A90/A937 Laurencekirk Improvement Scheme

Volume 1 – LA 114 Climate Chapter
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Executive Summary

This assessment outlines the potential climate impacts of the A90/A937 Laurencekirk Scheme and the Access to Oatyhill, as per the requirements of DMRB LA 114. These guidelines provide a framework for assessing how projects affect the climate and are an integral part of Environmental Impact Assessments (EIAs), which evaluate and manage a project's environmental effects.

Environmental assessments, as directed by the EIA Directive 2014/52/EU, must detail significant environmental impacts, including the project's greenhouse gas emissions and vulnerability to climate change. This assessment should consider various environmental factors and their implications, as well as the project's susceptibility to major accidents and disasters.

The subsequent sections of the report offer insights into the greenhouse gas emissions associated with the scheme. For instance, GHG emissions for the construction phase are estimated at 615 tCO_2e for Access to Oatyhill and 11,457 tCO_2e for the main portion of the scheme. "tCO_2e" refers to the tonnes of carbon dioxide equivalent, which is a standard unit for measuring greenhouse gas emissions, encompassing not only carbon dioxide but also other gases like methane.

Although these emissions represent a small portion of the UK's carbon budget, the report highlights the importance of implementing mitigation measures throughout all stages of the project to minimise environmental impact. This commitment aligns with the UK government's targets for reducing carbon emissions and ensures that the scheme contributes positively to broader environmental objectives while meeting infrastructure needs.

Furthermore, the report assesses the schemes vulnerability to climate change, offering analysis of current and projected climate conditions, identifying potential vulnerabilities and recommending adaptation measures. Climate risks to these schemes were all found the non-significant.

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Introduction

Background

This report provides a detailed analysis of the potential climate-related effects stemming from the proposed construction and operation of the A90/A937 Laurencekirk scheme. Amey's approach adheres to the prescribed methodology outlined in the Design Manual for Roads and Bridges (DMRB) LA 114 Climate.

The report begins by summarising the framework employed for assessment, summarising the legislative and policy landscape concerning climate change, and providing an overview of the current and anticipated future environmental conditions within the project vicinity. The report subsequently explores various aspects including the project's design features, proposed mitigation measures, residual impacts, and address any inherent limitations in our assessment process.

To comply with the standards outlined in DMRB LA 114 Climate, our climate assessment encompasses:

Evaluation of the scheme's impact on climate: This involves an analysis of the greenhouse gas emissions (GHG) associated with the project, including its potential implications for governmental targets in carbon reduction.

Assessment of the scheme's vulnerability to climate change: Here, we assess the project's resilience in light of anticipated climate change impacts, outlining how the design has been adapted to mitigate these risks.

The effective assessment and management of impacts on climate, as well as the effects of climate change on projects offers the opportunity to:

1. improve the resilience of projects to future climate conditions, such as increased risk and severity of flooding, drought, heatwaves, intense rainfall events and other extreme weather events; and
2. reduce the impact of projects on climate by minimising the magnitude of GHG emissions as far as possible.

Within the 2019 EIAR, the subject of climate was not contained within the relevant DMRB guidance. Therefore, in line with the current DMRB guidance, a new chapter on climate has been completed in line with DMRB LA 114: Climate.

The proposed scheme

The full breakdown of the need for the scheme is outlined in Section 1 within the 2019 EIAR.

The proposed A90/A937 Laurencekirk Junction Improvement Scheme will see the construction of a grade-separated junction approximately 600m southwest of Laurencekirk in Aberdeenshire. This will replace the existing at-grade crossing where the A937 meets the A90 Trunk Road. The proposed Scheme will consist of a full diamond layout with dumb-bell roundabouts and four slip roads forming the A90/A937 junction to the south of Laurencekirk.

The proposed northbound diverge and southbound merge slip roads to the grade-separated junction commence approximately 200m northeast of the existing Oatyhill junction with the A90. It is therefore proposed to close the Oatyhill junction and the associated central reserve crossing point on safety grounds. The intention is that local access to Oatyhill would subsequently be via the unclassified U91K local road over the Oatyhill Rail Bridge connecting to the A937 local realignment.

Oatyhill Rail Bridge (Reference No. U91K/20) is located approximately 500m to the southwest of the existing A937 south junction and carries the U91K road over the main Aberdeen – Edinburgh railway line. This bridge is reported to have serval structural defects throughout its structure. The bridge was closed by Aberdeenshire Council on 24 July 2020 under an initial temporary restriction for three weeks, with a further temporary restriction commencing on 14 August 2020 for a period of 18 months, both maintaining emergency and pedestrian access. Aberdeenshire Council have indicated that strengthening of the existing bridge is not considered viable due to the poor condition of the superstructure and the limited clearance between the soffit and the required headroom for passing trains.

With the closure of the existing Oatyhill Rail Bridge and the proposed closure of the Oatyhill junction to the A90, an alternative means of access is required to the four Oatyhill dwellings and to allow the A90/A937 Laurencekirk Junction Improvement Scheme to progress. Figure 1.1 in Section 13 shows the Access to Oatyhill site boundary and the A90/A937 Laurencekirk Junction Main scheme red line boundary.

This report assesses the climate effects of the A90/A937 Laurencekirk Junction Improvement Scheme including Oatyhill Access.

Legislation and Policy Framework

Legislation

Climate Change Act

The Climate Change Act 2008 was enacted as the UK Governments plan for tackling climate change. The act committed the UK to its first statutory carbon reduction target to reduce carbon emissions by at least 80% from 1990 levels by 2050. The Climate Change Act 2008 (2050 Target Amendment) Order 2019 amended the Climate Change Act 2008 by further committing the UK Government to reduce GHG emissions by 100%, reaching net-zero, by 2050 on a 1990 baseline.

The Climate Change Act 2008 sets out five-yearly carbon budgets to ensure that this target can be reached. The first three carbon budgets were set in 2009, with the fourth and fifth following in 2011 and 2016 respectively, and the sixth in 2021 as outlined in Table 2-1.

Carbon Budget Period	UK Carbon Budget	Reduction below 1990 Levels
1. 3rd carbon budget (2018-2022)	2,544MtCO_2e	37% by 2020
2. 4th carbon budget (2023-2027)	1,950 MtCO_2e	51% by 2025
3. 5th carbon budget (2028-2032)	1,725 MtCO_2e	57% by 2030
4. 6th carbon budget (2033-2037)	965 MtCO_2e	78% by 2035

Table 2-1- UK Carbon Budgets

The Climate Change Committee (CCC) has a legal duty to advise the Government on the Climate Change Risk Assessment (CCRA) – a five-yearly assessment on the UK's climate change risks and opportunities – and published an independent assessment of UK Climate Risk (UKCCRA3) in 2021. This includes a national summary for Scotland summarising climate risks and opportunities for Scotland. The Climate Change Act also mandates that the UK Government to conduct a climate change risk assessment (CCRA) every five years and formulate a plan for adapting to the identified risks. The third UK CCRA, released in 2021, identifies 61 risks and opportunities across various sectors. It evaluates risks at a national level, involving scientists, economists, and government officials. The assessment includes a technical report and summaries to provide detailed analysis and accessible overviews. Themes covered include physical climate impacts, health and well-being, built environment, and business. Recommendations focus on adaptation strategies to mitigate climate risks and enhance resilience.

The CCRA outlines notable risks to the nation's infrastructure, encompassing transport systems, due to potential events like embankment and bridge failures, river flooding, coastal inundation, erosion, and heightened instances of extreme weather phenomena such as strong winds, high temperatures, lightning, storms, and surging waves.

It underscores the imperative for infrastructure to be situated, planned, designed, and maintained with resilience against climate change effects, notably severe weather occurrences. Additionally, it underscores the necessity for enhanced information exchange among infrastructure operators to bolster overall risk mitigation efforts.

National Policy

The Climate Change: Third National Adaptation Programme (2023 – 2028)

The Climate Change: Third National Adaptation Programme (NAP) is a government strategy in the UK aimed at tackling the impacts of climate change by bolstering resilience to climate-related risks, including those linked to carbon emissions, greenhouse gases, and overall climate conditions. The NAP holds significance as it encourages actions to cut carbon emissions and mitigate the effects of greenhouse gases, aligning with broader efforts to combat climate change. Additionally, it underscores the need for road infrastructure to withstand climate change impacts, such as extreme weather events, and advocates for adaptation measures to address these challenges in road design, construction, and upkeep. By providing a policy framework guiding decisions on infrastructure development, the NAP ensures that new roads are planned and built in a manner that accounts for climate change impacts and contributes to overall resilience.

Clean Growth Strategy

The Clean Growth Strategy is a UK government initiative focused on achieving economic growth while reducing greenhouse gas emissions. It outlines plans to decarbonise various sectors of the economy, including energy, buildings, and transportation, throughout the 2020s. Clean growth aims to increase national income while cutting emissions, and aligning economic prosperity with environmental sustainability. The Clean Growth Strategy is relevant as it promotes the adoption of low-carbon technologies and sustainable practices. By advocating for cleaner fuels, like electric vehicles, and implementing carbon-neutral construction methods, the strategy aims to reduce emissions associated with road construction and transportation. Thus, integrating the principles of the Clean Growth Strategy into the development of new roads can contribute to mitigating climate change by reducing carbon emissions and promoting environmentally sustainable infrastructure.

Road to Zero Strategy

The "Road to Net Zero" strategy lays out a plan to achieve carbon neutrality, where carbon emissions are balanced by removal or offsetting measures. This involves cutting greenhouse gas emissions across sectors to tackle climate change. The strategy promotes adopting low-carbon technologies and sustainable practices. By encouraging electric vehicle use, enhancing fuel efficiency, and employing carbon-neutral construction methods, it aims to reduce the carbon footprint of road projects. Such efforts contribute to mitigating climate change by curbing greenhouse gas emissions, supporting global initiatives to combat climate change, and fostering a shift towards a sustainable, low-carbon economy.

