Appendix A20.1: Vulnerability to Climate Change

1.1 Vulnerability to Climate Change

1.1.1 In this appendix, the vulnerable receptors of the proposed scheme to climate change are identified, and the significance of each risk associated with the most important hazards for the Scottish road network is assessed.

1.1.2 The receptors considered are:

- Road surfaces and pavements;
- Structures (including embankments, cuttings and bridges);
- Drainage infrastructure;
- Road technology and street furniture (including signs, signals, and lighting);
- Landscaping; and
- Road users.

1.1.3 For the risk assessment, likelihood, consequence and significance have been considered (Tables 1 - 3), along with the use of professional judgement. Embedded mitigation has been taken into consideration.

1.1.4 For the risk assessment during construction, a qualitative approach has been applied. Tables 3.39 – 3.41 of DMRB LA 114 were used for the risk assessment during operation.

1.1.5 The vulnerability to climate change significance assessment is discussed in Table A20.1-4 below.

1.2 Assessment criteria

1.2.1 A qualitative assessment of the residual likelihood and consequence of each impact has been undertaken with reference to the indicative framework set out in Table 3.39a (likelihood categories) and Table 3.39b (measure of consequence) of DMRB LA 114 (replicated in Table A20.1-1 and Table A20.1-2 below).

1.2.2 The residual likelihood and consequence of each of the potential climate related impacts identified has been combined in order to assess significance as per Table 3.41 (significance matrix) of DMRB LA 114 (replicated in Table A20.1-3 below).

1.2.3 Potential opportunities for enhancement relevant to each impact are also identified (where applicable).

Table A20.1-1: Likelihood categories

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.

Likelihood category	Description (probability and frequency of occurrence)
High	The event occurs several times during the lifetime of the project (60 years) e.g. approximately once every five 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 occurs 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 A20.1-2: Measure of consequence

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

Table A20.1-3: Significance matrix

		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

NS = Not significant, S = Significant

Table A20.1-4: Vulnerability significance assessment

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
Road surfaces and pavements						
Increased precipitation during winter months and more frequent and intense rainfall events. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, mean winter precipitation will potentially increase by 26%. This increase is likely to occur as result of a combination of more wet days, as well as an increase in the intensity of rainfall events.	Rivers flooding the A9 road surface. This could result in direct impacts to end users through delays on / disruption to the network and safety risks to road users, together with damage to / deterioration of road pavements. Such impacts could also result in indirect impacts for the scheme operator in terms of increased management / maintenance requirements / costs.	Scheme designed so that mainline, junctions and surfaced access roads are above the design flood event level (i.e. 0.5% Annual Exceedance Probability (AEP) (200-year) plus climate change flood event). Current guidance advises a peak river flow allowance of 53% and a peak rainfall intensity allowance of 39% to be applied to the Tay River Basin Region. Where possible, a minimum freeboard of 600mm has been provided above the 0.5% AEP (200-year) plus climate change flood event.	Very low – Scheme designed so that flooding of A9 mainline would be very unlikely to occur, even accounting for climate change.	Moderate adverse – Both localised flooding of the network and additional maintenance/repair works could result in road closures and associated traffic delays. These impacts are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting more than one day but less than one week.	Not significant	None identified
	Drainage capacity being exceeded resulting in the flooding of the A9 road surface. This could result in direct impacts to end users through delays on / disruption to the network and safety risks to road users, together with damage to / deterioration of road pavements. Such impacts could also result in indirect impacts for the scheme operator in terms of increased management / maintenance requirements / costs.	Drainage networks designed to have no flooding in the 1 in 1-year storm event plus climate change allowance (39%) and to have no surging into the pavement layers during the 1 in 5-year event plus climate change allowance (39%) i.e. designed with enough capacity to avoid flooding with only less likely scenarios (less than 20% likelihood) resulting in flooding.	Low – Design developed to have ample drainage capacity for a 1 in 5 year event plus an allowance for climate change, so flooding should occur much less frequently.	Moderate adverse – Both localised flooding of the network and additional maintenance/repair works could result in road closures and associated traffic delays. These impacts are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting more than one day but less than one week.	Not significant	None identified
	Rise in ground water level could result in flooding (particularly in winter). This could result in direct impacts to end users through delays on / disruption to the network and safety risks to road users, together with damage to / deterioration of road pavements.	Site-specific ground water monitoring has been carried out to determine the seasonal ground water level fluctuation. The hydrogeological model will determine the maximum ground water level to be used in the designs and worse case conditions will be used for the design of drainage. The most appropriate drainage type will be selected and designed to meet	Low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Moderate adverse – Both localised flooding of the network and additional maintenance/repair works could result in road closures and associated traffic delays. These impacts are considered to have the potential to result in national level disruption to strategic route(s), including the A9, lasting more than one day but less than one week.	Not significant	None identified

