CONTENTS

7 GHG Emissions Assessment

7.1 Introduction

7.1.1 This appendix presents the summary quantifications of the GHG emissions assessment and associated assumptions made in the preliminary GHG emissions assessment, presented in Chapter 7: Climate of the Preliminary Environmental Information (PEI) Report.

7.2 Construction Phase GHG Emissions Assessment – Summary

7.2.1 Table 7-1: Construction phase GHG emissions by scheme presents construction phase GHG emissions across each of the eight schemes, including for each of the alternative route alignments currently under consideration.

7.2.2 Quantifications are calculated using quantities of the relevant emissions activity multiplied by the relevant GHG emission factor to provide a quantification of GHG emissions in tonnes of carbon dioxide equivalent (tCO_2e).

7.2.3 Total project-wide GHG emissions are presented at the bottom of Table 7-1: Construction phase GHG emissions by scheme. This is presented as a range to reflect the GHG emissions associated with combinations of scheme options within an aggregated total.

Table 7-1: Construction phase GHG emissions by scheme

Scheme	Alternative[1]	Materials Embedded (tCO_2e)	Materials Transport (tCO_2e)	Energy Use (tCO_2e)	Business & Employee Transport (tCO_2e)	Waste & Waste Transport (tCO_2e)[2]	Land Use Change (tCO_2)	Total GHG Emissions (tCO_2e)
M6 Junction 40 to Kemplay Bank	N/A No alternatives	89,866	1,702	965	563	2,721	12,742	108,559
Penrith to Temple Sowerby	N/A No alternatives	91,765	3,712	653	329	-	27,474	123,933
Temple Sowerby to Appleby	Blue alternative	569,065	9,766	2,730	1,177	13,079	6,349	602,166
	Red alternative	566,189	9,432	2,730	1,177	12,189	22,118	613,835
	Orange alternative	155,437	8,375	2,730	1,177	-	9,569	177,289
Appleby to Brough (Warcop)	Black-Black-Black route	188,042	12,260	2,405	703	-	1,684	205,094
	Black-Blue-Black	189,724	12,613	2,405	703	-	8,234	213,679
	Black-Black-Orange	189,677	12,188	2,405	703	-	27,860	232,833
	Black-Blue-Orange	189,097	12,740	2,405	703	-	34,410	239,355
Bowes Bypass	N/A No options	47,093	1,648	382	170	143	7,505	56,941
Cross Lanes to Rokeby	Blue + Black	52,202	5,044	802	261	-	21,324	79,633
	Blue + Red	52,969	5,081	802	261	-		59,113
	Black + Red	50,158	4,755	802	261	-		55,976

[1] As set out in Chapter 2 the project has been split into eight schemes. As a result of further ongoing work to understand the baseline environment and further development of the design of the Preferred Route and its terminal junctions additional alternative alignment routes have been included at this stage for a number of the schemes.
[2] It has been assumed that there will be no sharing of material between schemes as a conservative assumption (to be reviewed further at ES stage). Therefore, it has been assumed that any surplus identified in the earthworks assessment will need to be removed for reuse off site. Black cells are those where no surplus has been identified. Information on waste associated with site preparation and construction and route wide demolition was not available for the preliminary assessment. Further information on waste assumptions and limitations are presented in Tables 3 and 4

Scheme	Alternative[1]	Materials Embedded (tCO_2e)	Materials Transport (tCO_2e)	Energy Use (tCO_2e)	Business & Employee Transport (tCO_2e)	Waste & Waste Transport (tCO_2e)[2]	Land Use Change (tCO_2)	Total GHG Emissions (tCO_2e)
Stephen Bank to Carkin Moor	N/A No alternatives	142,881	3,880	1,109	361	-	29,363	177,593
A1 (M) Junction 53 Scotch Corner	N/A No alternatives	31	9	-	-	-	163	203

Total estimated project-wide construction GHG emissions (tCO_2e)	
High	**1,400,052**
Low	**905,588**

7.3 Operational Phase GHG Emissions Assessment – Summary

7.3.1 Table 7-2: GHG project-wide operation emissions sets out the estimated additional (net increase of) GHG emissions associated with the project during its operational phase.

Table 7-2: GHG project-wide operation emissions

Potential Sources of GHG Emissions	Estimated total additional emissions - modelled future year (2046) (tCO_2e)	Estimated total additional (net) emissions - over the 60 year assumed project lifetime (tCO_2e)
Vehicles using the highways infrastructure for the ARN3	46,891	2,919,394
Energy and material use for operation of the highway	1,037 - 1,111	62,209 - 66,649
Total	47,928 – 48,002	2,981,603 – 2,986,043

[3] Additional (net increase of) GHG emissions (tCO_2e) ('Do something' scenario minus the 'Do minimum' scenario)

7.4 GHG Assessment Assumptions and Limitations

Assumptions

7.4.1 Table 7-3: GHG emissions assessment assumptions presents the high level, conservative assumptions of the GHG emissions assessment.

Table 7-3: GHG emissions assessment assumptions

Category	Assumptions
Construction Phase	
Transport distances (Materials)	No detail on locations for sourcing materials were available for the preliminary assessment. Therefore, it has been assumed as a reasonable worst case that all materials will need to be transported 50km by HGV (Heavy Goods Vehicle). This is based on the assumption for 'local' material transport distances used in the Environment Agency Carbon Calculator.
Earthworks	As the design is still being finalised for the earthworks estimations, this information will be updated and made available as part of the ES. The earthworks estimates have been provided in volume (m^3) and have been converted to mass (tonnes) using the Environment Agency conversion factor of 1.5tonnes per cubic metre used for inert materials. This is consistent with the methodology used in Chapter 11: Material Assets and Waste.
Earthworks	It has been assumed that there will be no transfer of material between schemes (i.e. reuse of excavated material as fill elsewhere within the scheme) as there was no information available on likely reuse at the time of assessment. Therefore, it has been assumed that any deficit identified in the earthworks assessment will need to be imported. As with the material transport assumption above it has been assumed that earthworks material imports will be transported 50km by HGV. This is likely to be a conservative approach, as reuse between schemes will be a key objective during construction to minimise export and import of materials.
Earthworks	It has been assumed that 32.5% of the cut material can be lime stabilised, based on construction information currently available from the buildability contractor. Therefore, 67.5% of the relevant scheme's useable cut has been inputted into the Highways England Carbon Calculator using the 'Site won - Cut & Fill' category and 32.5% of useable cut inputted into the 'Ground stabilisation – Lime' category.
Fencing & Barriers	Based on the design information currently available it has been assumed that all fencing will be Highways England Carbon Calculator category 'timber rail fence (all types, includes posts)'.
Fencing & Barriers	Based on the design information currently available it has been assumed that 10% of each scheme length will use noise barriers and that these will be in the form of 2m high timber barriers.
Fencing & Barriers	Based on the design information currently available it has been assumed that the full length of the alignment in central reserve + verge and side road lengths will require safety barriers. It has been assumed barriers will be Highways England Carbon Calculator category 'steel RRS (Road Restraint System) barrier double sided'.
Road Pavements	Quantities for 'Sub-bases - type 1 unbound mixture - in carriageway, hardshoulder and hardstrip' have been provided in m^2. These quantities have