Decarbonising Transport

The Decarbonising Transport policy by the UK government aims to reduce carbon emissions and transition to a low-carbon transport system. This policy is crucial for mitigating climate change by cutting greenhouse gas emissions from the transport sector. It involves promoting sustainable modes of transportation like public transit, cycling, and walking, as well as encouraging the adoption of electric vehicles and alternative fuels. This policy influences the design and construction of new roads to align with sustainability goals. For instance, it may prioritise the development of infrastructure for electric vehicles, incorporate carbon-neutral construction practices, and promote the use of sustainable materials. Overall, the Decarbonising Transport policy contributes to the UK's efforts to combat climate change and fosters the development of environmentally friendly transportation infrastructure.

National Transport Strategy

National Transport Strategy (NTS2) sets out a vision for Scotland's transport system for the next 20 years to ensure that the climate is protects and improving quality of life. It sets out priorities to support to reduce inequalities, take climate action and help deliver economic growth. Related to climate change, it sets out the following priorities:

- Will help deliver our net-zero target
- Will adapt to the effects of climate change
- Will promote greener, cleaner choices.

Scotland's Climate Change Plan

The Scottish Government published an update to the Climate Change Plan in December 2020 which reflects the increased ambition of the new targets set by the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019.

As part of this, Scotland has set out a roadmap to reduce 20% of kms on the road by 2030. The roadmap integrates just transition principles, acknowledging that certain behaviours may be more practical in specific locations or for individuals with diverse needs. While it's a national aspiration, it recognises that reducing car use may vary across regions, particularly in rural or remote areas and for individuals with limited travel alternatives.

Scotland's Fourth National Planning Framework (NPF4)

The NPF4 provides the Scottish Government with a policy framework that is formulated at the local level. The NPF4 replaced the NPF3 (which was used to prepare the 2019 EIAR) in 2023 and states that the purpose of the planning system is to encourage sustainable economic growth. This policy sets Scotland's spatial principles, regional priorities, national developments, and national planning policy and thus brings together plans and strategies for transport development in Scotland. This includes a chapter on sustainable places which include policies on tackling the climate and nature crises and climate mitigation and adaptation.

Local Policy

Aberdeen City and Shire Strategic Development Plan 2020

The strategy for the growth of the Aberdeen City and Aberdeenshire areas of northeast Scotland is set out in the Aberdeen City and Shire Strategic Development Plan (2020). This plan contains targets and guidelines for tackling Sustainable Development and Climate Change such as: For all new developments to be designed to minimise resource demand and incorporate water and energy efficiency measures.

Aberdeenshire Local Development Plan (LDP) 2023

The purpose of the 2023 LDP is to promote four separate outcomes within the region. The policies and land use designations within the Local Development Plan will deliver six strategic outcomes during the Plan period: Increasing and diversifying the economy, making efficient use of the transport system, promoting high quality places, promoting green-blue networks, protecting and improving on what is best in our environment, and addressing the issues of climate.

Following on from the 2017 Aberdeenshire LDP (which identified the need for an improved junction on the A90 at Laurencekirk), the 2023 LDP also mentions the progression of this scheme and states that decisions regarding the scheme are welcome.

Standards and guidance

Impact of the scheme on climate (GHG emissions assessment)

This assessment has been guided by several standards and recommendations, including:

- DMRB LA 114 Climate: This outlines the criteria for evaluating and reporting the impact of greenhouse gas emissions from the construction, operation, and maintenance of Transport Scotland infrastructure projects.
- DMRB LA 105 Air Quality: This offers the methodology for calculating regional emissions generated by vehicles utilising the road network.
- Publicly Available Specification 2080 (PAS 2080:2023): This is a global standard for managing carbon in infrastructure, focusing on carbon management.
- Department for Environment Food & Rural Affairs Emissions Factors Toolkit User Guide: This offered a methodology for reporting tailpipe emissions from road users.
- One Click LCA guidance: This provides methodologies for reporting carbon emissions in adherence to PAS 2080 standards for all stages of a project's lifecycle.

Vulnerability of the scheme to climate change (climate change resilience assessment)

This assessment follows the guidance outlined by the DMRB LA 114 Climate: This standard offers the methodology for assessing and reporting the impacts of climate change on Transport Scotland's projects, particularly focusing on climate change resilience and adaptation. Aligned with the requirements of DMRB LA 114, this assessment covers two assessments, on:

- Impact of the Proposed Scheme on climate (GHG emissions assessment) - impacts on climate from carbon emissions arising from the Project, including whether the Project may affect the ability of the UK Government to meet its carbon reduction targets.

- Vulnerability of the Proposed Scheme to climate change (CCR assessment) - the ability of the Project to operate as intended despite climate change impacts and associated weather effects, including how the Project will take account of the Projected climate change.

Bath Inventory of Carbon and Energy (Circular Ecology, 2019)

Compiled initially in 2011 by Dr Craig Jones as part of Bath University's Sustainable Energy Research Team, the 'Bath Inventory' database (Bath Inventory of Carbon and Energy (Circular Ecology 2019) includes embodied carbon data for over 200 materials, including masonry, plastics, timber, minerals and many others.

This report has used carbon factors published in:

- ICE Database V3.0 – 10 Nov 2019; and
- ICE Cement, Mortar and Concrete Model – V1.1 Beta – 28 Nov 2019.

Assessment Methodology

Carbon assessment tools & process

One Click Life Cycle Assessment (LCA) has been used to conduct calculations for greenhouse gas emissions throughout the entire lifecycle. In this analysis, a carbon dioxide equivalent (CO_2e) figure has been used as a standardised unit to represent the various greenhouse gases. Additionally, in cases where One Click LCA could not provide precise data for certain materials, such as for product mass, the Bath Inventory 3.0 was used as a supplementary reference.

The Bill of Quantities (BOQ), along with traffic modelling data were carefully examined to identify assets readily available in the One Click LCA database, which were then directly incorporated into the model. However, it should be noted that information provided in the BOQ predominantly focuses on precast materials and is reflected in the carbon model.

The carbon emissions over the entire life cycle of the design elements were then calculated using the data provided in the product specification sheets where available. In cases where the carbon factors for materials and vehicle usage were not available in One Click LCA, carbon factors from Bath Inventory were used as private data points, which were subsequently integrated into One Click LCA for accurate calculations.

It is important to acknowledge that certain data points remain unspecified, which is left to making assumptions or excluding those data appoints altogether. These assumptions and exclusions are detailed in Section 4. Additionally, for a full breakdown of data inputs please refer to Appendices 3 and 4.

To align with the requirements of the DMRB LA 114, the climate assessment includes the following elements:

- Impact of the scheme on climate (GHG emissions assessment), and
- Vulnerability of the scheme to climate change (CCR assessment).

Impact of the scheme on climate (GHG emissions assessment)

The assessment of carbon emissions has been undertaken in accordance with DMRB LA 114 Climate and the principal steps identified in PAS 2080:2023. The One Click LCA calculation tool has been used to calculate product, construction process and maintenance/refurbishment emissions, except where specified. The Transport Analysis Guidance (TAG) Unit A3 Environmental Impact Tool and the DEFRA Emissions

Factor Toolkit (EFT) version 12.0.1 was used for the reporting of GHG emissions as a result of road user emissions.

The goal of the emissions quantification exercise is to calculate the emissions anticipated to be generated or avoided by the scheme. The purpose of this is to:

- Determine the magnitude of the scheme's emissions for the relevant scenarios - 'Do-Something' and 'Do-Minimum' (See scenario descriptions in Table 3-1)
- Enable comparison of the 'Do-Something' scenario against the 'Do-Minimum' scenario and the UK carbon reduction targets.
- Enable comparison of the 'Policy On' and 'Policy Off' Scenarios as per Scotland's Climate Change Plan**Error! Bookmark not defined.**.
- Enable identification of emissions hot spots within the 'Do-Something' scenario to inform identification and prioritisation of mitigation measures.

Assessment has included the life cycle stages of 'construction' and 'operation as per DMRB guidance. In line with DMRB LA 114, impacts from decommissioning have not been considered, as it is unlikely that the scheme would be decommissioned as the assets are likely to have become an integral part of the infrastructure in the area.

The assessment estimates three sources of carbon emissions during the construction and operation (use) life cycle stages, including:

- **Construction works and supply chain carbon emissions**. Carbon is assessed, based on information provided by design teams based on relevant drawings of the design where available. One Click LCA, an emissions modelling tool adherent to PAS2080:2023 standards is used along with its carbon factors for the calculation, supplemented with other factors where necessary as discussed in Section 0 Assessment assumptions and limitations.
- **Operational maintenance-related emissions**. An estimation of carbon emissions associated with maintenance of the road (calculated using the same method as the construction works and supply chain carbon emissions).
- **Operational traffic carbon emissions (user carbon) from vehicle tailpipes**. These are calculated for both the "Do-Minimum" and "Do-Something" scenarios from the traffic model, with the study area being the same as that of the traffic model.

Emissions from these sources are compared to a baseline 'Do-Minimum' scenario to quantify the impact of the schemes. The scenarios used for the GHG emissions assessment of the schemes are summarised in Table 3-1.

Scenario	Description
Do-minimum	The future baseline with minimal interventions and any new infrastructure.
Do-something	The scheme is implemented, taking into account embedded GHG mitigation measures.

Table 3-1 - Scenario Descriptions

To allow a sensitivity test, and to ensure all feasible options are assessed, the operational traffic carbon emissions (user carbon) from vehicle tailpipes are determined for both 'Policy On' and 'Policy Off' scenarios, aligning with Scotland's goal to reduce car usage. Table 3-2 shows Scotland's policy scenarios in accordance with the Scottish government's roadmap, aiming for a 20% reduction in car kilometres by 2030.

Scenario	Description
Policy On	Tailpipe emissions varying in line with the Scottish government's strategy to reduce car kilometres by 20%.
Policy Off	Tailpipe emissions varying in line with no policy.