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
	Such impacts could also result in indirect impacts for the scheme operator in terms of increased management / maintenance requirements / costs.	the requirements of DMRB CG 501 'Design of highway drainage systems' (Highways England et al., 2022) to allow for ground water interception.				
	Increased number of heavy rain days resulting in a higher stripping rate of pavements leading to texture depth reduction. This could lead to indirect impacts to road users through increased safety risks and increased maintenance requirements / costs to the scheme operator.	The Principal Contractor will, in the choice of permitted materials for sub-bases and bases, and in accordance with DMRB CD 226 (Highways England et al., 2021b), have regard to the nature of those materials and of the sub-grade or any capping and the need to protect them from deterioration due to the ingress of water, the adverse effects of weather and the use of construction plant for pavement construction activities.	Low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Minor adverse – Additional maintenance/repair works could result in road closures and associated traffic delays. These activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified
	Increased rainfall during winter months resulting in potholing, rutting, and cracking from moisture entering and remaining in pavements (particularly in combination with frost formation). This could lead to indirect impacts to road users through damage to vehicles and increased maintenance requirements / costs to the scheme operator. There is the potential, however, that the effect on pothole formation may be wholly or partially offset by summers being drier and winters being warmer (i.e., less freeze thaw erosion and less frost heaving, which are both significant contributors to pothole formation).	The pavement is designed to DMRB CD 226 'Design for new pavement construction' (Highways England et al., 2021b) and foundation designed to CD 225 'Design for new pavement foundations' (Highways England et al., 2020a) and materials would be laid to Manual of Contract Documents for Highway Works (MCHW) standards (Highways England et al., 2023). The design of a sub-surface drainage system in accordance with DMRB CG 501 'Design of highway drainage systems' (Highways England, 2022) will drain the sub-base pavement layers from any water ingress.	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Minor adverse – Additional maintenance/repair works could result in road closures and associated traffic delays. These activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified
Increase in maximum summer temperatures and number / duration of hot	Could result in permanent deformation of asphalt (part of the paving mixture, i.e., flexible surfacing), particularly during	Best practice construction techniques and appropriate material quality standards will be followed to	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years)	Minor adverse – Additional maintenance/repair works could result in road closures and associated traffic delays. These	Not significant	Special material such as polymer modified bitumen will be