Category	Assumptions
	been converted to volume (m^3) by assuming a thickness of 330mm (agreed with design teams). It has been assumed the subbase type 1 is equivalent to general quarried aggregate. Cubic metres has then been converted to tonnes using the Highways England Carbon Calculator material density conversion factor of 2tonnes/m^3 for quarried aggregate.
Road Pavements	Quantities for 'Bases - dense bitumen macadam (DBM50) - in carriageway hardshoulder and hardstrip' have been provided in m^2. These quantities have been converted to volume (m^3)) by assuming a thickness of 220mm (agreed with design teams). It has been assumed the dense bitumen macadam has the same carbon factor as general asphalt. Cubic metres have then been converted to tonnes using the Highways England Carbon Calculator material density conversion factor of 1.7tonnes/m^3 tonnes for asphalt.
Road Pavements	Quantities for 'Binder courses - dense bitumen macadam (DBM50) - in carriageway hardshoulder and hardstrip' have been provided in m^2. These quantities have been converted to volume (m^3)) by assuming a thickness of 220mm (agreed with design teams). It has been assumed the dense bitumen macadam has the same carbon factor as general asphalt. Cubic metres have then been converted to tonnes using the Highways England Carbon Calculator material density conversion factor of 1.7tonnes/m3 tonnes for asphalt.
Road Pavements	Quantities for 'Surface courses - close graded macadam - Thin - in carriageway, hardshoulder and hardstrip 10mm agg' have been provided in m^2. These quantities have been converted to volume (m^3)) by assuming a thickness of 220mm (agreed with design teams). It has been assumed the dense bitumen macadam has the same carbon factor as general asphalt. Cubic metres has then been converted to tonnes using the Highways England Carbon Calculator material density conversion factor of 1.7tonnes/m3 tonnes for asphalt.
Road Pavements	Based on the design information currently available it has been assumed that kerbs will be Highways England Carbon Calculator category 'pre-cast concrete, 125x305mm'. Where no quantity has been provided for kerbs it is assumed this will be overedge drainage.
Drainage	Based on the design information currently available it has been assumed that all plastic pipework will be Highways England Carbon Calculator category 'HDPE (high-density polyethylene), 900mm diameter'. It has been assumed that the full length of the alignment on both sides and the middle plus an additional 5km allowance for local network will require pipework.
Drainage	It has been assumed that all culverts will be Highways England Carbon Calculator category 'precast concrete circular pipework, 1500mm diameter'.
Drainage	Based on the design information currently available it has been assumed that one precast concrete inspection chamber will be required per attenuation pond. As the type of chamber was not known at the time of assumption, a worst case assumption of 1000mm diameter at a depth of 1.2-3m has been used.
Drainage	It has been assumed that 100% of attenuation ponds area (m^2) will require polyethylene membrane.
Drainage	It has been assumed that 100% of attenuation ponds (by m^2 area) will require sand.

Category	Assumptions
	The attenuation pond estimates were been provided in m^2 and have therefore been converted to volume (m^3) for the Highways England Carbon Calculator assuming a depth of 150mm (agreed with design teams). Volume has then been converted to tonnes using the Highways England Carbon Calculator material density conversion factor of 1.85tonnes/m^3 for sand.
Street Furniture	Based on the design information currently available it has been assumed that traffic signs will be Highways England Carbon Calculator category 'aluminium'.
Street Furniture	Based on the design information currently available it has been assumed that road lighting will be Highways England Carbon Calculator category 'LEDs lights'.
Street Furniture	Based on the design information currently available it has been assumed that cameras will be Highways England Carbon Calculator category 'hard shoulder camera and steel pole units'.
Street Furniture	Based on the design information currently available it has been assumed that there will be road studs along each side of the road pavement on both sides (i.e. length of studs will equal 4 x the length of the alignment). It has been assumed studs will be 9m apart.
Civils structures	Due to limited design information on the construction materials and quantities for bridges and underpasses bespoke assessments were not possible. Therefore, bridge and underpass factors have been taken from (Collings, D., 2006)[4]. Collings, 2006 paper presents CO_2 emissions during construction (kg/m_2 of deck area) for various structural forms and materials, including viaduct, girder, arch and cable stay bridges. For the purposes of this assessment and based on discussions with design teams, the following has been assumed: Overbridges will either use the Average Composite Girder factor of 2,750kgCO_2/m^2 OR the Average Composite Viaduct factor of 1,702kgCO_2/m^2 Underbridges will use the Average Composite Girder factor of 2,750kgCO_2/m^2 Underpasses will use the Average Composite Girder factor of 2,750kgCO_2/m^2 The Collings, 2006 paper provides carbon factors, which present emissions as CO_2 kg/m^2. It is assumed that no other emissions other than carbon were quantified and as such the factor is presented as CO_2 kg/m^2 not as CO_2e kg/m^2. The Collings, 2006 paper presents a carbon factor, which for this assessment has been converted from kg to tonnes to enable input into the Highways England Carbon Calculator using a factor of 1 kg.m2 = 0.001 t.m^2. Average Composite Girder = 2.75tCO_2/m^2 Average Composite Viaduct = 1.702tCO_2/m^2
Civils structures	Quantities for 'Retaining Walls: Precast Concrete' have been provided in m^3. Volume has then been converted to tonnes using the Highways England Carbon Calculator material density conversion factor of 2.4tonnes/m^3 for concrete.