Table 3-2 - Scotland's policy scenarios

GHG emissions in each scenario have been compared to assess the contribution of the schemes to climate change. Values are reported in metric tonnes of carbon dioxide equivalents (tCO_2e). This measure considers the six Kyoto Protocol gases: Carbon dioxide (CO_2); Methane (CH_4); Nitrous oxide (N_2O); Sulphur hexafluoride (SF6); Hydrofluorocarbons (HFCs); and Perfluorocarbons (PFCs), converted into tCO_2e. This calculation normalises the global warming potential of the main GHGs into one measure, based on the global warming potential of CO_2. In accordance with DMRB LA 114 Climate, the third lifecycle stage for a scheme's GHG emissions (the first and second being construction and operation) comprises opportunities to reduce the production/use of GHG emissions. Measures to reduce GHG emissions as far as practicable are considered in Section 0 Design, mitigation and enhancement measures.

Vulnerability of the scheme to climate change (CCR assessment)

The assessment of a project's vulnerability to climate change shall use published historical regional weather data to demonstrate the current climate impacts on a study area. The Met Office provides information on observed and future climate change relative to the baseline period of 1961-1990, based on the latest scientific understanding of UK CP18, along with future climate projections for different emissions scenarios.

In the case of flood risk, detailed planning requirements and design guidance relating to climate change exist. As part of the 2019 EIAR, a Flood Risk Assessment (FRA) was undertaken. That considered current Environment Agency (EA) climate change allowances for increases in peak river flow and rainfall intensity.

The climate change resilience assessment is composed of three main parts: the identification of climate hazards and benefits; the assessment of likelihood and consequences; and the evaluation of significance.

The following climate change hazards have been considered in the CCR risk assessment: high temperatures; high precipitation; and low precipitation.

As part of the climate change resilience assessment, the potential likelihood and consequence of climate change risks during the construction and operation of the infrastructure and assets associated with the schemes are scored using a qualitative five-point scale, based on DMRB LA 114 Climate. The tables below (Table 3-3 and Table 3-4) are reproduced based on the guidelines from the LA 114.

Likelihood category	Description (probability and frequency of occurrence)
Very High	The event occurs multiple times during the lifetime of the project (60 years) e.g. approximately annually, typically 60 events
High	The event occurs several times during the lifetime of the project (60 years) e.g. approximately once every 5 years, typically 12 events
Medium	The event occurs limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years, typically 4 events
Low	The event can occur once during the lifetime of the project (60 years) e.g. once in 60 years
Very Low	The event can occur once during the lifetime of the project (60 years)

Table 3-3 - Quantitative five-point scale of likelihood of climate change risks

Consequence of impact	Description
Very large adverse	Operation – national level (or greater) disruption to strategic routes(s) lasting more than one week

Large adverse	Operation – national level disruption to strategic routes(s) lasting more than one day but less than one week or regional level disruption to strategic route(s) lasting more than one week
Moderate adverse	Operation – regional level disruption to strategic routes(s) lasting more than one day but less than one week
Minor adverse	Operation – regional level disruption to strategic routes(s) lasting less than one day
Negligible	Operation – disruption to an isolated section of a strategic route lasting less than one day

Table 3-4 - Qualitative five-point scale consequences of climate change risks

As part of the risk assessment, the need for any essential resilience measures to protect against the impacts of climate change have been identified for any effects assessed as significant, as per the significance matrix in Table 3-6.

Assessment of significance

Impact of the scheme on climate (GHG emissions assessment)

An assessment of significance has been undertaken in accordance with DMRB LA 114 Climate. The emissions assessment is based on the One Click LCA carbon reporting tool and assessment of road user emissions in line with DMRB LA 105 Air Quality.

For the methodology related to quantification of user emissions (Module B9), please refer to EIAR Chapter Air Quality of the original EIAR. The traffic forecasting is in line with the current guidance.

For the calculation of GHG emissions associated with ongoing land use change/sequestration (module D), the areas of habitat losses and gains were calculated based on estimations provided via One Click LCA.

An estimate of the likely magnitude of GHG emissions associated with the schemes has been assessed against the legislated national UK carbon budgets. The UK Government has currently passed into law carbon budgets up to 2037, these are presented in Table 2-1.

In accordance with Paragraph 3.20 of DMRB LA 114 Climate, a significant effect occurs where the increase in carbon emissions resulting from the schemes would have a “material impact on the ability of Government to meet its carbon reduction targets”.

Vulnerability of the scheme to climate change (CCR assessment)

The evaluation of significance is a product of the likelihood and consequence of each impact as set out in Table 3-6. Significance conclusions for each impact incorporate confirmed design and mitigation measures. Note: NS = Not significant; S = Significant.

		Measure of likelihood				
		Very low	**Low**	**Medium**	**High**	**Very High**
Measure of consequence	**Very large**	NS	S	S	S	S
	Large	NS	NS	S	S	S
	Moderate	NS	NS	S	S	S
	Minor	NS	NS	NS	NS	NS
	Negligible	NS	NS	NS	NS	NS

Table 3-6 - Significance Matrix

Assumptions and limitations

Assumptions

Impact of the scheme on climate (GHG emissions assessment)

The GHG emissions assessment has been undertaken on the basis of the information available at the time of assessment. Where assumptions have been made, they have been selected to present the worst-case scenario for the particular item/factor.

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

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

Table 4-1 provides information on the DMRB life cycle modules that have formed part of the assessment along with justification where modules have been excluded.

Life Cycle Stage	Sub-stage of life cycle	Description	Included In Scope?	Justification
Construction stage	Preconstruction	Preliminary studies, consultations	No	Carbon emissions from the preliminary studies and works are largely office-based and are assumed to be insignificant
	Product	Raw material supply	Yes	A1-A3 emissions (i.e. from raw material extraction, product processing, and final product manufacture, its energy use, and waste management within these processes, transportation within the supply chain, and manufacture) are calculated using One Click LCA, based on information provided by design teams based on Bill of Quantities provided for exact measurements of materials used. Where possible EPD (Environmental product Declarations) were used
		Transport	Yes	
		Manufacture	Yes	
	Construction Process	Transport to the works site	Yes	A4 emissions have been calculated using One Click LCA and have been assumed to be 60km diesel vehicles and when stored on site 10km
		Construction/installation processes	Yes	A5 emissions have been calculated using One Click LCA based on information provided by design teams

Life Cycle Stage	Sub-stage of life cycle	Description	Included In Scope?	Justification
	Land use change	GHG emissions mobilised from vegetation or soil loss during construction	No	Emissions associated with land use change are assumed to be negligible
Operation (“use-stage”) (to extend 60yrs in line with appraisal period)	Use Phase, Operation and maintenance (including repair, replacement and refurbishment)	Use	No	Carbon emitted directly from the fabric of products and materials once they have been installed as part of the scheme sand it is in normal use are assumed to be insignificant. Land use/Sequestration emissions are negligible and have also been scoped out
		Maintenance	No	B2-B5 emissions associated with maintenance and refurbishment assume that the road surface would be replaced once every ten years for the duration of the assumed 60-year design life calculated using One Click LCA
		Repair	No	
		Replacement	Yes	
		Refurbishment	Yes	
		Operational energy use	No	Due to the nature of the schemes, there would be a negligible difference between the operational energy required for the schemes and therefore associated emissions are assumed to be insignificant
		Operational water use	No	Carbon emissions resulting from the consumption of water required by the schemes and presumably to enable it to operate and deliver its service are assumed to be insignificant
		Other operational processes	No	Other process carbon emissions arising from the schemes to enable it to operate and deliver its service, such as management of operational waste, are assumed to be insignificant
		Users utilisation of infrastructure	Yes	For the methodology related to the quantification of user emissions, please refer to Appendix 1
	Land Use and Forestry	Ongoing land use GHG emissions/ sequestration each year.	No	Emissions calculated at this stage were negligible
Opportunities for reductions	GHG emissions potential of recovery including re-use and recycling GHG emissions potential of benefits and loads of additional functions associated with the study system	Avoided GHG emissions through the substitution of virgin raw materials with those from recovered sources.	Yes	GHG emissions associated with re-use and recycling over the 60-year operational period have been considered as part of the One Click LCA Life Cycle tool

Table 4-1 - Justification of scoping in/out of DMRB Life cycle stages

Emissions have been calculated using the One Click LCA tool only. GHG emissions related to the construction element of embodied carbon (module A5) have been calculated using the One Click LCA calculation tool, based on information provided by design teams. The calculation includes the transport of materials and equipment on site and waste management activities (transport, processing, final disposal) associated with waste arising from the construction site.

To quantify operational emissions (module B2-B5) associated with maintenance of the road surface (in both the 'Do-Minimum' (baseline) and 'Do-Something' (with scheme) scenarios) it is estimated the road surface would be replaced once every ten years for the duration of the design life as seen in Section 2 in the appendix. Module B2-B5 emissions are calculated using the same method as the construction works (module A5) and supply chain (module A1-A3) carbon emissions: using One Click LCA emissions calculation tool, based on information provided by design teams for the schemes. For the calculation of GHG emissions associated with ongoing land use change/sequestration (module D), this was calculated on One Click LCA Emissions from immediate loss/disturbance of habitats (e.g. those mobilised from vegetation or soil loss during construction) are excluded from the calculation due to their likely being minor.

To calculate the road user emissions, traffic data was modelled on the Emissions Factor Toolkit (EFT) version 12.0.1 and analysed in the TAG workbook. In the 'policy off' scenario, the traffic congestion along the A90 would increase resulting in approximately a 1.5-hour delay on the A937. If delays of such magnitude were to occur, drivers would likely seek alternative routes beyond the scope of the current model. Consequently, the reliability of the model results is compromised as they do not account for these strategic rerouting behaviours. As a result, the policy off scenario accounts for years 2028-2040 whereas policy on scenarios account for 2028-2045.

Vulnerability of the scheme to climate change (CRR Assessment)

The CCR assessment has been informed by the following assumptions:

- The assessment has assumed that mitigation measures relevant to different assets would be implemented effectively, and
- The assessment is affected by assumptions associated with climate modelling and climate change projections, incorporated in UKCP18.

The CCR assessment has the following limitations:

- The assessment is largely qualitative,
- There is limited methodological guidance on climate change resilience assessment in EIA from Government, and other institutions,
- There is inherent uncertainty in climate change projections. This study has been quantified using UKCP18, the latest set of probabilistic climate projections for the UK,
- There is often uncertainty in the relationship between changes in climate hazards and the respective response in terms of asset performance. This uncertainty has been assessed qualitatively, and
- The evidence relating to climate change impacts for some categories of assets and infrastructure is limited at this stage in the design. In these cases, the assessment has been informed by professional judgement.