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
days, hot spells, and heatwaves. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, summer mean daily maximum temperatures could be +4.6°C warmer.	prolonged hot weather conditions, together with surface rutting leading to water ponding in ruts and reduced skid resistance due to fatting (accumulation of bituminous mix on the surface of the pavement). Indirect impacts to the pavement surface through soil shrinkage and / or subsidence and increased desiccation of soils. This could lead to potential indirect impacts on road users through increased safety risks and increased maintenance requirements / costs to the scheme operator.	ensure the design lives specified can be met. The surface will be laid as per DMRB CD 236 'Surface course materials for construction' (Highways England et al., 2021d) to ensure adequate Polished Stone Value (PSV) is adopted to reduce risk of skidding caused by increased rainfall, especially for high risk areas. Furthermore, the Scheme design will ensure the bound material is constructed on a sound foundation that should perform at its optimum over the design life.	e.g. approximately once every 15 years.	activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.		considered for areas subject to rutting.
	Could lead to an acceleration of bitumen binder hardening resulting in direct impacts to the pavements through cracking and fretting with age and traffic loads. This could lead to increased maintenance requirements / costs to the scheme operator.	The pavement is designed to DMRB CD 226 'Design for new pavement construction' (Highways England et al., 2021b) and foundation designed to CD 225 'Design for new pavement foundations' (Highways England et al., 2020a) and materials would be laid to MCHW standards (Highways England et al., 2023).	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Minor adverse – Additional maintenance/repair works could result in road closures and associated traffic delays. These activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	The pavement design will consider the use of special material selection, such as EME2 binder course (high strength, long life asphalt base and binder course), to mitigate against cracking and fretting of the carriageway.
	Increased temperatures may lead to longer growing seasons which could lead to deformation of pavements due to overgrown tree roots. This could lead to increased maintenance requirements / costs to the scheme operator. The growing season is a response to day length not just temperature, and trees in a stressed state from either drought or waterlogging are likely to experience restricted growth.	DMRB LD 117 'Landscape design' (Highways England et al., 2020b) requires large trees to be planted 9m from the edge of carriageway, medium trees 7m from the edge of carriageway and shrubs 4.5m from edge of carriageway.	Very Low – Such impacts could possibly occur once during the lifetime of the project (e.g. once in 60 years).	Negligible – Additional maintenance/repair works could result in lane closures and associated traffic disruption. These activities are considered to have the potential to result in disruption to an isolated section of the A9, lasting less than one day.	Not significant	None identified
Structures (including embankments, cuttings and bridges)						

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
Increased precipitation during winter months and more frequent and intense rainfall events. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, mean winter precipitation will potentially increase by 26%. This increase is likely to occur as result of a combination of more wet days, as well as an increase in the intensity of rainfall events.	Flooding and erosion or bridge scour (i.e. the removal of sediment such as sand and gravel from around bridge abutments or piers. Scour, caused by swiftly moving water, can scoop out scour holes, compromising the integrity of a structure). This could lead to indirect impacts to the scheme operator in terms of increased maintenance requirements / costs.	New and extended existing crossings over watercourses will have suitable scour protection measures designed to protect against a 0.5% AEP design flood event with an appropriate allowance for climate change and applied in accordance with DMRB CD 356 'Design of highway structures for hydraulic action' (Highways England et al., 2020d). Crossings will be protected on their approaches and through the structures, in the form of flexible stone mattresses or similar to mitigate against scour and undermining of the foundations. Flexible methods are preferred as they accommodate bed movement and are thus more environmentally beneficial than rigid methods. Revetments in these areas will also be suitably protected by concrete slabs or in situ concrete.	Low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Moderately adverse – Emergency repairs and more regular maintenance interventions may be required. These activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting more than one day but less than a week.	Not Significant	None identified
	Rise in groundwater level affecting earth pressures for retaining walls causing direct damage to retaining walls and subsequent ground movement. This could lead to indirect impacts to the scheme operator through increased maintenance requirements / costs.	Retaining structures to be designed for the worst-case groundwater conditions considering climate change. Positive drainage measures will be installed behind all walls with accessible maintenance rodding points. Weepholes will also be provided as an additional drainage measure.	Low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Minor adverse – Emergency repairs and more regular maintenance interventions may be required. These activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified
	Erosion at toe of embankments which could potentially lead to direct impacts on earthworks due to embankment failure. This could lead to indirect impacts to the scheme operator in terms of increased maintenance requirements / costs.	Embankments to be designed for the worst-case groundwater conditions considering climate change. Drainage measures to be installed to prevent water build-up at toes of slopes. Erosion protection measures to be installed where risk of erosion of the slope surface has potential to lead to shallow slip failures.	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Minor adverse – Emergency repairs and more regular maintenance interventions may be required. These activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
	Higher pore water pressure in embankments and / or cutting slopes, leading to instability and risk of failure. This could lead to indirect impacts on road users through delay / disruption to the network, together with increased maintenance requirements / costs to the scheme operator.	Earthworks to be designed for the worst-case groundwater conditions considering climate change. Slope drainage to be installed if ground water is required to be lowered to increase slope stability. Provide adequate drainage at pavement level to prevent surface water build-up and infiltration into the embankment fill. Provide adequate pre-earthworks drainage at crest of cuttings to capture overland flow originating from upslope and direct it away from cutting slopes. Underlying superficial deposits and materials likely to be site won are predominantly granular which would limit the build up of pore water pressures in embankments. Additional drainage layers would be incorporated if required where cohesive materials are used.	Low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Moderate adverse – Debris or material on the road network and additional maintenance/repair works could result in road closures and associated traffic delays. These impacts are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting more than one day but less than one week.	Not significant	None identified
	Increased groundwater level changes resulting in variations in groundwater levels causing softening of embankment fill through capillary action and accelerated weathering effects, weakening embankments. This could lead to indirect impacts on road users through delay / disruption to the network, together with increased maintenance requirements / costs to the scheme operator.	Earthworks to be designed for the worst-case groundwater conditions considering climate change. Underlying superficial deposits and materials likely to be site won are predominantly granular which are less susceptible to weathering. If capillary action is considered an issue, additional drainage or sub-surface drainage would be considered where groundwater levels are close to the base of embankments.	Low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Moderate adverse – Debris or material on the road network and additional maintenance/repair works could result in road closures and associated traffic delays. These impacts are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting more than one day but less than one week.	Not significant	None identified

