medium	Not Significant
		Excessive vegetation growth	Minor adverse	High	Significant
		Operational disruption	Minor adverse	Medium	Not Significant
		Reduced opportunities for maintenance	Minor adverse	Medium	Not Significant
	Wetter winters (including flooding and/or repeated wet cycles)	Increasingly difficult working conditions, including time available to undertake works	Minor adverse	Medium	Not Significant
		Reduced opportunities for maintenance	Minor adverse	Medium	Not Significant
	Extreme temperatures, including	Reduced working periods and delays	Minor adverse	Medium	Not Significant
		Reduced opportunities for maintenance	Minor adverse	High	Not Significant
		Operational disruption	Moderate adverse	Medium	Significant

Component	Description of potential impacts		Consequence	Likelihood	Significance of effect (without adaptation)
	Climate hazard	Potential impacts			
	hotter summers	Greater demand for cooling (e.g. of equipment)	Minor adverse	Medium	Not Significant
	Storms (snow, hail and lightning)	Risks to power sources	Moderate adverse	Very low	Not Significant
		Risks to operational loss of power	Moderate adverse	Very low	Not Significant
		Electrical surges	Moderate adverse	Very low	Not Significant
		Fire risk	Moderate adverse	Very low	Not Significant
	Water quality	Increased maintenance costs and risks to operation	Moderate adverse	Very low	Not Significant
H&S of users (operators and customers)	Extreme rainfall events, including wetter winters	Difficult working conditions	Minor adverse	Medium	Not Significant
		Movement of debris causing slip, trip and fall hazards	Minor adverse	Medium	Not Significant
		Skid and accident risk	Moderate adverse	Medium	Significant
	Drought, including long periods of dry weather	More dust and particulates	Minor adverse	Medium	Not Significant
		Evaporation of construction water	Minor adverse	Medium	Not Significant
	Extreme temperature events, including	Difficult working conditions	Minor adverse	Medium	Not Significant
		Increased fire risk	Moderate adverse	Medium	Significant
		Hot surfaces may cause injury	Minor adverse	Medium	Not Significant
		Failure of temperature controls	Minor adverse	Medium	Not Significant

Component	Description of potential impacts		Consequence	Likelihood	Significance of effect (without adaptation)
	Climate hazard	Potential impacts			
	hotter temperatures	More dust	Minor adverse	Medium	Not Significant
	Gales and extreme wind events	Difficult working conditions	Minor adverse	Medium	Not Significant
		Health and safety risks to road users (e.g. from falling trees and vegetation)	Moderate adverse	Medium	Significant
	Relative humidity	Uncomfortable working conditions	Minor adverse	Medium	Not Significant

14.10.24. Where a significant climate risk was found, the level of resilience has been determined i.e. the reduction in the likelihood and/or consequence of climate impacts. This is based on the integration of the design, mitigation and enhancement measures set out in **Section 14.9**.

14.10.25. Note, Scheme phases (construction and operation) are differentiated where appropriate.

14.10.26. Resilience is considered according to the following categories leading to the stated conclusions on the residual significance of climate risks:

a. Low - a low level of climate resilience leading to significant residual climate risk. Remedial action or adaptation is required as a priority.
b. Moderate – a moderate degree of climate resilience leading to no significant residual climate risk. However, ongoing monitoring and/or remedial action or adaptation could be considered (see **Section 14.11**).
c. High – a strong degree of climate resilience leading to no significant residual climate risk. Remedial action or adaptation may be required but is not a priority.

14.10.27. The conclusions of this analysis of resilience and likely significant effects are shown in **Table 14-17,** there are no differences between Allerdene embankments option and Allerdene viaduct option.

Table 14-17 – Climate resilience rating following integration of the proposed adaptation measures

Component	Risk	Resilience Rating	Significance
Structural stability	Damage to structures due to increased runoff (operation)	High	Not Significant
	Loss of vegetation leading to greater erosion risk (operation)	High	Not Significant
	Overheating of equipment (during construction and operation e.g. gantries and electronic signage)	High	Not Significant
	Risk of damage to structures and foundations, including flood scour and/or runoff (construction and operation)	High	Not Significant
	Damage to signage and site structures (operation)	High	Not Significant
Weather proofing and detailing	Water accumulation (construction and operation)	High	Not Significant

Component	Risk	Resilience Rating	Significance
	Excessive vegetation growth (operation)	Moderate	Not Significant
	Higher day and night-time temperatures leading to greater cooling demands (operation)	High	Not Significant
Material durability	Water accumulation (construction and operation)	High	Not Significant
	Excessive vegetation growth (operation)	Moderate	Not Significant
	Increased rate of deterioration of materials, potentially leading to early replacement (operation)	Moderate	Not Significant
Site contents and business continuity	Water accumulation causing disruption (during construction and operation)	High	Not Significant
	Stopping of services due to asset failure (operation)	High	Not Significant
	Scour of embankments leading to increased maintenance (operation)	High	Not Significant
	Excessive vegetation growth (operation)	Moderate	Not Significant
	Increasingly difficult working conditions (construction)	Moderate	Not Significant
	Reduced opportunities for maintenance (operation)	Moderate	Not Significant
H&S of users (operators and customers)	Difficult working conditions owing to extreme precipitation, temperatures, wind and relative humidity (construction and operation)	Moderate	Not Significant

Component	Risk	Resilience Rating	Significance
	Movement of debris causing slip, trip and fall hazards due to excess water (construction)	Moderate	Not Significant
	Skid and accident risk (operation)	High	Not Significant
	More dust and particulates (construction)	High	Not Significant
	Increased fire risk (operation)	High	Not Significant
	Hot surfaces may cause injury (operation)	High	Not Significant
	Failure of temperature controls (operation)	High	Not Significant
	Health and safety risks to road users (e.g. from falling trees and vegetation) (operation)	Moderate	Not Significant

14.11. MONITORING

EFFECTS OF THE SCHEME ON CLIMATE

14.11.1. As part of the monitoring activities, which would be detailed in the CEMP, the Applicant's supply chain is responsible for providing monthly or quarterly carbon data returns using its Carbon Tool (**Ref 14.10**). As such, it is anticipated that during the construction phase, actuals data would be collected for materials, waste and fuel/electricity consumption, which would enable embedded GHG emissions and emissions from energy to be monitored. The actual GHG emissions of the Scheme (outturn data) can then be compared to the GHG emissions estimates at the ES stage (i.e. this chapter) and Highways England can iteratively feedback into the environmental assessment process. Any noteworthy increases in GHG emissions associated with the outturn data in comparison with the GHG emissions estimates at the ES stage would be managed accordingly through the CEMP.

VULNERABILITY OF THE SCHEME TO CLIMATE CHANGE

14.11.2. A number of vulnerabilities to climate and weather-related events have been identified in this assessment (**Table 14-13**). Adaptation and resilience to climate and weather-related

risks should be considered periodically through maintenance regimes. For example, and as noted in **Table 14-13**, regular inspections (at minimum 2 and 6-yearly intervals) should be undertaken for structures to mitigate the impacts of excessive vegetation growth and deterioration of materials.

14.11.3. In addition, a list of weather related incidents (for example, road surface deformations, snow and ice etc.) should be maintained to assist in identifying thresholds which, when exceeded, require maintenance.

14.11.4. Given the uncertainties inherent in climate science and the associated (UKCP09) projections used in this assessment, it is recommended that the vulnerabilities and risks identified in this assessment are revisited when new and/or updated information becomes available, where applicable.

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