Limits of deviation

This assessment has been conducted within the Limits of Deviation. The LoD have been considered having regard to the scope for change. The worst case has been taken into account and it is considered that the outcome of the climate assessments contained within this chapter would not change unless the schemes or the assumptions change significantly. The proposed LoD would therefore not give rise to any materially new or materially worse adverse environmental effects from those already reported in the ES.

Study area

Study Area

Impact of the scheme on climate (GHG emissions assessment)

The assessment of GHG emissions has considered the following emissions sources:

- Carbon emissions during construction, i.e. material supply including primary extraction, manufacturing, transportation and construction process and site works associated with the scheme.
- Carbon emissions during operation, are associated with the maintenance and refurbishment of the scheme.
- Road user carbon emissions (during operation) arise from the use of the asset (vehicle emissions).

In line with DMRB LA 114 Climate, carbon emissions arising from the decommissioning of the schemes have been excluded from the assessment due to the long design life of the asset and given that emissions associated with the end of life are commonly relatively small.

Carbon emissions during construction

For the assessment of carbon emissions associated with the construction of the schemes, the study area takes account of emissions associated with the extraction, processing and transport of materials from outside of the spatial boundaries of the projects as well as site-based emissions that result from the construction activities within the boundaries.

Carbon emissions during operation

Maintenance emissions

For the assessment of carbon emissions associated with maintenance and refurbishment of the scheme, the study area is defined by the spatial boundaries and takes account of emissions associated with the extraction, processing and transport of materials as well as site-based emissions that result from the maintenance and refurbishment activities within the boundaries. There are likely minimal direct emissions associated with operating the schemes since the scheme’s lighting is minimal. Power consumption has been assumed as negligible in the context of the schemes and therefore the associated carbon impact does not form part of the GHG emissions assessment.

Road user carbon emissions

The study area for operational road user carbon is consistent with the Traffic Reliability Area (TRA) as defined by the scheme’s traffic model. The TRA is approximately 4.05km to the south of the schemes and 6.67km to the north of the schemes.

The relevant TRA is defined for the project by applying the scoping criteria included in DMRB LA 114, whereby road links are included within the TRA 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, and
- A change in daily average speed of more than 20km/h.

DMRB LA 114 requires consideration of:

- Whether there is (or is likely to be, within the timescales of the assessment) sufficient certainty on the availability of quantitative GHG emissions information.
- Whether the availability of information allows the effects on climate resulting from GHG emissions to be assessed.

Baseline and assessment scenarios

The baseline scenario is the 'Do-Minimum' approach, which represents the continual operation of the existing network without the schemes. The baseline scenario includes current operational maintenance GHG emissions, operational user GHG emissions and land use change/sequestration GHG emissions. The GHG baseline is a 'business as usual' scenario where the Proposed Development is not implemented. The baseline comprises existing sources of GHG emissions within the existing site boundary, as well as the emissions that may be avoided as a result of the Proposed Development.

GHG assessment will follow a project lifecycle approach to calculate the estimated GHG emissions arising from the construction and operation of the Proposed Development A 60-year appraisal period has been adopted in line with the methodology set out in DMRB LA 114 Climate. The baseline scenario is set out in Section 6 Baseline Conditions. The assessment scenario is the 'Do-Something' approach, i.e. implementing the schemes. The assessment scenario includes the construction, operational maintenance, operational user and sequestration GHG emissions. GHG emissions in this scenario are compared to the baseline to assess the net contribution of the schemes to climate change (in tCO_2e) from construction and operation over the 60-year appraisal period.

Vulnerability of the scheme to climate change (climate change resilience assessment)

The study area for this assessment is based on the construction footprint and includes temporary and completed works within the boundaries. The study includes all potential climate hazards for infrastructure and assets associated with the schemes. The assessment of climate effects on the schemes is assessed over the 60-year operational life cycle in line with the methodology set out in DMRB LA 114 Climate.

Baseline and assessment scenarios

Assessment scenarios are based on current and future climate baselines. The CCR assessment is based on climate trends associated with the UKCP18 high emissions scenario (50% probability) projection. Recent weather patterns and extreme weather events i.e. observed data have been identified and used to provide an indication of how the schemes would account for climate change in the immediate future i.e. during construction. The time periods for climate projections are selected based on the assumed lifespan and stages of the schemes (60 years), with construction assumed to commence in 2024 and operation assumed from 2026 to 2085. Additionally, DMRB LA 114 Climate, Section 3.30, requires that H++ (which are typically extreme) climate scenarios are used to test the sensitivity of vulnerable safety critical features, to ensure that such features would not be affected by more radical changes to the climate beyond that projected in UKCP18. Safety critical features that are vulnerable to climate change have been identified for the schemed to include:

- Drainage
- Earthworks
- Bridges

A high-level sensitivity test using H++ climate scenarios has been undertaken and is presented in Section 9 Assessment of likely significant effects. The integral safety of the schemes has also been considered against UKCP18 (and Representative Concentration Pathways 8.5 (RCP8.5) models therein).

Baseline Conditions

Impact of the scheme on climate (GHG emissions assessment)

Current and future baseline

This section identifies the GHG emissions without implementing the schemes for the current and future baseline (Do-minimum scenarios). In these scenarios, it is assumed that no construction activity would take place on any of the roads in the area, aside from maintenance, across the study period. The estimated baseline GHG emissions for the 'Do-minimum' scenario in the future baseline years (2028 and 2040) and over the study period (60 years) are summarised in Table 6-1.

GHG emissions component	Definition	2028 annualised (modelling opening year) tCO_2e)	2040 Annualised design (future) modelled assessment year (tCO_2e)	Cumulative estimated GHG emissions over 60-year study period (tCO_2e)
Operational maintenance – related GHG emissions	GHG emissions associated with maintenance of the existing road (s) within the study area for the schemes	0	3,862	4,368
Operational user GHG emissions (policy on)	GHG emissions from the tailpipes of vehicles driving in the TRA	21,871.7	17,118.3	331,637.8
Operational user GHG emissions (policy off)	GHG emissions from the tailpipes of vehicles driving in the TRA	23,353.7	21,061.8	288,060.2
Land use change/sequestration GHG emissions	GHG emissions associated with ongoing land use/sequestration	Negligible emissions	Negligible emissions	N/A
Total Policy On		**21,871.7**	**20,980.3**	**336,005.8**
Total Policy Off		**23,353.7**	**24,923.8**	**292,428.2**

Table 6-1 - GHG emissions over time

Vulnerability of the scheme to climate change (climate change resilience assessment) - current climate baseline

Historic observed regional weather data

The Met Office generates climatologies for different areas of the UK, known as climate districts, including historical regional climate information. The schemes is located within Eastern Scotland's regional climate. High-level climate observations for Eastern Scotland over a 30-year averaging period between 1981-2010 are presented in Table 6-2.

Parameter	Eastern Scotland's Climate Observations
Temperature	Annual mean temperatures vary from 9 °C close to the Firth of Forth to less than 6 °C over the higher ground of the Grampians, A90/A937 Laurencekirk being situated closer to the latter. The mean temperature drops to its coldest around January where it can range from 2 °C in areas of East Lothian and Fife bordering the Firth of Forth and on the NE coast of Grampian, to less than -2 °C covering the higher ground. Temperatures are generally at their highest in July where daily maximum temperatures at low levels inland approaching 20 °C, and less than 17 °C over the higher ground and along the coast of the Grampian region.
Sunshine	The number of hours of bright sunshine is controlled by the length of day and by cloudiness. In general, December is the dullest month and May or June is the sunniest. Sunshine duration

Parameter	Eastern Scotland's Climate Observations
	decreases with increasing altitude, increasing latitude, distance from the coast, sheltered topography and pollution. Eastern Scotland includes the sunniest places in Scotland, these being on the coast of Fife where the average is about 1,500 hours per year.
Rainfall	Rainfall is generally well-distributed throughout the year. The frequency of Atlantic depressions is normally greatest during the autumn and winter but, unlike other parts of the UK, Scotland tends to remain under their influence for much of the summer too. The wettest months tend to be in autumn and early winter. High altitudes are associated with greater rainfall. Much of Eastern Scotland is sheltered from the rain-bearing westerly winds. This shelter reaches its greatest potential along the coasts of East Lothian, Fife and the Moray Firth – where the Proposed Scheme lies – and these areas receive less than 700 mm of rainfall in an average year. In contrast, the wettest area is the southern Grampians where the average annual rainfall is over 1500 mm. These values can be compared with annual totals of around 500 mm in the driest parts of eastern England and over 4000 mm in the western Scottish Highlands. In winter (December to February), there are about 30 wet days on average along the coasts of East Lothian and Fife, rising to over 55 days in the Grampian mountains. In summer (June to August) the East Lothian and Fife coasts have about 27 wet days and the Grampian Mountains over 40 days. Periods of prolonged rainfall can lead to widespread flooding, especially in winter and early spring when soils are usually near saturation and snowmelt can be a contributing factor.
Wind	Eastern Scotland is one of the windier parts of the UK, being relatively close to the track of Atlantic depressions. The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions are greatest in the winter half of the year, especially from December to February, and this is when mean speeds and gusts (short duration peak values) are high. The penetration of westerly winds into eastern Scotland is controlled to a large extent by topography, with the Central Lowlands assisting this but the higher ground on either side providing shelter. Springtime tends to have a maximum frequency of winds from the north east.
Snowfall	Over most of the area, snowfall is normally confined to the months from November to April, but upland areas often have brief falls in October and May. Snow rarely lies at lower levels outside of the period November to April. On average, the number of days with snow falling is about 20 per winter along the coast but over 80 days over the Grampians. The number of days with snow lying has a similar distribution, with less than 10 along the East Lothian coast but over 60 days over the higher ground of Grampian. These averages can be compared with the coasts of SW England where less than 3 days per year have lying snow.