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
	Accumulation of excess water on bridges. This could lead to indirect impacts on road users through delay / disruption to the network, together with increased maintenance requirements / costs to the scheme operator.	Adequate long and crossfalls will be provided on all new bridge decks and positive drainage will be installed in the form of combined bridge deck drainage units to prevent build-up of water over the deck. Subsurface deck drainage systems will be installed on top of deck waterproofing systems at low points adjacent to deck joints to collect and dispose of seeping water through the surfacing material.	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Minor adverse – Excess water on overbridges could result in traffic delays. Emergency repairs and more regular maintenance interventions may be required for the bridge deck drainage systems, in response to silt build-up. These impacts/activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified
Lower rainfall during summer and more frequent drought events and dry spells. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, mean summer precipitation will potentially decrease by 29%. This decrease is likely to be accompanied by more frequent dry spells and drought events.	Soil shrinkage and / or subsidence could lead to adverse impacts on foundations, including for bridges and other structures, which may result in increased maintenance requirements or failure for the scheme operator.	Risk will be managed by best practice design. For example, embankment stability will be analysed using site specific soil parameters and embankments will be compacted and constructed in line with best practice, including alignment with DMRB standards. Other design measures include: ▪ Completing stability assessments as part of design. ▪ Undertaking an appropriate ground investigation. ▪ Design of the temporary and permanent works to minimise movement; and ▪ Appropriate analysis to predict magnitude of movements.	Very low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Minor adverse - Emergency repairs and more regular maintenance interventions may be required. These activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified
	Increased desiccation of soils resulting in direct impacts through slope stability reduction and earthworks failure or landslide occurring upslope of the scheme boundary during or immediately after summer storm events falling on desiccated soils. This could also lead to indirect impacts of delay/ disruption to road users (end user) and increased	Retaining structures and earthworks to be designed for the worst-case groundwater conditions considering climate change. The side slopes will be designed to be shallower in gradient or appropriately engineered fill material properties will be used to mitigate global stability concerns. <u>Note:</u> consideration will be given to the landscaping/vegetation and	Low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Moderate adverse - Emergency repairs and more regular maintenance interventions may be required. These activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting between one day and one week, especially if there is failure of a slope onto the carriageway.	Not significant	None identified