[4] Collings, D., (2006) An environmental comparison of bridge forms. Proceedings of the Institution of Civil Engineers - Bridge Engineering, 159(4), pp.163-168

Category	Assumptions
Civils structures	Quantities for 'Retaining Walls: Sheet Piles' have been provided in m^2 and have therefore been converted to volume (m^3) by assuming a thickness of 3.5mm[5]. Volume has then been converted to tonnes using the Highways England Carbon Calculator material density conversion factor of 8tonnes/m^3 for steel. It has been assumed that steel sheet piles will be used.
Fuel and Energy	Fuel usage has been estimated based on assumptions of typical plant gangs. These estimates are based on data from previous schemes and assume: An average fuel usage of 0.69l/m^3 of material Diesel fuel will be used
Business Transport	Employee commuting has been estimated based on assumptions of likely staff numbers. These estimates are based on data from previous schemes and assume: A 25km each way journey distance average Private vehicles will be used 2 people will share each vehicle
Waste	It has been assumed that there will be no sharing of material between schemes. Therefore, it has been assumed that any surplus identified in the earthworks assessment will need to be removed for reuse off site (assumption taken from Chapter 11: Material Assets and Waste). It has been assumed that surplus will be transported 50km by HGV. This is likely to be a conservative approach, as reuse between schemes will be a key objective during construction to minimise export and import of materials.
Land Use Change	It has been assumed that the following Phase 1 Habitat types do not store carbon: G1 Standing water, G2 Running water, I2.1 Quarry, I2.2 Spoil Heap, J2.4 Fence, J2.5 Wall, J3 Built-up areas, J3.4 Caravans, J3.6 Buildings, J4 Bare Ground and Hardstanding. Quantifications are based upon the Natural England 2021 paper (Natural England, 2021)[6] and it's supporting assumptions. Carbon stocks lost due to the loss of habitat and soils has been calculated for using the baseline scenario and assuming mature habitats, which are in equilibrium (i.e. not sequestering further carbon and have reached their full carbon storage potential). It is assumed that all habitats are in a near-natural state. If any of the habitats are in a degraded state, their current carbon storage is likely to be lower than estimated. Carbon stored in topsoil layers has been calculated using an assumed soil depth of 30cm. This depth is based on the results of preliminary geotechnics ground investigations, which indicate an average soil depth of around 30cm within the draft DCO boundary.

[5] No information from design available on thickness at time of assessment on design, therefore thickness has been assumed based on industry examples taken from https://safefence.co.uk/sheet-piles-l8.html [Accessed 26 August 2021]
[6] Natural England (2021) NERR094 - Edition 1: Carbon Storage and Sequestration by Habitat. Available at: http://publications.naturalengland.org.uk/file/6726246198411264 [accessed 26 August 2021]

<table>
<tr><th>Category</th><th>Assumptions</th></tr>
<tr><td></td><td>In reality, it is reasonable to expect the soil to be disturbed to a much greater depth during construction and therefore more carbon is likely to be released to the atmosphere. As a result, the GHG emissions from land use change may be underestimated. The quantifications of carbon stock loss during construction will be further refined at ES, once detailed geotechnical information on soil depths is available. This may involve refining the soil depth assumption in some parts of the project to account for different soil depths and different potential carbon stock loss.
The literature used for the quantification assumes a 15cm soil depth and so quantifications have been extrapolated to represent the 30cm soil depth assumption for the project. It has been assumed that carbon stock is stored equally within the soil depth profile.
Carbon stock values for improved grassland were amended to provide a factor for a 30cm soil depth to standardise the soil depth across quantifications of habitat impacts (rather than the 100cm given in the literature). This depth is based on the results of preliminary geotechnics ground investigations, which indicate an average soil depth of around 30cm within the draft DCO boundary. It has been assumed that carbon stock is stored equally within the soil depth profile.</td></tr>
<tr><td colspan="2">Operational Phase</td></tr>
<tr><td>Maintenance and Refurbishment</td><td>Assumed replacement periods for key material types are set out in the table as follows:
<table>
<tr><th>Material type/application</th><th>Assumed replacement period (years)</th><th>Number of replacements in study period</th></tr>
<tr><td>Surface courses</td><td>20</td><td>2</td></tr>
<tr><td>Sub-base / base course</td><td>40</td><td>1</td></tr>
<tr><td>Fencing / sound barriers</td><td>30</td><td>1</td></tr>
<tr><td>Safety barriers</td><td>30</td><td>1</td></tr>
<tr><td>Concrete elements and structures</td><td>Not replaced in study period (60 years)</td><td>0</td></tr>
<tr><td>Drainage materials</td><td>Not replaced in stud period (60 years)</td><td>0</td></tr>
</table>
Where the replacement factor is 2 the estimated construction emissions have been doubled.</td></tr>
<tr><td>Vehicles using the highways infrastructure</td><td>As noted in Section 7.3: Study Area of the climate chapter the Affected Road Network (ARN) has been defined for the project by applying the scoping criteria included in DMRB LA 114, whereby road links are included within the ARN (for climate) where any of the following criteria are met:

A change of more than 10% in Annual Average Daily Traffic (AADT)
A change of more than 10% to the number of heavy duty vehicles
A change in daily average speed of more than 20km/h
</td></tr>
</table>

Category	Assumptions
Vehicles using the highways infrastructure	The assessment of road user emissions is based on considering traffic volumes for the ARN. Consideration of the long-term future emissions requires assumptions to be made on likely changes to the future efficiency and carbon intensity of road vehicles, informed by modelled projections. The ARN was determined based on the regional screening criteria set out in *DMRB LA 114*. Emissions were taken from *DMRB LA 105* screening tool, which are based on the EFT v10 emission factors (Department for Environment, Food and Rural Affairs, 2021)[7]. For the forecast year emission factors for 2030 have been held constant. This assumption would result in a conservative estimate of emissions as the transition to low emission vehicles is anticipated to further progress beyond 2030. It is anticipated that this will be resolved during ES through the use of WebTAG values, to refine traffic modelling to better reflect the transition to low emission vehicles beyond 2030.
Vehicles using the highways infrastructure	Emissions drawn from the traffic modelling are provided in carbon dioxide (CO_2) not carbon dioxide equivalents (CO_2e). To provide GHG emissions estimates as CO_2e, carbon emissions data has been converted to CO_2e by applying an additional 1% of the CO_2 emissions[8].

[7] Department for Environment, Food and Rural Affairs (2021) Emissions Factor Toolkit, available from: https://laqm.defra.gov.uk/review-and-assessment/tools/emissions-factors-toolkit.html [accessed 11 August 2021]
[8] Assumption of 1% conversion factor, assumes petrol and diesel fuels are used in vehicles using the highway infrastructure and is based upon analysis of the BEIS Conversion factors for Fuels, comparing the difference of CO_2 and CO_2e emissions factors on 'Fuels', which gives an approximate 1% difference in the factors. This uplift of 1% has then been used to convert CO_2 to CO_2e for emissions from vehicles using the highways infrastructure.