Table 6-2 - Climate observations for Eastern Scotland

Recent weather patterns and extreme weather events

A Local Climate Impacts Profile (LCLIP) for Aberdeenshire Council was developed by the UK Climate Impacts Programme (UKCIP) to assist local authorities and organisations to assess their exposure and vulnerability to past weather events, as a step towards preparing for future risks.

Table 6-3 summarises the primary weather events affecting the region between 2019 and 2022 and provides a high-level overview of the impacts experienced.

Weather Event	Impact
Heavy rain/Flash floods	13 incidents of excessive rainfall causing surface water flooding, town flooding, and building damage. This has led to significant infrastructure damage and service disruption, affecting community life and safety.
Storms and high winds	There were 18 storm incidents resulting in building damage, debris on roads, and power failure. These events have caused substantial economic losses for businesses and required financial assistance from government schemes.

Weather Event	Impact
Extreme low temperatures/ snow and ice	11 periods of snow/ice had impacts like round-the-clock gritting and transport network disruption. This has disrupted council services, including waste management, transportation, and school operations.
Extreme high temperatures/heatwaves	Nine occurrences of heatwaves led to water shortage and increased air pollution. These events have highlighted the need for effective climate change adaptation strategies to manage future climate risks effectively.

Table 6-3 - Weather events Aberdeenshire Region 2019-2022

Vulnerability of the scheme to climate change (climate change resilience assessment) - future baseline

This section presents future projected climate conditions and extreme weather events for the area encompassing the schemes for the 2020s and 2080s. These time periods cover the assumed construction period (commencing in early 2026 for a period of 24 months) and the assumed 60-year operational life (2028 to 2087).

Using the historical baseline data, two methods were implemented to establish the future climate baseline:

- The changes in average climate conditions were obtained from the UKCP18 probabilistic projections of climate change
- The changes in extreme weather events were obtained using UKCP18 regional projections.

Climate change projections for a range of meteorological parameters are presented for different probability levels within the RCP8.5 high emission scenario for the near-term and long-term future time periods. Table 6-4 presents changes in extreme weather events for the 2020s and 2060s, such as number of heavy rain days and Table 6-5 presents expected changes in climate conditions, such as mean temperature and precipitation for the 2020s and 2080s.

Parameter	Baseline (1981 – 2010)		2000s (2010-2039)			2060s (2050-2079)		
			Min	Mean	Max	Min	Mean	Max
Temperature	Number of frost days (daily minimum temperature equal or lower than 0°C)	48.2	46.1	44.0	40.2	39.2	36.0	32.1
	Heatwaves (2 days with a maximum temperature higher than 29°C and a minimum temperature higher than 15°C)	0.2	0.1	0.8	1.6	2.6	3.5	4.4
	Annual Count of Tropical Nights (minimum temperature above 20°C)	0.1	0.1	0.2	0.5	0.8	1.5	2.6
Precipitation	Dry spells (10 days or more with no precipitation)	6.2	5.4	6.4	7.0	6.4	7.2	8.0
	Annual number of days per year when precipitation is greater than 25mm per day (Met Office definition of 'heavy rain).	1.4	1.0	1.6	2.2	4.1	5.2	6.6
Wind	Wind above 10m/s	1.1	0.2	1.0	2.4	0.2	1.1	2.7

Table 6-4 - Climatic conditions over asset's life

Parameter	Baseline (1981 – 2010)		Anomalies from baseline 2020s (2010-2039)			Anomalies from baseline 2060s (2050-2079)		
			10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
Temperature (°C)	Mean winter daily temperature	4.5	-0.2	0.7	1.7	0.5	2.2	3.6
	Mean summer daily temperature	16.1	0	0.7	1.7	0.8	2.7	4.2
Precipitation (% change from baseline)	Winter mean precipitation rate	2.3mm	-5	12	25	-10	18	42
	Summer mean precipitation rate	2mm	-15	-5	12	-40	-15	10

Table 6-5 - Further climatic conditions over asset's life

1.1. H++ scenarios

DMRB LA 114, Section 3.30, requires that H++ climate scenarios are used to test the sensitivity of vulnerable safety critical features, to ensure that such features would not be affected by more radical changes to the climate beyond that projected in UKCP18. These are typically high impact, low likelihood events. H++ scenarios are a set of plausible 'high-end' climate change scenarios which are typically extreme climate change scenarios on the margins or outside of the 10th to 90th percentile range presented in the UK Climate Projections 2009 (UKCP09). The UKCP18 projections do not include an updated H++ scenario so the H++ scenario developed from UKCP09 remains current and applicable. The H++ scenarios are shown in Table 6-6 and cover the following climate hazards: heat waves, cold snaps, low and high rainfall, droughts, floods and windstorms.

Hazard	Scenario	Scenario description
Heat waves	H++	Annual average summer maximum temperatures exceeding 30°C over most of the UK. Hottest days would exceed 40°C in some locations, with 48°C being reached in extreme cases.
Low rainfall	H++	A 6-month duration summer drought with rainfall deficits of up to 60% below the long-term average (1900-1999). Longer dry periods spanning several years with rainfall deficits of up to 20% below the long-term average (1900-1999) across all of England and Wales, similar to the most severe and extensive long droughts in the historical record.
Low river falls	H++	A 30-60% reduction in 'low flows' (Q95) in a single summer. For multi-season droughts, including 2 summers, a 20 to 50% reduction in low flows. For longer droughts (2 years or more), a 45% reduction in low flows.
High rainfall	H++	A 70%-100% increase in winter rainfall (Dec to Feb) in a single winter (from a 1961-1990 baseline). An up to five-fold increase in frequency and a 60% to 80% increase in heavy daily and sub-daily rainfall depths, for both summer and winter events (all year round).
High river flows	H++	A 55% to 125% increase in peak flows at the 'lower end' of the H++ scenarios in Scotland. The upper limit is a 290% increase in peak flows (1961-1990 baseline).

Hazard	Scenario	Scenario description
Windstorms	H++	A 50-80% increase in the number of days per year with strong winds over the UK (1975-2005 baseline). A strong wind day is defined as one where the daily mean wind speed at 850 hPa, averaged over the UK (8W-2E, 50N-60N), is greater than the 99th percentile of the historical simulations.
Cold snaps	L--	In the 2020s, UK average winter temperatures (December, January and February) of 0.3°C and for the 2080s, UK average

Table 6-6 - H++ Scenarios

All climate scenario descriptions are related to Scotland where possible, and if not the UK. For low rainfall, the current generation of climate models are not capable of synthesising realistic droughts for regional scale and less credibility is assigned to the change in risk over these regions.

Potential Impacts

Mitigation measures incorporated in the design and construction of the schemes are reported as embedded mitigation. Prior to the implementation of mitigation, the schemes has the potential to affect climate during construction and operation, both beneficially and adversely.

Impact of the scheme on climate (GHG emissions assessment)

The schemes would result in GHG emissions during construction as well as changes to emissions during operation. The duration of the construction works for the project is expected to be approximately two years.

The potential sources of GHG emissions during the construction phase of the project are listed in Table 7-1, reproduced from DMRB LA 114.

Sub-stage of life cycle	Potential sources of GHG emissions
Product stage: Raw material supply, transport and manufacture	• Embodied GHG emissions associated with the required raw materials. • Vehicle emissions for transportation prior to the factory gate. • Industrial and energy emissions in the manufacture of materials
Construction process stage: Transport to/from works site and construction/installation processes	• Vehicle emissions for transportation of materials to the site. • Energy use in construction processes.
Land use change	• GHG emissions mobilised from vegetation or soil loss/degradation during the construction phase.

Table 7-1 - Potential sources of GHG emissions

The design lifetime of the Project is assumed to be 60 years for the purpose of quantifying emissions for this assessment.

The potential GHG emissions during the operation phase of the project are listed in Table 7-2, reproduced from DMRB LA 114.

Sub-stage of life cycle	Potential sources of GHG emissions
Use of the infrastructure by the end-user (road user)	• Embodied GHG emissions associated with the required raw materials. • Vehicle emissions for transportation prior to factory gate. • Industrial and energy emissions in the manufacture of materials
Operation and maintenance, including repair, replacement and refurbishment	• Energy consumption for infrastructure operation and activities of organisations conducting routine maintenance including extraction manufacture, transportation and installation energy use.
Land use change and forestry	• Ongoing land use GHG emissions/sequestration each year during the lifetime of the infrastructure.

Table 7-2 - Potential sources of GHG emissions

Opportunities identified for reduction of GHG emissions and mitigation measures incorporated in the design and construction of the schemes are set out in Section 8 Design, mitigation and enhancement measures.

Vulnerability of the scheme to climate change (climate change resilience assessment)

Vulnerability to climate change during construction

Climate change is expected to lead to changes in temperature and weather patterns which have the potential to impact on the construction of the Project:

- During construction, an increase in the frequency of extreme weather events could cause damage and delays, leading to health and safety impacts and increased costs.
- Increased temperatures, and prolonged periods of hot, dry weather could exacerbate dust generation and dispersion, leading to health and safety impacts on construction workers.

- Increased precipitation, and intense periods of rainfall, may result in flooding and soil erosion, an increased risk of waterbody contamination, disruption to the supply of materials and goods, and landslides.

The construction period is anticipated to be approximately 2 years in duration and is therefore considered to be a short duration and the likely mitigation measures, and effects associated with climate change during the construction phase are considered not to be significant.

Vulnerability to climate change during operation

Climate change is projected to increase peak rainfall intensity, and thus increase highway runoff rates and volumes. Flooding in watercourses is similarly expected to increase; therefore scour, bank erosion and exceedance of current minimum future climate design specifications for civil assets will potentially be more likely in the future. These effects could lead to increased risk of damage and/or requirements for maintenance during operation.

- An increase in climatic variability could lead to higher groundwater levels and more saturated soils but also an increased risk of extreme drought. Both impacts can affect ground stability in locations on vulnerable soils. Increased seasonal variability could lead to soil moisture fluctuations and therefore potentially increased risk of shrink-swell related failures.