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
	maintenance requirements/ costs (scheme operator).	choice of topsoil materials included in these areas. The drainage design will consider operational maintenance aspects by including accessible sediment traps (catchpits) that will be regularly cleared. Catch pits will have sumps where silt can be trapped and more easily removed than manholes. The drainage design measures will require periodic inspection for sediment build up at culverts, within ponds (at pond inlets and outlets) including sediments removal, as and when required, to maintain the operational functionality (for attenuation storage capacity and treatment) over its design life. Monitoring regime to include additional inspections following periods of extreme weather, including summer storms.				
Increase in maximum summer temperatures and number / duration of hot days, hot spells, and heatwaves. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, summer mean daily maximum temperatures could be +4.6°C warmer.	Heating and thermal expansion beyond the design capability of structures which could result in the damage or failure of structures. This may result in increased maintenance requirements for the scheme operator.	The structures will be designed in accordance with the current version of Eurocode standard EN 1991-1-5 and its associated National Annex. The bridges are designed as fully integral structures where possible, meaning there are no bridge bearings or mechanical movement joints. Temperature effects in the structure will be considered through the soil and structure interaction in accordance with Eurocode 7: Geotechnical Design (British Standards Institution, 2004) and DMRB standards. Structures will be routinely monitored by the operator throughout the life of the Scheme. Where bearings and deck movement joints are required, they will be routinely inspected and maintained	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Minor adverse - Emergency repairs and more regular maintenance interventions may be required, in response to changes in deterioration rates. These activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
		at periodic General and Principal Inspections.				
	Increased annual and summer mean temperatures may lead to longer growing season for trees and other vegetation which could result in stability impacts on structures. This may result in increased maintenance requirements for the scheme operator. The growing season, however, is a response to day length not just temperature, and trees in a stressed state from either drought or waterlogging are likely to experience restricted growth.	Good practice methods such as appropriate planting mix near structures with consideration of impact of roots close to structural foundations, and suitable planting offset distances from structures both to safeguard structure integrity and for future inspection / maintenance purposes. DMRB LD 117 – SNAA 'Scotland National Application Annex for Landscape design' (Transport Scotland, 2024) requires the minimum offset distances from the trafficked edge of carriageway, hard shoulder, or hard strip where present, to planting should be 3 metres for shrubs and 5 metres for trees.	Very Low - Such impacts could possibly occur once during the lifetime of the project (e.g. once in 60 years).	Negligible – Additional maintenance/repair works could result in lane closures and associated traffic disruption. These activities are considered to have the potential to result in disruption to an isolated section of the A9, lasting less than one day.	Not significant	None identified
Maximum wind gusts and wind speeds. The intensity of the 90th percentile of maximum wind gusts is projected to remain the same at 19.7m/s (upper limits used) both during 1981–2010 and 2061–2080, indicating that higher wind speeds will potentially occur at the same frequency in the future. UKCP18 projections (for the RCP 8.5 high emissions scenario) also suggest that by the 2080s, the annual number of days with wind gust events exceeding 45mph will potentially remain the same at up to 32 days.	Maximum wind gusts and wind speeds resulting in impacts to large traffic signs etc.	Large traffics signs are given a structural foundation.	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Negligible – Additional maintenance/repair works could result in lane closures and associated traffic disruption. These activities are considered to have the potential to result in disruption to an isolated section of the A9, lasting less than one day.	Not significant	None identified