Limitations

7.4.2 Table 7-4: GHG emissions assessment limitations presents the limitations of the GHG emissions assessment.

Table 7-4: GHG emissions assessment limitations

Category	Limitations
Overall assumption – material quantities	The assessment is based on quantities that reflect the actual likely design and construction of each alternative alignment, no allowance has been made to account for under-estimation or over-estimation within the design team quantification.
Earthworks	As the design is still being finalised, cut and fill estimates provided for each scheme have been provided at a high level. The level of detail and confidence in the information provided differs between schemes. For the Temple Sowerby to Appleby scheme, basic cut and fill estimates have also been provided for each of the alternative route alignments (Blue, Orange and Red alternatives). These estimates have been used in the highways England Carbon Calculator to provide a quantification of GHG emissions for alternative alignments. Cut and fill estimates have not been provided for the alternative route alignments on the Appleby to Brough (Warcop) scheme or the Cross Lanes to Rokeby scheme. Therefore, the same high level scheme estimates have been used for each of these alternative alignments. This difference in detail and confidence in information is recognised as a limitation for the PEI Report and is anticipated to be overcome through more detailed assessment at ES, once preferred routes for all schemes are known.
Earthworks	Cut and fill information provided for schemes where there are alternative alignments is less detailed than on schemes where a preferred option is known. It is considered that this could result in an underestimation of the GHG emissions associated with waste (e.g. top soil strip material) for those alternative alignments.
Civils Structures	Due to limited design information on the construction materials for bridges and underpasses bridge and underpass factors have been taken from Collings, D. (2006). The Collings, 2006 paper provides carbon factors, which present emissions as CO_2 kg/m². It is assumed that no other emissions other than carbon were quantified and as such the factor is presented as CO_2 kg/m2 not as CO_2e kg/m². The age of the Collings paper used is recognised as a limitation, however this provides a conservative approach due to the decarbonisation trends for concrete/steel in the period since the paper was written, and as such this is expected to provide an over-estimation of impacts rather than under-estimation. Further investigation of relevant literature will be made at ES to seek to address this limitation.
Civils Structures	Penrith to Temple Sowerby - At the time of the assessment no data was available for Slack overbridge. Therefore, the actual carbon emissions associated with structures for the Penrith to Temple Sowerby (Center Parcs) scheme will likely be higher than those presented.

Category	Limitations
	Temple Sowerby to Appleby (Orange alternative) - At the time of the assessment no quantity was available for viaduct span/deck area as flood modelling results were still awaited. Therefore, the actual carbon emissions associated with structures for the Temple Sowerby to Appleby (Orange alternative) scheme will likely be higher than those presented.
Waste	Information on waste associated with site preparation and construction and route wide demolition was not available for the preliminary assessment. Therefore, there is likely to be an underestimation in the emissions associated with waste.
Land Use Change	Quantifications are based upon the *Natural England 2021 paper* and it's supporting limitations. Due to high uncertainty and variability in data on carbon storage in waterbodies and watercourses, they have been excluded from the assessment. Therefore, GHG emissions from land use change in the context of freshwater habitats may not be representative of actual emissions. The assessment data source focuses on the carbon storage and flux of soils and vegetation of the identified habitat, and therefore in some cases may not fully account for the potential release of other GHGs, such as methane. This assessment assumes all carbon stored within the soil is oxidised and converted to carbon dioxide. In reality, it is possible that some carbon could be converted to methane, a more potent greenhouse gas. As a result the GHG emissions from soil disturbance may be underestimated, however given the benchmarks available within the Natural England paper, this remains the most robust assessment of carbon in habitats. Similarly, no allowance has been made for any nitrous oxide released during land use change which may also lead to an underestimation of GHG from land use change.
Operational emissions/ Analysis of emissions	The traffic data used for the operational phase modelling is based on an opening year (2031) later than that which is used throughout this PEI Report (2029). This is due to changes in the construction programme as a result of acceleration of the project and applies to all modelled aspects of the assessment. As a result of the modelled opening year, GHG emissions, as taken from the traffic modelling, could have been underestimated for the year 2029-30 (assuming consistent traffic volumes). This is as the modelling uses an opening year of 2031 and as emissions factors remain static/constant in the traffic model after 2030. The assumptions and limitations of the traffic model are further explained in Chapter 5: Air Quality. Overall, the difference in effects is considered unlikely to be significant or influence the conclusion of the GHG emissions assessment. The GHG emissions assessment will be refined at the ES stage, in light of revised traffic modelling.

Category	Limitations
Operational emissions	Operational emissions associated with road lighting have not been quantified at this stage. Therefore, there is likely to be an underestimation of emissions associated with operational energy use. Quantification will be made at ES to seek to address this limitation.
Study Area	The preliminary assessment does not include consideration of any mitigation measures implemented to address impacts from other EIA topics, which will be considered during ES once information on measures is available. For example, in some cases, mitigation measures for biodiversity may also have a net benefit for GHG emissions, through the sequestration of carbon; this will be quantified during ES, where information on the mitigation measures is available.
Analysis of emissions	It is noted that the Design Year, the project's operational phase and assumed 60 year design life are beyond the Sixth Carbon Budget.
Analysis of emissions	Operational phase emissions have been assessed against the Sixth Carbon Budget (2033-37) as the Carbon Budget set furthest into the operational phase. This approach is likely to underestimate the likely significance of effect, as future Carbon Budgets are likely to be smaller, against which the emissions would represent a larger percentage of the UK's Carbon Budget during the project's operational phase.

CONTENTS

7 Climate Mitigation

7.1 Mitigation for the Impact of the Project on Climate

7.1.1 Table 7 1: GHG mitigation and enhancement measures considered by the project presents GHG emissions mitigation measures that have been considered by the project to date, as provided by the design teams working on the project.

7.1.2 Refinement of proposed mitigation measures will be presented within the GHG emissions assessment in the Environmental Statement (ES). This will include consideration of how measures set out within the recently published Net Zero Highways: 2030/2040/2050 plan (Highways England, 2021a)[1] can contribute to the mitigation of GHG emissions from the project. For example, Highways England have committed to all Tier 1 and Tier 2 suppliers have certified carbon management systems in place by 2025.