- Vegetation stress due to drought conditions could also be a risk to the infrastructure depending on the width of the soft estate, steepened slopes and potential damage to root systems. In addition, increased wind velocities due to climate change are predicted. These impacts could result in an increased loss/damage to trees.

Table 7-3 presents the primary weather events currently affecting the study area and provides a high-level overview of the types of potential impacts. These include the impacts identified in DMRB LA 114.

Primary weather event	Potential impacts
Heavy rain/flooding	• Raised river levels flooded drains collapsed culverts • Road closures • Danger to road users • Contaminated water • Fallen trees • Water scour causing structural damage • Weakening or wash out of structural soils • Changes in ground water level and soil moisture
High winds/gales	• Damage to structures from windborne debris and power cuts • Additional or uneven loading of structures • Fallen trees and damage to landscaping • Disruption and potential danger to crossing users • Road closure • Danger to road users
Increased temperatures and prolonged periods of hot weather	• Health impacts from breathing problems and sunstroke • Danger to road users • Impact to biodiversity • Grass and forest fires • Stress on structures and technology • Challenges from maintenance regimes
Increased frequency of extreme weather events	• Increased requirement for maintenance and repair • Danger to road users • Increased costs
Lightning	• Structural damage • Danger to road users • Power surge and tripping electricity breakers • Fires • Health impacts from direct strikes
Snow and ice	• Road closures • Danger to road users • Damage to roads • Health impacts from slipping on ice and chest illnesses
Fog	• Danger to road users

Table 7-3 - Primary weather events

Design, mitigation and enhancement measures

Design and construction mitigation

The scheme has been designed to avoid and prevent adverse environmental effects on climate through the process of design development and consideration of good design principles.

Impact of the scheme on climate (GHG emissions assessment)

In accordance with DMRB LA 114 Climate, the third lifecycle stage for a project's GHG emissions (the first and second being construction and operation) comprises opportunities to reduce the production of GHG emissions.

Aligned with Transport Scotland's National Transport Strategy (2023), which outlines the agency's goal to diminish carbon emissions, and in accordance with the UK Government's carbon reduction plan objectives, along with the principles outlined in DMRB GG 103 for sustainable development and design, the project has endeavoured and will persist in its efforts, to minimise greenhouse gas emissions to the greatest extent feasible. This commitment aims to support the UK's overall reduction targets for carbon emissions and optimize its capacity to mitigate greenhouse gas emissions.

Mitigation measures mentioned in Table 9-7 in Section 9 Assessment of Likely Significant Effects and the climate Appendix 2: Mitigation Measures.

Vulnerability of the scheme to climate change (climate change resilience assessment)

The schemes have been designed to improve its resilience to climate change through a range of design and material specification measures including where practicable: the use of construction materials with superior properties (such as increased tolerance to fluctuating temperatures), incorporation of current road design standards and future climate change allowances. Embedded mitigation and adaption measures for all climate risks identified within the CCRA are set out in Table 9-7 in Section 9 Assessment of likely significant effects. Additionally, the integral safety of the schemes has been considered against UKCP18 (and RCP8.5 models therein). A sensitivity test of the safety critical features against H++ scenarios is set out in Table within Section 9 Assessment of likely significant effects.

All weather and climate-related risks to construction activities are expected to be mitigated through best practice site management, including relevant specific measures. The best practice site management measures and relevant specific measures would provide a level of resilience to the schemes throughout construction. Taking this mitigation into consideration, the vulnerability of the schemes to impacts from climate change during construction has been scoped out of the assessment in line with PINS' Scoping Opinion on the schemes.

Operational mitigation

Impact of the scheme on climate (GHG emissions assessment)

In addition to the mitigation measures identified within Table 9-7, no essential operational mitigation measures have been proposed. It is not practical to monitor GHG emissions from road users during the operational phase of the scheme as Transport Scotland does not have direct control over road user emissions.

Vulnerability of the scheme to climate change (climate change resilience assessment)

The Project will be designed to be resilient to impacts arising from weather events and climatic conditions in accordance with current planning, design and engineering practice, standards and codes. The climate assessment assumes that design and engineering practice standards and codes incorporate conservative assumptions of future climatic conditions, as guided by UKCP18, and that these are being used in the design process, particularly for safety critical assets.

Most weather and climate-related resilience effects during operation are expected to be mitigated through measures embedded in the design of the Project as a result of meeting current planning, design and engineering practice and codes. It is expected that these practices and codes will provide effective resilience throughout the operational phase of the Project (for the study period of a 60-year project lifetime).

1.1.1 A summary of the key climate resilience and adaptation measures embedded in the design are summarised in Table 9-8.

Assessment of Likely Significant Effects

This section presents the assessment of likely significant effects on climate resulting from the construction and operation of the schemes. The assessment of effects takes into account the potential impacts on each receptor following the implementation of embedded and essential mitigation measures to determine the significance of the residual effects.

Impact of the scheme on climate (GHG emissions assessment)

This assessment presents a calculation of the emissions calculated for the ‘Do Something’ scenario, a comparison against the ‘Do-Minimum’ baseline, and an assessment against legislated UK Government carbon budgets. Due to the embedded nature of the mitigation measures proposed, as outlined in Section 8 Design, mitigation and enhancement measures, some of which have already been incorporated into the design and some of which are yet to be incorporated, it is not practicable to complete a quantitative assessment of 'before' and 'after' mitigation. Rather, the assessment shows a snapshot of the current design.

Do-Something' scenario emissions

Construction

A high-level breakdown of construction phase emissions is displayed in Table 9-1. All assumptions used in the calculations are contained within Appendix 2 carbon modelling assumptions, methodology and emissions factors and Section 4 Assessment assumptions and limitations. Emissions from the construction phase are predicted to total in the region of 11,457 tCO_2e for the main scheme and 615 tCO_2e for Oatyhill.

Main Stage of project life cycle	Sub-stage of life cycle	Oatyhill Emissions (tCO_2e)	Main Scheme Emissions (tCO_2e)
Construction Stage	Product stage	121	3,910
	Transport	132	3251
	Construction process stage	362	4,296
	Land use change	-	-
	Total Construction Stage	**615**	**11,457**

Table 9-1 - Construction emissions

For Main Scheme Emissions, the largest magnitude of emissions during construction is likely to arise from emissions from on-site construction processes followed by the production of materials, and the transport of materials.

Operation

As noted in Section 5 Study Area, there are likely minimal direct emissions associated with operating the scheme since the schemes lighting is minimal. Power consumption has been assumed as negligible in the context of the schemes and therefore does not form part of the GHG emissions assessment. Emissions associated with maintenance and refurbishment assume that the road surface would be replaced once every ten years for the duration of the assumed 60-year design life. Road user GHG emissions are expected to constitute the majority of the whole life GHG emissions of the schemes. Operational phase emissions for the modelled opening and design years and the total over the modelled 60-year operational period are shown in Table 9-2.

Main Stage of project life cycle	Sub-stage of life cycle	Oatyhill Emissions (tCO_2e)	Main Scheme Emissions (tCO_2e)
Operation Stage	Use of the infrastructure by the end-user (road user emissions) – policy on	298,255.9	
	Use of the infrastructure by the end-user (road user emissions) – policy off	364,238.4	
	Maintenance and refurbishment	168	4,200

	Land Use and Forestry	-	-
	Total Operation Stage (excluding road user emissions)	**168**	**4,200**

Table 9-2 - Operational emissions

Comparing ‘Do-Minimum’ and ‘Do-Something’ scenarios

As GHG emissions associated with construction do not occur in the ‘Do-Minimum’ scenario, it can be considered that the construction stage of the schemes would have the effect of releasing in the region of an additional 11,457 and 615 tCO_2e into the atmosphere in the ‘Do-Something’ scenario for both schemes. The calculated annualised operation stage emissions from tailpipe emissions for the modelled 2028 and 2040 for Policy Off and 2028- 2045 for Policy On ‘Do-Minimum’ and ‘Do-Something’ scenarios is compared in Table 9-3 and Table 9-4.

Policy on

Scenario	2028 (tCO_2e)	2032 (tCO_2e)	2038 (tCO_2e)	2040 (tCO_2e)	2045 (tCO_2e)
Do-Min	21,871.7	20,673.3	18,875.6	17,118.3	12,725.2
Do-Some	22,894.4	21,523.7	19,467.7	18,390.5	18,211.0
Difference	1,022.7	850.4	592.0	4,786.7	5,486.0

Table 9-3 - Policy on road user emissions

Policy off

Scenario	2028 (tCO_2e)	2032 (tCO_2e)	2038 (tCO_2e)	2040 (tCO_2e)
Do-Min	23,353.7	22,547.0	21,337.1	21,061.8
Do-Some	24,102.0	23,320.8	22,148.9	21,867.5
Difference	748.4	773.8	811.9	805.7

Table 9-4 - Policy off road user emissions

A summary of the total emissions associated with the schemes can be found below in Table 9-5.

Project Stage Life Cycle Stages	Emissions (tCO_2e)	
	Oatyhill	Laurencekirk Main Scheme
	Do Something	**Do Something**
A1- A3 Product stage	121	3,910
A4 Transport	132	3,251
A5 Construction process	362	4,269
B4-5 Material replacement and refurbishment	168	4,200

Project Stage Life Cycle Stages	Emissions (tCO_2e)	
	Oatyhill	Laurencekirk Main Scheme
	Do Something	Do Something
B6-9 Use Phase Policy On	271,388.2	
B6-9 Use Phase Policy Off	298,255.9	
Total	**783 (without use phase emissions)**	**15,630 (without use phase emissions)**

Table 9-5 - Emissions summary

Assessment against legislated UK carbon budgets

Table shows the relevant carbon budget periods against which the schemes would contribute. This approximation assumes an even distribution of emissions across the assumed overall construction period. Construction is expected to start in 2026 and the schemes are expected to be open to traffic in 2028 which places both the schemes construction phase within carbon budgets 4 and 5, the construction period for the schemes falls wholly within the fourth carbon budget. Operation of the schemes would commence in 2028 and is assessed against the fifth and sixth carbon budgets, up to 2045. Operational and maintenance emissions for Do Something scenarios between 2033 and 2037 (the period for the sixth carbon budget) are provided in Table 9-6, however, emissions after 2037 are not assessed as this new target has yet to be legislated.