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
Drainage infrastructure						
Increased precipitation during winter months and more frequent and intense rainfall events. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, mean winter precipitation will potentially increase by 26%. This increase is likely to occur as result of a combination of more wet days, as well as an increase in the intensity of rainfall events.	Increased debris and sediment runoff resulting in direct impacts to the drainage system through a reduction in capacity of Sustainable Drainage Systems (SuDS) over time due to sediment build-up. This could also lead to indirect impacts to the soft estate.	The drainage networks have been designed to include increased surface runoff rates resulting from climate change. These rates are dictated by guidance from the Scottish Environment Protection Agency (SEPA) and in this location is 39%. Appropriate inspection of the drainage and SuDS across the scheme would be undertaken	Low – Changes in the climate have been considered and accounted for within the design based on latest guidance.	Minor adverse - Both flooding and additional maintenance/repair could cause road closures and associated traffic delays. These impacts/activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified
	Increased debris washing into drainage infrastructure (e.g., gullies and culverts), via normal flow or following landslide occurring upslope of the scheme boundary, could lead to direct impacts through blockages of the drainage system. This could also lead to indirect impacts of delay / disruption to road users (end user) and increased maintenance. requirements / costs (scheme operator).	The drainage networks have been designed to include increased surface runoff rates resulting from climate change. These rates are dictated by guidance from the Scottish Environment Protection Agency (SEPA) and in this location is 39%. Appropriate inspection of the drainage and SuDS across the scheme would be undertaken. Monitoring regime to include additional inspections following periods of extreme weather.	Low – Changes in the climate have been considered and accounted for within the design based on latest guidance. This could be increased to medium (1 in 15 years) if caused by a landslide (no significant effect still expected overall).	Minor adverse - Both flooding and additional maintenance/repair could cause road closures and associated traffic delays. These impacts/activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified
Lower rainfall during summer and more frequent drought events and dry spells. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, mean summer precipitation will potentially decrease by 29%. This decrease is likely to be accompanied by more frequent dry spells and drought events.	Reduced inflow into SuDS resulting in direct impacts to drainage and the soft estate through failure of planting / seeding reducing SuDS functional capacity.	Embankments will be compacted and seeded. Topsoil retention systems may be used, if deemed necessary. Ponds will be designed to include a pool of permanent water at the base to retain operational functionality (treatment). Permanently wet ‘scrapes’ will be incorporated into SuDS basins.	Low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Minor adverse - Additional maintenance/repair could cause road closures and associated traffic delays. These impacts/activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not Significant	None identified

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
Increase in maximum summer temperatures and number / duration of hot days, hot spells, and heatwaves. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, summer mean daily maximum temperatures could be +4.6°C warmer.	Increased annual and summer mean temperature may lead to longer growing season for trees and other vegetation which could lead to direct impacts on drainage and the soft estate where additional maintenance needs for soft estate and SuDS could potentially be required due to overgrown vegetation.	The drainage design measures will require periodic inspection for overgrown grass and vegetation including maintenance cutting / removal, where necessary, to maintain the SuDS features' operational functionality (for attenuation storage capacity and treatment) over their design life.	Low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Negligible - More regular maintenance of the soft estate may be required. These activities are considered to have the potential to result in disruption to an isolated section of the A9, lasting less than one day.	Not significant	None identified
Road technology and street furniture (including signs, signals, and lighting)						
Increased precipitation during winter months and more frequent and intense rainfall events. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, mean winter precipitation will potentially increase by 26%. This increase is likely to occur as result of a combination of more wet days, as well as an increase in the intensity of rainfall events.	Water ingress to cables and electrical equipment (e.g., signage), which could result in direct impacts through damaging the electrical infrastructure equipment. This could also lead to indirect impacts on the end users through increased risk and / or delay / disruption, together with increased maintenance requirements / costs for the scheme operator. During wet conditions and on wet roads the greater light output required (increased driver current) will increase energy consumption.	Key electrical components will be regularly checked by their operators, and replacement cycles may be shortened if deterioration rates increase. Cabinet and equipment housings are designed to mitigate and minimise water ingress, with vegetation cleared and maintenance of the assets undertaken to ensure this is upheld. The scheme design will include the specification of suitable Ingress Protection ratings for both feeder pillars and luminaires to protect from water ingress. Cables will be specified correctly including a Medium Density Polyethylene (MDPE) sheath where there is a risk of being located in water.	Low - The likelihood of water ingress into electrical equipment or cabinets is deemed to be low due to the tested and British Standard certified equipment used which is tested and installed in a safe manner fit for its safe operation. Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Minor Adverse – Extreme weather could result in assets and associated connected devices becoming non-operational. This could lead to gaps in driver information and loss of ability to view and manage the road network through CCTV or to monitor traffic flows using Motorway Incident and Detection and Automatic Signalling (MIDAS), thus preventing the protection of road users at the back of queuing traffic. Roadside technology could become unsafe which could be harmful to those coming into contact with the equipment including maintainers or road users. These impacts are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified
	Lightning strikes to electrical equipment (e.g., signage), which could result in direct impacts through damaging the electrical infrastructure equipment. This could also lead to indirect impacts on the end users through increased risk and / or delay /	Electrical equipment will be protected against main electrical supply surge and lightning current by Surge Protection Devices.	Low – The likelihood of a lightning strike is low due to the low level and flat nature of the Scheme. This issue becomes more prominent on elevated sections or on routes with viaducts or similarly raised structures. Such impacts are considered to have	Minor Adverse – Extreme weather could result in assets and associated connected devices becoming non-operational. This could lead to gaps in driver information, CCTV or MIDAS or potentially lead to unsafe roadside technology which could be harmful	Not significant	None identified

