17. Climate Vulnerability

17.1. Introduction

17.1.1. The climate assessment is split into two parts. Volume 2, Chapter 16: Effects on Climate contains the climate emissions assessment, which considers the potential effects of the Proposed Scheme on climate. This chapter contains the climate vulnerability assessment, which considers the resilience of the Proposed Scheme to climate change impacts.

17.1.2. The main objective of the climate vulnerability assessment is to ensure that climate change and impacts associated with extreme weather are considered during the planning of the Proposed Scheme so that they can be avoided and, if that is not possible, mitigated during its construction and operation. To achieve this objective this chapter presents:

- an examination of the current climate baseline using the Meteorological Offices (Met Office) latest regional dataset of 30-year averages and data from nearby long running meteorological stations
- a consideration of the projected future climate for the study area
- an assessment of how the Proposed Scheme may be vulnerable to the impacts of climate change during its construction and operation
- identification of specific mitigation to adapt the design and operational processes to reduce the Proposed Scheme's potential adverse climate vulnerabilities and
- an assessment of the residual climate change vulnerability of the Proposed Scheme that considers both adverse and beneficial vulnerability impacts by quantifying their likelihood and consequence of each potential vulnerability.

17.1.3. The adopted assessment approach reviews how climate change could affect the Proposed Scheme's assets and end-users. The methodology follows guidance set out in Design Manual for Roads and Bridges (DMRB) LA 114 Climate and is informed by best practice climate assessment approaches and literature, as well as professional judgement.

17.1.4. This chapter should be read in conjunction with the description of the development presented in Chapter 4: The Proposed Scheme. It is noted that the scope of the climate vulnerability assessment has overlaps with aspects of other chapters in this report, in particular Chapter 19: Road Drainage and the Water Environment which includes consideration of the impact of future climate change on the water environment through and, for example, how this could affect flood risk.

17.2. Approach and Methods

17.2.1. The assessment has been carried out in accordance with the guidance contained in the DMRB LA 114. The approach and methods have been informed by legislation, policy and guidance and a full list of those that are relevant to the topic are contained in Volume 4, Appendix 17.1: Climate Vulnerability Legislation, Policy, and Guidance.

Study Area

17.2.2. In accordance with Section 3.25 of DMRB LA 114, the study area for the climate vulnerability assessment incorporates the construction footprint of the Proposed Scheme. The temporal scope of the study is, in accordance with Section 3.31 of DMRB LA 114, taken as the lifespan of the project (60 years).

Method of Baseline Data Collection

17.2.3. The climate vulnerability assessment relies on information from the Met Office. Data from the Met Office is used to summarise the Argyll River Basin current climate. The Met Office's standard average data tables are used, they show the latest set of 30-year averages covering the period 1981-2010. Context to this is provided by including comparison to the equivalent national dataset (UK minimum, average and maximum temperatures). The closest long running meteorological station (met station) is located at Dunstaffnage (188100E, 734000N; approximately 25 miles northwest of the Proposed Scheme) and has been recording observations since 1972. Climate data from this met station and the Transport Scotland Rest and Be Thankful climate station is presented.

17.2.4. Climate projections presented are from United Kingdom Climate Projections 2018 (UKCP18). These projections have been developed by the Met Office Hadley Centre Climate Programme which is supported by the Department of Business, Energy and Industrial Strategy (BEIS) and the Department for Environment, Food and Rural Affairs (DEFRA). In accordance with DMRB LA 114 the scenario presented is Representative Concentration Pathway (RCP) 8.5, a high emissions scenario. This is a Greenhouse Gas (GHG) concentration trajectory under which it is assumed that emissions continue to rise throughout the 21st Century. There is considerable uncertainty regarding if, how far and how quickly emissions will be reduced in the future. This precautionary approach ensures that the mitigation proposed will be robust even if greenhouse gas emissions do not reduce.

Consultation

17.2.5. A detailed Flood Risk Assessment (FRA) has been undertaken. Consultation with stakeholders, including Scottish Environment Protection Agency (SEPA), on the FRA has occurred to agree it's scope and specific approaches regarding:

- climate change allowances
- assessment of the baseline flood risk and
- assessment of the flood risk with the scheme in place to evaluate the designs effectiveness and determine if any additional mitigation is required.

17.2.6. Further details about the projects consultation on the FRA can be found in Volume 4, Appendix 19.6: Flood Risk Assessment and Chapter 19: Road Drainage and the Water Environment.

Assessment Methodology

17.2.7. Where the climate change impact on project receptors is potentially significant, a risk assessment has been undertaken. The method for this assessment is set out in Volume 4, Appendix 17.2: Climate Vulnerability Methodology and summarised here. It follows the guidance set out in DMRB LA 114 and is informed by best practice climate assessment approaches, literature and professional judgement.