Table 7-1: GHG mitigation and enhancement measures considered by the project

Topic	Mitigation
Material recovery	As part of the schemes, material will need to be excavated and placed to form the desired road alignments. Where possible material recovered from the site will be used to profile the new vertical and horizontal geometry. It is anticipated that the percentage of site won material will vary between schemes depending on the structures, new road construction and associated earthworks. Mass transfer between schemes will be assessed for opportunity as the project progresses through design.
Material with recycled content	The project is committed to use materials with recycled content where possible to reduce environmental impacts. Whole lifecycle assessments will be undertaken to consider the impact of transportation as well as embodied GHG emissions. Material with recycled content offer different levels of environmental credentials. For concrete, it is common for 20% of the material by volume to be secondary sourced material, which can be increased beyond 40% depending on the mix, workability, and strength gain requirements. For steel, most of the steel sourced for bridge beams or ground support solutions is made from over 90% recycled steel. In relation to drainage products, there are now many drainage products on the market that incorporate over 60% recycled content, most notably with plastic drainage products and kerbs.
Construction traffic	Most of the material excavated within the schemes will be retained and used, but in some instances, there is need for additional fill or the movement of cut. Where this occurs, efforts will be made to reduce the off-site haul distance of such material, by prioritising its use on neighbouring schemes.
Phased traffic management	Appropriate traffic management measures would be put in place to ensure that traffic flows on the existing A66 are maintained where possible with limited disruption caused. All works will be phased to ensure the A66 traffic can be maintained, with more complex interface areas likely being undertaken on nights to further reduce

[1] Highways England (2021a) Net zero highways: our 2030/2040/2050 plan, available from: https://highwaysengland.co.uk/media/eispcjem/net-zero-highways-our-2030-2040-2050-plan.pdf [accessed 26 August1]

Topic	Mitigation
	any disruption. This will help reduce GHG emissions impacts from road diversions and congestion.
Construction GHG emissions management	Good practice would see construction contractors set targets to minimise GHG emissions and reduce GHG emissions during construction. For example, reducing GHG emissions associated with “off grid” energy use and earthworks; informing compound locations with consideration to the amount of earthworks required and where nearby utilities can be utilised; and keeping imported raw materials to a minimum with value engineered pavement and foundations solutions sought for temporary compound areas.

7.1.3 As the project progresses through design, GHG mitigation and enhancement measures will continue to be considered and incorporated.

7.1.4 Opportunities to mitigate GHG emissions will be developed in line with the hierarchy of mitigation presented in *DMRB LA 114* (Highways England, 2021b)[2] and be based on a carbon management strategy. For example:

Avoid/prevent

- Maximise potential for re-using and/or refurbishing existing assets to reduce the extent of new construction required, and/or explore lower carbon alternatives to deliver the project objectives (i.e. shorter route alternatives with smaller construction footprints).
- Careful construction management to avoid over-ordering of materials, to reduce transportation emissions.
- The sustainable reuse of soil and aggregate materials won from excavation.

Reduce

- Apply low carbon and/or reduced resource consumption solutions (including technologies, materials and products) to minimise resource consumption during the construction, operation and at end of life.
- The re-use, where possible, of materials and waste generated from construction works, including reuse of excess excavation materials.
- The specification and use of materials with lower embodied carbon, such as those with higher recycled content.
- Procurement of locally produced materials where practicable to reduce transportation emissions.
- Implementation of a range of measures through the Environmental Management Plan (EMP) to minimise construction-stage emissions including:
  - Training of construction staff
  - Implementation of travel planning for construction staff
  - Monitoring of construction site impacts (energy use, water use, waste, delivery and transportation record keeping etc.)
  - Powering down of equipment/plant during periods of non-utilisation
  - Optimising vehicle utilisation; use of energy efficient lighting, etc.
  - Implementation of energy saving measures (e.g. minimising the use of diesel or petrol-powered generators and instead using mains electricity or battery powered equipment)

[2] Highways England (2021b) Design manual for Roads and Bridges LA 114 Climate, available from: https://www.standardsforhighways.co.uk/prod/attachments/d1ec82f3-834b-4d5f-89c6-d7d7d299dce0?inline=true [accessed 26 August 2021]

Remediate

- Identify, assess and integrate measures to further reduce carbon through on or off site offsetting or sequestration.

7.1.5 Opportunities to reduce operational phase emissions from road users (e.g. supporting the transition to low emissions vehicles) will also be identified and considered as part of the ongoing design process.

7.2 Vulnerability of the Project to Climate Change

7.2.1 Table 7 2: Examples of embedded mitigation in the project design, considered within the CCR assessment presents examples of key embedded mitigation measures for climate resilience.

7.2.2 Refinement of proposed mitigation measures will be presented within the CCR assessment in the ES.

Table 7-2: Examples of embedded mitigation in the project design, considered within the CCR assessment

Climate Hazard	Examples of Embedded Mitigation
Heavy precipitation/flooding	Flood risk assessment and modelling informs design mitigation, including modelling allowances of up to 95% increase in peak river flow (compared to 1961 to 1990 baseline) (Environment Agency, 2016)[3] to assess structure vulnerability In line with drainage design standards, runoff drainage systems are being designed to take into account a 40% increase in peak rainfall intensity by the 2080s[3], to make sure there is no increase in the rate of runoff discharged from the site Geotechnical design of slopes consider long-term stability and risk from surface water scouring, groundwater and pore water pressure Pavement design, material specification and maintenance regime mitigates against surface deterioration and associated risks to road users Maintenance regimes monitor sediment build up in drainage systems and remove wind-blown debris causing blockages
High winds/gales	Structure designs apply wind loading criteria, as required in design standards
Increased temperatures and prolonged periods of hot weather	Pavement design, material specification and maintenance regime mitigates against surface deterioration and impacts of hot weather Structure foundation design and depths make conservative assumptions regarding the potential for soil shrinkage Asset design standards consider climate change for the impacts of upper and lower bound temperatures on structure design

[3] Environment Agency (2016) Flood risk assessments: climate change allowances, available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances [accessed 26 August 2021]

CONTENTS

7 Climate Change Resilience Assessment

7.1 Introduction

7.1.1 This appendix provides the detailed climate change resiliance (CCR) assessment completed for Chapter 7: Climate of the Preliminary Environmental Information (PEI) Report.

7.2 Assumptions and Limitations

7.2.1 This section details the assumptions and limitations associated with the CCR assessment.

7.2.2 Data on the historic climate baseline and future projections are based on publicly available information from third parties, including the historical meteorological variables recorded by the Meteorological Office (Met Office) and the UK Climate Projections (UKCP18) (Met Office, 2018)[1] developed by the Met Office.