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
	disruption, together with increased maintenance requirements / costs for the scheme operator.		the potential to occur during the lifetime of the project (e.g. once in 60 years).	to those coming into contact with the equipment including maintainers or road users. These impacts are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.		
Increase in maximum summer temperatures and number / duration of hot days, hot spells, and heatwaves. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, summer mean daily maximum temperatures could be +4.6°C warmer.	Increased maximum (summer) temperatures may impact on performance of electrical equipment including reduced efficiency and lifespan of LED luminaires etc.	For excessive temperatures, such as heat waves / hot spells, this is more difficult to control and will include a design specification of suitable equipment to meet the requirements. This specification shall be provided by the manufacturer regarding the design measures taken to mitigate this as much as possible (e.g. thermal cut offs, thermally protected electronics). For feeder pillar locations the design will ensure there is sufficient free space to dissipate heat and passive cooling as required. Luminaires selected for the Scheme design are tested to withstand heat in extreme weather climates such as the United Arab Emirates. Use of LED units with breather glands to remove heat to maintain a 'constant ambient', keeping the heat-sink free of debris which is essential in keeping the LED within the required temperature range.	Low – Such impacts are considered to have the potential to occur during the lifetime of the project (e.g. once in 60 years).	Negligible – This could result in increased maintenance frequency and replacements/cost. These activities are considered to have the potential to result in disruption to an isolated section of the A9, lasting less than one day.	Not significant	None identified
Maximum wind gusts and wind speeds. The intensity of the 90th percentile of maximum wind gusts is projected to remain the same at 19.7m/s (upper limits used) both during 1981–2010 and 2061–2080,	Maximum wind gusts and wind speeds resulting in impacts to signage, lighting etc.	Technology equipment enclosures and mounting arrangements are designed to standards that will withstand wind gusts. All electrical equipment is required to confirm with BS EN60068 and BS EN12966.	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Minor adverse - Emergency repairs and more regular maintenance interventions may be required, in response to impacts from increased wind speeds / gusts impacts on signage, lighting etc. These activities are considered to have the potential to result in regional level disruption to	Not significant	None identified