17.2.8. In summary, there are four stages to the climate vulnerability assessment method:

- Stage 1 - Identify the hazards and receptors
- Stage 2 - Assess the likelihood of impacts on each receptor
- Stage 3 - Assess the consequence of impacts for each receptor and
- Stage 4 - Determine the significance of each impact based on a combination of the likelihood of an impact occurring and the consequences of that impact.

Limitations of the Assessment

17.2.9. The climate vulnerability assessment provides a broad, high-level indication of the potential impacts of climate change on the Proposed Scheme based on professional judgement.

17.2.10. The climate projections used are from UKCP18. The UKCP18 projections do not provide a single precise prediction of how weather and climate will change years into the future. Instead, UKCP18 provides ranges that aim to capture a spread of possible climate responses. This better represents the uncertainty of climate prediction science. It should also be noted that the level of uncertainty of the projections is dependent on the climate variable, for example, there is greater confidence around changes in temperature than there is in wind. In the climate vulnerability assessment this is considered when assessing the likelihood of impacts.

17.2.11. Climate change can cause climate hazards (e.g. increased rainfall); a climate hazard may have an impact (e.g. a landslide); impacts have consequences (e.g. a road closure). Detailed modelling that would provide future return periods for specific climate impacts or their consequences in the study area is not available. The likelihood that is stated for each climate vulnerability impact in this assessment is related to the climate hazard. This provides a precautionary approach since the likelihood of climate impacts may be less than the likelihood of climate hazards. Since UKCP18 projections are probabilistic, to capture the uncertainty of climate prediction science (see Section 17.2.10), likelihood is defined qualitatively.

17.2.12. Other key caveats and limitations of UKCP18 data are presented on the Met Office website.

17.3. Baseline Conditions

17.3.1. The complete set of baseline conditions can be found in Volume 4, Appendix 17.3: Climate Vulnerability Baseline and are not repeated here in their entirety. A summary of the current climate and future projections can be found below.

Study Area Context

17.3.2. The baseline for climate change vulnerability is presented in two parts:

- the first section describes the current climatic conditions in the study area and
- the second presents a range of possible future climate projections in the study area.

17.3.3. It should be noted that climate change is not only a challenge for the future. The UK has, and is, already observing changes in its climate since pre-industrial levels.

Current climate baseline

17.3.4. The Proposed Scheme is situated within the Argyll River Basin, this is shown on Figure 3 within the UKCP18 Guidance document: Data availability, access and formats. The climate in the Argyll River Basin is one of relatively mild winters and warm summers. Observation from the Dunstaffnage met station reveal that seven of the 10 highest monthly mean daily maximum temperatures it has recorded have been since 2006. The data from the Dunstaffnage met station also shows that over the period 1930 to 2022 both the average daily summer maximum temperatures and average daily winter maximum temperatures have been increasing.

17.3.5. The Transport Scotland Rest and Be Thankful climate station suggests similar trends to the Dunstaffnage met station over the available years of data (2018-2022), although actual temperatures are approximately 3°C cooler.

17.3.6. Long-term average daily rainfall for each month (1981-2010) in the Argyll River Basin is in line with the maximum for the UK. Across the UK, the amount of rain from extremely wet days has increased by 17% when comparing the period 2008-2017 to 1961-1990 period (Met Office, 2018). Other extreme rainfall indices exhibit large inter-annual variability but are broadly consistent with increased rainfall over the UK. With regard to storminess, across the UK historical data provides no compelling trends as determined by maximum gust speeds from the UK wind network over the last four decades (UKCP18).

17.3.7. In the study area, effects from extreme weather have been recorded. Winter *et al.*, (2019) discusses the economic effects of landslides and floods on road networks using the A83 as a case study. It highlights the regular occurrence of landslide events when the monthly average rainfall is substantially in excess of the average in Scotland. The A83 site is identified as being extremely active in recent years with multiple debris flow events and associated road closures. Nine of the years between 2007 and 2019 had at least one event that had an adverse effect on the travelling public. Regular monitoring and risk reviews from BEAR Scotland have also identified a relationship between excessive rainfall, and subsequent soil saturation, and landslide occurrence.

17.3.8. Currently a risk management system is in place to ensure the public does not use the road when the landslide risk is high. There is continuous monitoring around the site and alert levels, which also take account of predicted rainfall and saturation of the hillside, have been set that trigger traffic management actions.