7.2.1 Climate projections are not predictions or forecasts but are simulations of potential scenarios of future climate, under a range of hypothetical emissions scenarios and assumptions. Therefore, the results from running climate models cannot be treated as exact or factual. They represent consistent representations of how the climate may evolve in response to a range of potential forcing scenarios, and their reliability varies between different climate variables (temperature, rainfall etc). Furthermore, the degree of uncertainty associated with all climate change projections increases for projections further into the future due to the nature of longer term modelling and as uncertainties compound over time. There is particular uncertainty about the climatic changes with regards to wind over the 21st century.Climate projections for wind metrics have the highest level of uncertainty and interannual variability and therefore quantitative projections have not been used. Instead, climate change risks associated with wind have been assessed based on the UKCP18 general trends for the UK. This shows an increase in near surface wind speeds over the UK for the second half of the 21st century for the winter season when more significant impacts of wind are experienced. This is accompanied by an increase in the frequency of winter storms (Met Office, 2019)[2].

7.2.2 The preliminary CCR assessment has been informed by the following principle assumptions. The assessment has:

- assumed that identified embedded mitigation measures relevant to different assets would be implemented successfully and are effective at addressing the risk, including having effective monitoring and site safety procedures in place to manage climate risk
- assumed that any additional mitigation measures identified to mitigate those climate impacts and risks that are assessed as significant will be implemented successfully
- been based upon, and therefore influenced by, the assumptions associated with climate modelling and climate change projections of the UKCP18.

[1] Met Office (2018) UK Climate Projections, available at: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/index [accessed 9 September 2021]
[2] Met Office (2019) UKCP18 Factsheet: Wind. Available at: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-fact-sheet-wind_march21.pdf [accessed 19 July 2021]

- assumed that disruption to the project resulting from any climate risk would cause, at worst, a regional level disruption (on the basis that alternative highway routes exist and such disruption would not be considered 'national' in scale). Therefore, no risk is assessed to have greater than a 'large adverse' consequence in line with the rating approach specified in *Design Manual for Roads and Bridges (DMRB) LA 114 Climate (DMRB LA 114)* (Highways England, 2019)[3]

7.2.3 The CCR assessment is considered to have the following limitations:

- the assessment is qualitative, and based on the professional judgement of climate experts, structural and drainage engineers and geotechnical experts
- although there is guidance provided on the assessment methodology (IEMA and *DMRB LA 114*), the guidance and available case studies on the assessment of individual climate risks and impacts on different aspects of the project are limited
- as climate projections represent an uncertain future, there are inherent uncertainties in the climate change projections that will have been used to inform the CCR assessment. This study has been informed using UKCP18, the latest available set of probabilistic climate projections for the UK at the time of assessment. However, projections are regularly updated and superseded based on updated and developing scientific understanding
- there is often uncertainty in the relationship between changes in climate hazards and the respective response in terms of infrastructure asset performance. This creates uncertainty when assessing the likelihood and consequence of climate risks on assets within the project
- there is a limited level of detail on the design of some infrastructure assets at this stage of the project design. In these cases, climate change resilience has been assessed using professional judgement, based upon the best available information
- the preliminary assessment does not include consideration of or to any mitigation measures implemented to address impacts from other EIA topics, which will be considered during Environmental Statement (ES) once information on measures is available
- a flood risk assessment (FRA) (led by the Drainage and Water Environment topic) will not be considered as part of the PEI Report. The FRA will be completed for the ES and will incorporate the Environment Agency's updated 2021 allowance for increases in rainfall intensity and peak river flow in a future changed climate. Therefore, the CCR assessment is currently based upon professional judgement in relation to flood risk and water management. The design standards upon which the project has been designed take conservative assumptions on flood risks. Design and assessment will be further refined at ES following the receipt of FRA information.

7.3 CCR Assessment

Project-wide assessment

7.3.1 As outlined in the assessment methodology, risks have been assessed on a project-wide basis, based on the 'worst-case' climate projection for each climate parameter

[3] Highways England (2019) Design Manual for Roads and Bridges LA 114 Climate, available from: https://standardsforhighways.co.uk/dmrb/search/d1ec82f3-834b-4d5f-89c6-d7d7d299dce0 [accessed 9 September 2021]

across the extent of the route, on the basis that many risks will have the same risk of impact regardless of where they take place within the proposed scheme.

7.3.2 Schemes for which identified project-wide risks are either not applicable or for which the likelihood and consequence of a risk is likely to differ (e.g. due to scheme or location specific factors or design) to the project-wide assessment have also been identified.

7.3.3 As outlined in the assessment methodology and in the assumptions above, the conclusions of 'not significant' take account of embedded mitigitation that is within the engineering boundary, as advised by the project designers, and assumes this mitigation is implemented successfully, in full and that it is effective in mitigating the identified risk.

7.3.4 Table 7 1: Project-wide climate change resilience risk assessment outlines: the potential impacts to the project as a result of climate change are identified and assessed as part of the CCR assessment; any relevant embedded mitigation considered already in place prior to the assessment of each risk; the assessment itself (of likelihood, consequence and significance); and, notes on any scheme-specific considerations, e.g. where a risk is considered less relevant to a particular scheme.

7.3.5 Consideration of alternative routes or junctions is presented in a commentary in Table 7 2: Summary of climate change resilience risks for scheme alternatives, to describe where climate risks may differ to the project-wide assessment, e.g. identifying alternatives where risks associated with flooding could be more likely or of higher consequence.

7.3.6 Further CCR assessment will be carried out as part of the ES, including consideration of the climate conditions assumed in the embedded mitigation described within this preliminary assessment.