Project Stage	Estimated total (cumulative) GHG emissions over carbon budgets (tCO2e) ('Do-Minimum scenario	Net (cumulative) GHG emissions over carbon budgets (tCO2e) ('Do Something)	Net (cumulative) scheme GHG emissions per relevant carbon budget (tCO_2e)		
			Fourth (2023-2027)	Fifth (2028-2032)	Sixth (2033-2037)
Construction (over a period of 42 months, assumed to commence in early 2026-2028)	-	12,045	12,072		
Operation – tailpipe emissions Policy On	205,234.7	213,523.8		111,045.4	102,478.5
Operation – tailpipe emissions Policy Off	224,461.9	232,231.4		118,557.1	113,674.3
Operation – Maintenance and refurbishment	-	8,831		2,184	2,814
Total Policy On	**205,234.7**	**234,399.8**	**12,072**	**113,229.4**	**105,292.5**
Total Policy Off	**224,461.9**	**253,107.4**	**12,072**	**120,741.1**	**116,488.3**

Table 9-6 - Emissions across the UK carbon budget

Significant effects

The construction and operation phases of the schemes which fall within legislated carbon budget periods are expected to have an insignificant impact on the ability of the UK Government to meet its carbon budgets. Construction of the schemes is estimated to contribute approximately 0.00619% of the fourth carbon budget. Operation of the schemes are estimated to contribute approximately 0.013% of the fifth carbon budget and 0.023% of the sixth carbon budget. It is considered that this magnitude of emissions from the schemes in isolation would not have a material impact on the ability of the UK Government to meet its carbon budgets and therefore is not anticipated to give rise to a significant effect on climate.

Vulnerability of the scheme to climate change (climate change resilience assessment)

Vulnerability during construction

Climate change is expected to lead to changes in temperature and weather patterns which have the potential to impact the construction of the Project:

- During construction, an increase in the frequency of extreme weather events could cause damage and delays, leading to health and safety impacts and increased costs.
- Increased temperatures, and prolonged periods of hot, dry weather could exacerbate dust generation and dispersion, leading to health and safety impacts on construction workers.
- Increased precipitation, and intense periods of rainfall, may result in flooding and soil erosion, an increased risk of waterbody contamination, disruption to the supply of materials and goods, and landslides.

The construction period is anticipated to be approximately 2 years in duration. Given the short length of time of the construction period and the likely mitigation measures, effects associated with climate change during the construction phase are considered not to be significant.

The schemes have been designed to avoid and prevent adverse environmental effects on climate through the process of design development and consideration of good design principles, embedded mitigation measures are detailed in Table 9-8.

Vulnerability during operation

Climate change risks to infrastructure assets designed and constructed as part of the schemes have been assessed during operation. The assessment finds all climate change risks to assets during the operation of the schemes to be 'not significant' because of mitigation measures already built into the design and assumed management practices. Details of the mitigation measures identified to date and the significance assessment are contained in Climate Chapter Appendix 2 Maintenance measures. These non-significant climate resilience impacts, identified using criteria set out in the assessment methodology, are detailed in Table 9-7.

The embedded design resilience and potential operation impacts of changing environmental conditions are presented in Table 9-8.

Risk ID	Potential climate change risk	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequences of hazard impact (should the impact occur)	Evaluation of significance	Scheme
1	High temperatures asphalt surfaces may be altered by hot conditions.	Material selection criteria takes into consideration durability. Maintenance measures are appropriate for risk.	Low	Minor adverse	Not significant	Both
2	Flooding of the road's surface	The schemes has been designed to cater for the climate change contingency factor of 35% Flood Risk Assessment in Land Use Planning (SEPA 2019) through the use of SuDS.	Medium	Moderate adverse	Not significant	Both

Risk ID	Potential climate change risk	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequences of hazard impact (should the impact occur)	Evaluation of significance	Scheme
3	Increased risk to high-sided vehicles due to high wind speeds	Oatyhill 's structure isn't designed to be that high above the ground, so it's more sheltered / less exposed and therefore due to its design, will not be as exposed to extreme wind events.	Low	Minor Adverse	Not Significant	Both
4	Increased risk to high-sided vehicles due to high wind speeds	Relevant wind monitoring will be carried out according to the High Wind Strategy And National Wind Management Guidelines.	Medium	Moderate Adverse	Not Significant	Main Scheme
4	Increased risk of erosion at embankments	Relevant maintenance measures will be undertaken. Regular inspections will monitor risks.	Low	Minor Adverse	Not significant	Both
5	Structural failure of multi-span bridges due to high wind.	The two main structures of the proposed schemes will be designed to avoid the need for bearings, which are replaceable elements, and typically need to be designed for wind loading. Without bearings, the structures will be more resilient to any increases in wind loads due to climate change. Furthermore, the overall planned design life of the structure will also ensure that any changes to environmental conditions in which the structure is situated are accounted for to ensure that the strength and structural integrity is not undermined.	Low	Minor Adverse	Not significant	Both
6	Extended periods of hot dry weather lead to a risk of spontaneous grassland fires in the vicinity of the route, affecting safety on the road.	Risk to be sufficiently mitigated through standard emergency procedures. Additionally, 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 from one side to the other.	Low	Moderate Adverse	Not significant	Both
7	Inability to flex under traffic loads. Increased risk of road surface cracking and fretting with age.	This risk would be managed through the proposed maintenance regimes	Low	Minor adverse	Not significant	Both
8	Increased erosion at the toe of the embankment.	To be mitigated through drainage design.	Low	Large adverse	Not significant	Both
9	Increased risk of earthworks failure and landslides. Exacerbated by the variance between high and low precipitation events and soil moisture levels.	To be mitigated through geotechnical and drainage design.	Low	Minor adverse	Not significant	Both

Risk ID	Potential climate change risk	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequences of hazard impact (should the impact occur)	Evaluation of significance	Scheme
10	Increased risk of debris washing into drainage gullies, blocking them. A blockage may result in flooding and effects.	Mitigated through drainage design and monitoring and maintenance procedures proposed for drainage systems.	Low	Minor adverse	Not significant	Both
11	A wetter surface may lead to reduced skid resistance.	This risk would be managed through the selection of suitable road surface material as well as through the proposed maintenance regimes for road surfaces.	Low	Moderate adverse	Not significant	Both
12	Increased likelihood of potholing, rutting and cracking from moisture entering and remaining on road surfaces.	This risk would be managed through the proposed maintenance regimes for road surfaces.	High	Minor adverse	Not significant	Both

Table 9-7 - Climate resilience

Climate Change Factor	Potential Climate Change Risk to the Project	Embedded Mitigation	Likelihood	Consequence	Significance
Increased periods of Heavy Rain – Wetter, Warmer Winters	Increased periods of rainfall may overwhelm the infrastructure leading to a flooding event along the carriageways and potential scour/ erosion damage to earthwork slopes.	In relation to the drainage design element which has been designed to account for the 35% uplift to peak flow, in line with SEPA guidance. This means that all proposed SuDS Attenuation Basins have been designed to accommodate attenuation from the carriageway runoff from a 100-year return period rainfall event to the 1 in 2-year pre-development runoff rate while achieving sufficient freeboard. The basin will accommodate a 1 in 200-year return period rainfall event without flooding. Therefore, the planned drainage network is designed to cope with any potential severe flooding events within the area of the scheme.	**Possible -** Predictions of rainfall patterns across the UK are not uniform and vary on seasonal and regional scales and will continue to vary in the future. For example, in the 2050 – 2079 RCP4.5 scenario, winter rainfall anomaly is -10% to +40% for the 10^{th} and 90^{th} percentile, respectively.	**Beneficial –** During the scheme's drainage design the flooding capacity will provide a positive benefit to the existing conditions in the event of increased rainfall periods. The design development and embedded mitigation factors has taken this factor into account.	The impact of this climate change factor is considered **- Not Significant**
Dry and Hotter Periods - Dry, hot summers, Warmer Winters	Hotter temperatures combined with the projected reduction in summer average rainfall could lead to increased erosion as soils and their substrates dry out. The increase in temperature may also have an adverse impact on the materials used within the pavement structure and	Within the maintenance of the proposed drainage design, the Inspections of Attenuation Basins Inlet / Outlets every year and Maintenance on the rest of the planned drainage network will be as required, or in the event of blockages within pipes or ditches. The planned maintenance and rehabilitation of the pavement structure will ensure that the replacement and improvement to the approx. 17,000m^2 that the design incorporates will be accounted for within the maintenance plan.	**Possible -** By the end of the 21st century, all areas of the UK are projected to be warmer, more so in summer than in winter. The high emission scenario (RCP8.5) for Laurencekirk shows that by: 2070 summers could be up to 4.9°C hotter. With embedded mitigation in place and the planned maintenance scheduling for the design. The likelihood of an accelerated impact due to climate factor may be possible and is accounted for within the embedded mitigation of the design.	**Beneficial –** During the design's operation. Pavement maintenance and repair costs would initially be reduced. The difference in this reduction with and without the Scheme is similar**.** There is still a high likelihood to wearing damage occurring to the assets during the lifespan of the Design regardless of any other factors.	The impact of this climate change factor is considered **- Not Significant**