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
indicating that higher wind speeds will potentially occur at the same frequency in the future. UKCP18 projections (for the RCP 8.5 high emissions scenario) also suggest that by the 2080s, the annual number of days with wind gust events exceeding 45mph will potentially remain the same at up to 32 days.				strategic route(s), including the A9, lasting less than one day.		
Landscaping						
Hotter and drier summers UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, summer mean daily maximum temperatures could be +4.6°C warmer and mean summer precipitation will potentially decrease by 29%.	Hotter and drier summers will increase soil moisture deficits in the future which could negatively impact the landscape design measures and planting for the Scheme. The landscaping has aesthetic benefits but also prevents excessive soil erosion and protects structures from surface water runoff scour.	The proposed landscape design will futureproof the Scheme in terms of climate change as well as in terms of pests/diseases by adhering to best practice. This will include diversifying planting species as much as possible, including using drought tolerant species, whilst still having regard to the local character, and generally planting native species.	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Negligible – Additional maintenance, including replacement of failed species may be required e.g. in areas where it is critical to provide screening. Depending on where these are located, lane closures maybe required to facilitate the replacement of these failed species. These activities are considered to have the potential to result in disruption to an isolated section of the A9, lasting less than one day.	Not significant	None identified
Increased precipitation during winter months and more frequent and intense rainfall events. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, mean winter precipitation will potentially increase by 26%. This increase is likely to occur as result of a combination of more wet days, as well as an	Extreme rainfall and localised flooding events in the future have the potential to impact on the landscaping design measures and planting for the Scheme	The proposed landscape design will futureproof the Scheme with regards to flooding by including species tolerant of flooding, such as willow and alder, on floodplains and next to watercourses.	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Negligible – Additional maintenance including replacement planting on floodplains and next to watercourses is unlikely to require lane closures. These activities are considered to have the potential to result in disruption to an isolated section of the A9, lasting less than one day.	Not significant	None identified

Climate trend	Potential climate event / impact(s)	Embedded mitigation	Likelihood with embedded mitigation (from Table 1.1)	Consequence (from Table 1.2)	Significance (from Table 1.3)	Potential opportunity for enhancement
increase in the intensity of rainfall events.						
Road users						
Increase in maximum summer temperatures and number / duration of hot days, hot spells, and heatwaves. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, summer mean daily maximum temperatures could be +4.6°C warmer.	Increased in summer temperatures in the future leading to hotter and drier summer months (with increased hot spells / days and heatwaves) in the future could result in scheme wide impacts on road users, particularly in relation to traffic congestion, traffic incidents and vehicle breakdowns.	The proposed ITS design across the A9 includes for Variable Message Signs (VMS) for display of messages to road users which can include road closures, diversion routes, etc. At VMS locations, and at junctions with turn-around capability, CCTV cameras are to be located to provide network coverage which will help to inform Transport Scotland of local traffic conditions. Finally sub-surface loops are to be installed at VMS locations to provide traffic count data, which will reinforce the images from the CCTV cameras and help to inform the VMS messages.	Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Minor adverse – Increases in summer temperatures in the future including hotter and drier summer months (with increased hot spells / days and heatwaves) could cause scheme wide impacts and delays, particularly in relation to road closures, traffic congestion, traffic incidents and vehicle breakdowns. These impacts/activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified
Increased precipitation during winter months and more frequent and intense rainfall events. UKCP18 projections (for the RCP 8.5 high emissions scenario) suggest that by the 2080s, mean winter precipitation will potentially increase by 26%. This increase is likely to occur as result of a combination of more wet days, as well as an increase in the intensity of rainfall events.	Increased precipitation during winter months (including increased intensity in rainfall events) in the future could result in scheme wide impacts on road users, particularly in relation to traffic congestion, traffic incidents and vehicle breakdowns.		Medium – Such impacts are considered to have the potential to occur limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years.	Minor adverse – Increases in precipitation during winter months (including increased intensity in rainfall events) in the future could cause scheme wide impacts and delays, particularly in relation to road closures, traffic congestion, traffic incidents and vehicle breakdowns. These impacts/activities are considered to have the potential to result in regional level disruption to strategic route(s), including the A9, lasting less than one day.	Not significant	None identified

Acronyms and initialisms

Acronym or initialism	Term
BS	British Standard
CCTV	Closed circuit television
DMRB	Design Manual for Roads and Bridges
LED	Light emitting diode
MDPE	Medium density polyethylene
PSV	Polished Stone Value
RCP	Receptor Concentration Pathway
SuDS	Sustainable drainage systems
UKCP	UK Climate Projections
VMS	Variable Message Sign