Table 7-1: Project-wide climate change resilience risk assessment

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
High temperatures	Increased heat stress for staff, particularly outdoor maintenance works, due to increased number of hot days (operational phase maintenance)	Proposed maintenance delivery regimes to incorporate potential temperature impacts on maintenance workers through risk assessments. These will be reviewed regularly to ensure health and safety requirements within Highways England are met	High	Negligible	Not significant	Relevant to all schemes
High temperatures	Increased risk of thermal expansion joints being pushed beyond their design capability, presenting a direct risk of damage to	Design standards consider climate change allowances for the upper and lower bound temperatures on structure design	Very low	Large adverse	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
	structures and assets					
High temperatures	Asphalt surfaces may exhibit permanent deformation in long periods of hot, sunny conditions	Engineers will incorporate resilience through pavement design and material specifications. Regular monitoring and maintenance regimes will preserve pavement surface conditions throughout operation	Low	Minor adverse	Not significant	Relevant to all schemes
High temperatures	High temperatures increase the risk of asphalt surface deterioration. This can reduce skid resistance and increase risk of vehicle accidents	Mitigated through appropriate pavement design, material specifications, and regular monitoring and maintenance regimes	Low	Minor adverse	Not significant	Relevant to all schemes
High temperatures	Increased temperatures can impact the	Mitigated through regular monitoring and	Low	Minor adverse	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
	bitumen hardening rate, leading to an inability to flex under heavy traffic loads, leading to surface cracking	maintenance regimes				
High temperatures	In higher temperatures fuel has a decreased viscosity and so leads to faster spreading of diesel in the event of a spillage. Higher temperatures and increased number of hot, dry days increase the likelihood of ignition of this diesel leading to road and wildfires	Mitigated through regular monitoring and maintenance regimes The likelihood of this risk is expected to decrease over time with the increase in proportion of electric vehicles used on the highway infrastructure	Low	Minor adverse	Not significant	Relevant to all schemes
High temperatures	Increased temperatures may impact the performance of	Mitigated through monitoring regimes to identify	Medium	Negligible	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
	electrical equipment, such as the reduced efficiency and lifespan of LED luminaries	equipment failures and maintenance regimes to replace failed equipment as quickly as possible				
High temperatures	Prolonged dry periods in summer could lead to soil shrinkage, leading to possible ground movement and impact upon foundations of civil structures	Mitigated through conservative assumptions for foundation depths during design	Very low	Minor adverse	Not significant	Relevant to all schemes
High temperatures	Prolonged dry periods could lead to increased desiccation of soils, reducing slope stability and leading to potential remedial earthworks	Mitigated through conservative assumptions made during design, informed by geotechnical ground investigations	Very low	Minor adverse	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
	following summer storm events					
High winds	Increased risk of extreme winds leading to possible blockage of drainage systems due to obstructions from wind-blown debris	Mitigated through drainage design and monitoring and maintenance regimes	Medium	Minor adverse	Not significant	Relevant to all schemes
High winds	Increased risk of wind borne debris on the road during high winds, affecting road user safety	Mitigated through design barriers, including noise barriers and landscaping features	Medium	Minor adverse	Not significant	Relevant to all schemes
High winds	Failure of, or damage to, assets as a result of high winds	Mitigated by applying wind loading criteria as required by standards during design	Very low	Moderate adverse	Not significant	Relevant to all schemes
Lightning	Increased risk of lightning strikes leading to indirect and direct damage to roadside	No embedded mitigation identified during assessment	Medium	Minor adverse	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
	equipment and damaging trees and vehicles					
High humidity	Increased humidity leading to accelerated stripping process of road surface	Mitigated through appropriate pavement design, material specifications, and regular monitoring and maintenance regimes	Low	Minor adverse	Not significant	Relevant to all schemes
High temperatures	Increased temperatures and humidity lengthening the growing season for weeds, leading to road infrastructure damage	Mitigated through appropriate pavement design, material specifications, and regular monitoring and maintenance regimes	Medium	Negligible	Not significant	Relevant to all schemes
High temperatures	Low albedo of road surface leading to increased insolation (retention of solar radiation and heat) and higher	Mitigated through appropriate pavement design, material specifications, and regular monitoring and	Low	Minor adverse	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
	road surface temperatures, increasing the risk of cracking and surface rutting	maintenance regimes				
High temperatures	Extended periods of hot dry weathers leading to a risk of spontaneous grassland fires and peatland habitat fires in the vicinity of the route, affecting safety on the road	Standard emergency procedures to manage the impacts of smoke and fire risk on the carriageway. The road would act as a firebreak, providing a gap in combustible material that would act as a barrier to slow or prevent the progress of a wildfire	High	Moderate adverse	Significant	Not considered applicable to M6 Junction 40 to Kemplay Bank scheme because the surrounding area is highly urbanised.
High precipitation	Increased flooding of the A66 road surface	Where the carriageway is in a cutting, the top of drains in the cutting will route overland flow to	High	Minor adverse	Not significant	Relevant to all schemes. Particular risks identified for Temple Sowerby to Appleby,

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
		the nearest watercourses Flood modelling will be carried out to assess the potential flooding impact on the scheme and to assist in the design of mitigation to address risks identified in modelling				Appleby to Brough (Warcop), and Bowes Bypass (A66/A67) schemes. The reasons for this and the specific design mitigation measures discussed in main chapter (paragraph 7.9.32)
High precipitation	Increased flooding of access roads and infrastructure	Flood modelling will be carried out to assess the potential flooding impact on the scheme and to assist in the design of mitigation to address risks identified in modelling In line with drainage design	High	Minor adverse	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
		standards, runoff drainage systems will be designed to accommodate the risks associated with a 40% increase in peak rainfall intensity by the 2080s, reduce the likelihood of an increase in the rate of runoff discharged from the site				
High precipitation	Increased risk of sewage outflow in floodwater causing damage and impacting health of maintenance workers	Mitigated through monitoring and maintenance regimes which may be adapted to ensure health and safety requirements within Highways England are met.	Very low	Minor adverse	Not significant	Not considered applicable to Bowes Bypass (A66/A67); Cross Lanes to Rokeby; and Stephen Bank to Carkin Moor schemes (as sewage pipes not present)
High precipitation	Increased risk of scouring of structures due to increased wet	Structural design to take account of potential scouring (as set out in	Low	Minor adverse	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
	weather or flooding	design standards by DMRB)				
High precipitation	Increased pore water pressure in embankments and cuttings	Geotechnical design of slopes will consider long term stability impacts and risk from groundwater	Medium	Minor adverse	Not significant	Relevant to all schemes
High precipitation	Increased erosion at the toe of embankments through increased surface run-off	Cut-off drains and toe-of-earthworks drains to be provided in the design. Geotechnics are informing the design in relation to groundwater. Drainage designs will be informed by Environment Agency guidance on the future impacts of climate[4]	Medium	Minor adverse	Not significant	Relevant to all schemes.
High precipitation	Water ingress to signalling, lighting	Street furniture design will	Low	Negligible	Not significant	Relevant to all schemes

[4] Environment Agency (2016) Flood risk assessments: climate change allowances, available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances [accessed 20 July 2021]