17.3.9. Recent examples of extreme weather impacting road users include:

- In September 2020, a landslide closed the A83 after 75mm of rain fell in 24 hours. This event closed both the A83 and the alternative route (the Old Military Road (OMR)). The route had only reopened a week earlier after a 10,000 tonne landslide at the beginning of August.
- I November 2020 a landslide brought about by rain blocked the road. It left motorists with a 60 mile diversion as the single track alternative route (the OMR) was also closed that evening due to heavy rain forecasted and associated landslide risks.
- In early October 2023, a month's worth of rainfall (approximately 160mm) was observed over 36 hours. The road was closed on 7 October 2023 and 10 people had to be airlifted from their vehicles. The road reopened on 11 October 2023 and BEAR Scotland reported that during this period there had been seven landslides requiring approximately 12,000 tonnes of mud and rock to be removed from the A83.
- In the first six months of 2024 the A83 has been diverted due to landslide risk on three occasions.

Future climate projections

17.3.10. By 2071-89 UKCP18, the average summer rainfall projections for RCP8.5 range between a +0.3mm to -1.6mm, with a central estimate of change (i.e. 50th percentile) of 0.7mm (16%) reduction. These projections suggest that future average rainfall trends are uncertain, but it is more likely than not that summer rainfall will decrease. For winter mean precipitation, an increase of 1.9mm (over 660%) for the same projection and scenario is predicted. This aligns with the UK wide trend in UKCP18 data that points to an increase in frequency and intensity of rainfall. However, the variation in rainfall from year to year is still large and levels are expected to continue to vary widely.

17.3.11. Under RCP 8.5, extreme rainfall events (exceeding 20mm/hr) in the UK could be four times as frequent by 2080 compared to the 1980s. When looking regionally, future changes in extreme rainfall events could be almost 10 times more frequent in Northwest Scotland in 2080 compared to the 1980s. Given the established relationship between them in areas with predicted increases in rainfall intensity, landslide activity is also expected to increase.

17.3.12. The RCP8.5 scenario predicts average winter temperatures in the Argyll River Basin are expected to increase from 3.4ºC (observed average 1981-2010) to 6.1ºC (projected average 2071-2089), an increase of 2.7ºC (based on the central estimate, i.e. 50th percentile). In summer, the central estimate (i.e., 50th percentile) projects an increase of 3.0ºC in summer mean daily maximum temperatures by 2071-89.

17.3.13. For the period 2060-2079, under a high emissions scenario (RCP8.5), the Regional (12km) and Local (2.2km) projections show a decrease in both falling and lying snow across the UK relative to the 1981-2000 baseline. Future projections of storms and high winds are uncertain. They depict a wide spread of future changes in mean surface wind speed.

Potential Effects Scoped Out of the Assessment

17.3.14. The climate of the study area has already changed from its natural state, as a result of climate change. However, the Proposed Scheme's construction is not expected to be so far in the future that the climate would notably change further from the current baseline prior to construction. As such, Table 17.1 outlines construction related impacts that are scoped out of further assessment.

Table 17.1 – Potential construction effects scoped out of further assessment

Potential effect	Mitigation	Reason for scoping out
Construction related climate vulnerability effects linked to slow onset changes in the climate, for example, changes in average temperature.	Mitigation not applicable.	The Proposed Scheme's construction is not expected to be so far in the future that the climate would notably change further from the current baseline prior to construction and are therefore not expected to impact construction.
If construction coincides with one or more extreme weather events, there may potentially be construction related flood risk effects.	Appropriate construction controls to manage construction related flood risk effects are identified in Volume 2, Chapter 19: Road Drainage and the Water Environment.	As the potential construction related flood risk effects are addressed in the appropriate discipline chapter, it is not scoped in here for further assessment. It is noted that potential construction related impacts associated with extreme weather and landslide impacts are scoped in and so are assessed further in Section 17.5.

17.3.15. Table 17.2 presents operational climate vulnerability effects that are scoped out of further assessment as mitigation that is part of the design will remove them or reduce them to acceptable levels.

Table 17.2 - Potential operational effects scoped out of further assessment.

Potential effect	Mitigation	Reason for scoping out
Warmer winters could reduce winter maintenance and associated traffic disruption (benefit from reduced road salting requirements and less freeze thaw damage).	Mitigation not included as impact is beneficial.	Impact would happen with or without the Proposed Scheme.
Warmer winters could improve winter driver safety and so could reduce traffic disruption caused by accidents.	Mitigation not included as impact is beneficial.	Impact would happen with or without the Proposed Scheme.
Hotter summers increase accident rates and so could increase traffic disruption. During warm weather, accident rates typically increase. This is attributable to more solar glare, more people being out (particularly in the evening), and an increase in fine particulates on the road surface which reduces skid resistance.	It is noted that risks associated with driving cannot be fully removed by changes to the Proposed Scheme design. This reflects the fact that the cause of most traffic accidents is composite and often includes driver error.	Mitigated by design. Impact would happen with or without the Proposed Scheme.