Climate Change Factor	Potential Climate Change Risk to the Project	Embedded Mitigation	Likelihood	Consequence	Significance
	elements of the bridge structure				
More Frequent Extreme Weather Events – Storm Events, Longer Periods of High Winds	More regular and intense storms in the future could increase the regularity of lightning strikes on infrastructure. High winds in these storms could also overload the main bridge structures and any ancillary structures for example traffic signs.	For the two main structures in the proposed scheme, they will be designed to avoid the need for bearings, which are replaceable elements, and typically need to be designed for wind loading. Without bearings, the structures will be more resilient to any increases in wind loads due to climate change. Furthermore, the overall planned design life of the structure will also ensure that any changes to environmental conditions in which the structure is situated in, are accounted for to ensure that the strength and structural integrity is not undermined.	**Possible –** UK Climate Projections show an increase in mean wind speed in winter by the late 21st century, but this is small compared to the natural year-to-year variability. Different climate models show different trends including decreases, so the magnitude of this change is subject to uncertainty. UK Climate Projections show an increase in windstorm number and intensity over the UK by the late 21st century but given the widespread and interannual variability, large uncertainties remain. With embedded mitigation in place and the planned maintenance scheduling for the design, the likelihood of an accelerated impact due to climate factor may be possible and is accounted for within the embedded mitigation of the design.	**Severe Potential –** Road traffic deaths & injuries and potentially significant disruption to traffic. It should be noted that the consequence of this impact would be equal or greater without the Design which will incorporate safer junctions for traffic users therefore providing areas of improved safety during extreme weather events.	The impact of this climate change factor is considered **- Not Significant**

Table 9-8 – Embedded Design Resilience and Potential Operation Impacts of Changing Environmental Conditions

Sensitivity test of the scheme's vulnerable safety critical features against H++ climate scenarios

This section reports a sensitivity test of the vulnerable safety critical features of the schemes against the H++ climate scenarios to assess the extent to which such features would be affected by more radical changes to the climate beyond that projected in UKCP18. Safety critical features that are vulnerable to climate change have been identified for the schemes to include:

- Drainage
- Earthworks
- Bridge Structure

Other safety critical features of the schemes have been scoped out of the sensitivity test due to their limited vulnerability to climate change, their embedded resilience due to the use of appropriate design standards or risks being controlled through appropriate adaptive management and maintenance procedures already identified in the CCR assessment.

The sensitivity testing has been informed by published research and guidance, including:

- Met Office, University of Reading and CEH for the Adaptation Sub-Committee (2015) Developing H++ climate change scenarios for heat waves, droughts, floods, windstorms and cold snaps.
- Transport Scotland's Approach to Climate Change Adaptation and Resilience.

Hazard (and scenario)	H++ (or L--) future climate scenario description	A90/A937 Laurencekirk vulnerable safety critical features		
		Drainage	Earthworks	Bridge Structure
Heat Waves (H++)	Annual average summer maximum temperatures exceeding 30°C over most of the UK. Hottest days would exceed 40°C in some locations, with 48°C being reached in extreme cases.	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A	**Risks/Consequences:** An increase in average summer maximum temperatures would result in an increased frequency of soils and sub soil desiccation, leading to surface erosion if followed by increases in extreme precipitation. **Adaptation measures:** The increase in average maximum temperatures would need to be considered for soil slopes as part of the detailed design.	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A
Low Rainfall (H++)	A 6-month duration summer drought with rainfall deficits of up to 60% below the long-term average (1900-1999). Longer dry periods spanning several years with rainfall deficits of up to 20% below the long-term average (1900-1999) across all of England and Wales, similar to the most severe and extensive long droughts in the historical record.	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A	**Risks/Consequences:** Extensive drought conditions could impact the growth of vegetation on soil slopes, which would otherwise provide erosion protection. This combined with soil and sub soil desiccation could lead to surface erosion over time. **Adaptation measures:** Erosion management would need to be considered as part of the design and maintenance of the schemes.	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A
Low river flows (H++)	A 30-60% reduction in 'low flows' (Q95) in a single summer. For multi-season droughts, including 2 summers, a 20 to 50% reduction in low flows. For longer	**Risks/Consequences:** Pollution - with a reduction in river flows, drainage dilution levels would be more concentrated due to receiving water courses carrying less water.	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A

Hazard (and scenario)	H++ (or L--) future climate scenario description	A90/A937 Laurencekirk vulnerable safety critical features		
		Drainage	Earthworks	Bridge Structure
	droughts (2 years or more), a 45% reduction in low flows.	**Adaptation measures:** Drainage and attenuation ponds will allow settlement and removal of pollutants before water enters the receiving water courses. Swales will be implemented to provide a level of removal of metals present in the water.		
High rainfall (H++)	A 70%-100% increase in winter rainfall (Dec to Feb) in a single winter (from a 1961-1990 baseline). An up to five-fold increase in frequency and a 60% to 80% increase in heavy daily and sub-daily rainfall depths, for both summer and winter events (all year round).	**Risks/consequences:** An increase in the flooding of the highway would impact the performance of the network itself, including congestion and impacting user safety. Deterioration of the performance of other assets, for example, the road pavement due to standing water. This could lead to an increased risk of flooding within the highway would impact the performance of the network, including congestion and incidents (safety). **Adaptation measures:** The drainage systems within the designs take into account a climate change allowance for high rainfall, beyond that required by the DMRB standards. However, H++ scenarios have not informed the Project design. Carriageway collection systems and water levels in drainage systems are designed for storm events.	**Risks/consequences:** An increase in winter precipitation could adversely impact the stability of earthworks, including cutting slopes and embankments, through increased groundwater levels, porewater pressures and the erosion of the toe of earthworks. Increased rainfall would also result in increased groundwater flows emerging from springs which could result in internal erosion of earthwork embankments. **Adaptation measures:** Risks to earthworks' stability from increased rainfall, surface runoff and internal erosion will need to be considered at the detailed design stage. Adaptation measures could include the implementation of masonry gullies or additional earth retention or reinforcement.	**Risks/consequences:**Scour, a significant cause of bridge failures, results from erosion around bridge foundations due to factors like heavy rainfall. This erosion weakens the structural integrity of bridges, potentially leading to collapses. **Adaptation measures:** Bridge stability due to scour adaptation measures will need to be considered in alignment with Earthworks.
High river flows (H++)	A 55% to 125% increase in peak flows at the 'lower end' of the H++ scenarios in Scotland. The upper limit is a 290% increase in peak flows (1961-1990 baseline).	**Risks/consequences:** Watercourses affected by the schemes are serving relatively small catchments so direct rainfall allowances apply (see "High Rainfall"). **Adaptation measures:** A more extreme increase in peak river flows could result in increased operational disruption in areas that are vulnerable to fluvial flooding. A precautionary approach could be taken to increase the elevation of the road surface above the floodplain in vulnerable locations during initial construction. Alternatively, adaptation pathways could be defined and incorporated into the design to allow the elevation of the road surface to be increased in the future if required based on observed impacts.	**Risks/consequences:** Increased river flows, resulting in flooding, could lead to the erosion of earthworks. **Adaptation measures:** Mitigation for earthworks that are vulnerable to increased peak river flows will need to be considered as part of the detailed design.	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A

Hazard (and scenario)	H++ (or L--) future climate scenario description	A90/A937 Laurencekirk vulnerable safety critical features		
		Drainage	Earthworks	Bridge Structure
Windstorms (H++)	A 50-80% increase in the number of days per year with strong winds over the UK (1975-2005 baseline). A strong wind day is defined as one where the daily mean wind speed at 850 hPa, averaged over the UK (8W-2E, 50N-60N), is greater than the 99th percentile of the historical simulations.	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A	**Risks/consequences:** Risk of bridge stability due to high winds. **Adaptation measures:** Bridges are designed based on specifications within relevant British Standards (e.g. bridges and structures). Monitoring wind strength and direction is vital for effective high wind management in accordance with Transport Scotland's "High Wind Strategy and National Wind Management Guidelines".
Cold snaps (L--)	In the 2020s, the UK average winter temperatures (December, January and February) of 0.3°C and for the 2080s, the UK average	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A	**Risks/consequences:** N/A - No vulnerable features identified **Adaptation measures:** N/A

Table 9-8 – H++ Sensitivity analysis

The sensitivity test of the vulnerable safety critical features against the H++ climate scenarios at this stage in the design indicates that such features would not be significantly affected by more radical changes to the climate beyond that projected in UKCP18. The extreme climate scenarios would continue to be taken in to account through detailed design and maintenance to ensure the schemes are designed with resilience to climate change as a key consideration.

Monitoring

Impact of the scheme on climate (GHG emissions assessment)

As no significant effects have been identified for the GHG emissions assessment, no monitoring of significant effects is required. An adaptive management approach as outlined by DMRB and IEMA in their Climate Change Resilience document is recommended for this project. This enables uncertainty to be included in operational decision-making. Adaptive management enables the potential impacts from changes in the climate to be dealt with as they become more likely. By taking an adaptive management approach, projects can introduce additional mitigation if the project's impact is starting to cause unacceptable effects on the receiving environment. This concept is not currently commonly used in EIA, but it will become increasingly important to avoid inappropriate mitigation being implemented at the wrong time in a project lifecycle.

In line with the monitoring requirements set out in DMRB LA 114 Climate, quarterly GHG emission returns during construction and operation shall be reported in accordance with Transport for Scotland's requirements. Data provided for the GHG returns shall be evaluated to inform any ongoing monitoring of GHG emissions and feedback into future assessment of projects during design development and planning approval.

Vulnerability of the scheme to climate change (climate change resilience assessment)

As no likely significant effects have been identified within the climate change resilience assessment, no monitoring of significant effects is required.

Summary

Impact of the scheme on climate (GHG emissions assessment)

The schemes would result in GHG emissions due to construction materials and activities during the construction phase; maintenance and refurbishment during the operation phase; vehicles using the road during the operation phase; and land use change over the assumed 60-year operational period.

Vulnerability of the scheme to climate change (climate change resilience assessment)

Assets and infrastructure designed as part of the schemes are likely to be affected by climate change. A number of potential risks have been identified and assessed; these would be mitigated by applying robust design standards or relevant mitigation measures or would be incorporated in the relevant asset management processes.

Significance

The assessment of schemes impacts is considered to be not significant based on evidence that in isolation the scheme would not have a material impact on the ability of the UK Government to meet its carbon reduction targets. Therefore, the following conclusions can be made.

Construction assessment

- Impact of the schemes on climate: no significant effect.
- Vulnerability of the scheme to climate change: no significant effects.

Operation assessment

- Impact of the schemes on climate: no significant effect.
- Vulnerability of the schemes to climate change: no significant effects

2. References

Table of references.

No.	Reference
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24	IEMA - Institute of Environmental Management and Assessment

3. Figures

Figure 1.1 - A map of the schemes boundaries and further details