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
	and other operational electrical equipment	consider the potential for water ingress. Watertight cables will be housed in plastic ducts				
High and low precipitation	Changes in group water level affecting earth pressures and foundation settlement, causing possible large ground movements	Geotechnics will inform the structural design in relation to groundwater	Low	Moderate adverse	Not significant	Relevant to all schemes
High precipitation	Increased risk of debris deposit from water seeping up to the surface through the pavement (e.g. calcium sulphate) leading to reduced skid resistance	Mitigated through appropriate pavement design, material specifications as informed by geotechnics, and regular monitoring and maintenance regime	Low	Moderate adverse	Not significant	Relevant to all schemes
High precipitation	Increased water levels in winter may lead to	Current proposals indicate extensions to two	Medium	Minor adverse	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
	flooding of underpasses	existing underpasses. Flood risk assessments will be carried out to assess risk and identify mitigation to address risks identified in modelling				M6 Junction 40 to Kemplay Bank scheme is assessed separately below
High precipitation	Increased water level in winter may lead to flooding of the underpass on the mainline at Kemplay Bank (M6 Junction 40 to Kemplay Bank scheme)	The vertical geometry of the A66 mainline has been designed to mitigate any potential low spots and sags where water could pond The flood risk assessment (FRA), which will be carried out at ES will incorporate Environment	Medium	Moderate Adverse	Significant	Only applicable to Kemplay Bank (M6 Junction 40 to Kemplay Bank scheme) where specific design mitigation reduces the likelihood of flooding to low

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
		Agency guidance on the impacts of future climate change[4]				
High and low precipitation	Increased risk of earthworks failure and landslides exacerbated by variance between high and low precipitation events and soil moisture levels	Geotechnical design of slopes takes into account long term stability impacts. Material used for embankments will be in accordance with the Manual of Contract Documents for Highways Works (MCHW), including site-won material	Low	Moderate adverse	Not significant	Relevant to all schemes
High precipitation	Reduced capacity of attenuation ponds due to sediment build up following increased surface run-off	Maintenance regime will be established to monitor sediment build up	Medium	Minor adverse	Not significant	Not applicable to M6 Junction 40 to Kemplay Bank scheme
High precipitation	Increased risk of debris washing into drainage	Regular monitoring and maintenance	Medium	Minor adverse	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
	gullies and causing blockages	regime will be established				
High precipitation	Increased stripping rate of road surface due to increased number of high precipitation days	Mitigated through appropriate pavement design, material specifications, and regular monitoring and maintenance regime	Medium	Minor adverse	Not significant	Relevant to all schemes
High precipitation	Reduced skid resistance due to increased frequency of wet surfaces	Mitigated through appropriate pavement design, material specifications, and regular monitoring and maintenance regime	Very high	Negligible	Not significant	Relevant to all schemes
High precipitation	Increased likelihood of potholing, rutting and cracking from moisture entering and remaining in road surfaces	Mitigated through appropriate pavement design, material specifications, and regular monitoring and	Medium	Minor adverse	Not significant	Relevant to all schemes

Climate Hazard	Potential Climate Change Impacts to Project	Existing or Embedded Mitigation Measure	Likelihood of Impact Occurring	Consequence of Impact (should the impact occur)	Evaluation of Significance	Scheme Specific Considerations
		maintenance regime				
High precipitation	Increased flow of groundwater causing accelerated weathering and weakening of embankments	Geotechnics will inform the design of earthworks in relation to groundwater	Very low	Large adverse	Not significant	Relevant to all schemes
High precipitation	Increased surface run-off resulting in scouring of embankments and cuttings, leading to earthworks failure	In line with drainage design standards, runoff drainage systems will be designed to take into account a 40% increase in peak rainfall intensity by the 2080s, to make sure there is no increase in the rate of runoff discharged from the site	Medium	Large Adverse	Significant	Relevant to all schemes

Scheme alternatives assessment

7.3.7 Table 7 2: Summary of climate change resilience risks for scheme alternatives discusses the risks associated with each alternative alignment for schemes where alternative alignments are presented at Statutory Consultation. Each alternative alignment is assessed independently and not in comparison to each other.

7.3.8 7.3.8 Each risk in Table 7 1: Project-wide climate change resilience risk assessment has been qualitatively considered for each alternative alignment, but only those risks where the likelihood or consequence may differ from the project-wide assessment in Table 7 1: Project-wide climate change resilience risk assessment are discussed (and set out for each alternative alignment in Table 7 2: Summary of climate change resilience risks for scheme alternatives).

7.3.9 For any risks not referenced in Table 7-2: Summary of climate change resilience risks for scheme alternatives (consideration of alternative alignments), the assessment in Table 7-1: Project-wide climate change resilience risk assessment (project wide assessment) also applies to the alternative alignment.

Table 7-2: Summary of climate change resilience risks for scheme alternatives

Scheme	Route Alternative	Commentary
Temple Sowerby to Appleby	Blue alternative	Climate risks and significance considered to be similar to the project-wide assessment, noting the risks to earthworks associated with this design. Large multi-span bridge structures located within a floodplain considered to be at risk of scouring due to increased wet weather or floodwaters. Structural design should take account of potential scouring and implement mitigation to address the risk if this alternative route is selected.
	Red alternative	Climate risks and significance considered to be similar to the project-wide assessment, noting the risks to earthworks associated with this design. Large multi-span bridge structures located within a floodplain considered to be at risk of scouring due to increased wet weather or floodwaters. Structural design should take account of potential scouring and implement mitigation to address the risk if this alternative route is selected.
	Orange alternative	Climate risks and significance considered to be similar to the project-wide assessment. Lower risk of wildfires impacting this alternative route due to more urban setting.
Appleby to Brough (central section)	Black alternative	Climate risks and significance considered to be similar to the project-wide assessment, noting the risks to earthworks associated with this design. Embankment located within a floodplain considered to be at risk of erosion and structural weakening due to increased wet weather or floodwaters, and changes in pore water pressure. Structural design should take account of potential erosion and pore water pressure impacts and implement mitigation to address the risk if this alternative route is selected.

Scheme	Route Alternative	Commentary
	Blue alternative	Road surface considered to be at a higher risk of flooding compared to the project-wide assessment due to the road running at grade (level with the surrounding environment) through a floodplain. Particular attention would need to be given to the results of the flood risk assessment in this area. Additional mitigation is likely to be needed to address the risk if this alternative route is selected.
Appleby to Brough (eastern section)	Black alternative	Climate risks and significance considered to be similar to the project-wide assessment.
	Orange alternative	Climate risks and significance considered to be similar to the project-wide assessment.
Cross Lanes to Rokeby - Cross Lanes Junction	Black alternative	Climate risks and significance considered to be similar to the project-wide assessment.
	Blue alternative	Climate risks and significance considered to be similar to the project-wide assessment.
Cross Lanes to Rokeby - Rokeby Junction	Black alternative	Climate risks and significance considered to be similar to the project-wide assessment. Noting the project-wide risk of underpasses flooding, this junction contains an underpass considered to be at risk of flooding.
	Red alternative	Climate risks and significance considered to be similar to the project-wide assessment. Lower risk of flooding against the project-wide assessment as the road surface geometry design maintains overland flow to prevent the potential for ponding withing the underpass.