Potential effect	Mitigation	Reason for scoping out
Hotter temperatures can dry out soils and so increase erosion. This may cause sedimentation within the Proposed Scheme's drainage infrastructure and reduce its drainage capacity, therefore increasing the risk of flooding causing traffic disruption. Additional maintenance work to prevent flooding may also cause traffic disruption.	The long-term landscape design will not include large areas of exposed soil that could become mobile in hot dry weather (blowing onto the road and reducing skid resistance). SuDS, including a detention basin, filter drains and wet swales are included in the design to attenuate flows. These will collect any eroded sediment and will be managed appropriately to avoid sediment build-up effecting their efficiency.	Mitigated by design. Impact would happen with or without the Proposed Scheme.
Heavier rain and wetter winters can cause potholes (by weakening the soil beneath the carriageway) that could increase maintenance requirements and associated traffic disruption.	The design will ensure continuity of drainage in the pavement and road layers. This will reduce the risk of water getting trapped in the foundation layers which could lead to an increase in moisture content and thus a decrease in performance, for example, lack of sufficient support to the overlaying bound material.	Mitigated by design. Impact would happen with or without the Proposed Scheme.

Potential effect	Mitigation	Reason for scoping out
Heavier rain and wetter winters can affect driver experience, reducing visibility and stopping distances. Additionally, it could increase the likelihood of standing water creating an aquaplaning hazard.	To inform the design of the Proposed Scheme an FRA has been completed along with a detailed Drainage Strategy. These describe how the Proposed Scheme will ensure drainage will be sufficient for future rainfall being designed in accordance with DMRB and Local Authority standards, ensuring no flooding of the carriageway during the 1 in 5 year (A83) and 1 in 30 year flood event (B828 and OMR drainage networks) plus climate change (46%). Risks associated with driving cannot be fully removed by changes to the Proposed Scheme design. This reflects the fact that the cause of most traffic accidents is composite and often includes driver error.	Mitigated by design and assessed in Volume 2, Chapter 19: Road Drainage and the Water Environment.
Extreme weather (high winds) could reduce driver safety, in particular potentially affecting high sided vehicles at exposed locations, and so could increase traffic disruption associated with accidents.	The road alignment is not being significantly changed and a large portion will be sheltered within the debris flow shelter. Significant traffic disruption related to wind exposure is therefore not expected.	Scoped out as impact is not anticipated to be significant.

17.4. Embedded Mitigation

17.4.1. Potential impacts for climate vulnerability are largely addressed through embedded mitigation and design as detailed in Chapter 4: The Proposed Scheme with the embedded mitigation reference used presented as “CV-Embed” in the tables below. Specific details for each identified potential impact are detailed in Table 17.3 to 17.5.

17.5. Potential Impacts

17.5.1. This section presents the climate vulnerability assessment. The assessment of construction impacts is presented in Table 17.3 and the assessment of operational impacts is split across two tables, one for each broad type of receptor: assets (Table 17.4) and end users (Table 17.5).

Table 17.3 - Potential construction impacts

Potential Impact (PI) and reference ID (PIX)	Embedded mitigation and reference ID (CV-EmbedX)	Additional mitigation and reference ID (CVX)	Likelihood	Consequence	Significance
PI1: Wetter winters and extreme weather, particularly heavy rainfall, increases the risk of landslides and other geohazards occurring. Construction will be occurring within landslide prone areas. It could therefore affect the safety of construction workers or increase landslide risk to unacceptable levels that require construction work to be suspended.	CV-Embed1 - The alignment of the DFS has been designed such that it removes the need for earthworks or retaining structures on the downhill side of the A83. This is to minimise construction on potentially unstable existing debris flow deposits. To facilitate excavation into the hillside, protective measures in the form of rock/debris fall fences and mesh will be applied upslope of the excavation. The excavation works will be undertaken in a phased manner following erection of sufficient sections of protective measures as required to reduce safety risk to As Low As Reasonably Practical (ALARP). Additional mitigation to address this is set out in CV1 (see additional mitigation column).	CV1 - Health and Safety protocols will be included in the Construction Environmental Management Plan (CEMP), for example weather forecasts, severe weather plans and stability observations and protocols to protect the safety of the construction workers. See also Volume 2, Chapter 18: Major Accidents and Disasters which assesses risk of construction work causing ground movement leading to a landslide on the OMR.	Low - Following Transport Scotland's DMRB guidance and in line with the UKCP18 and the precautionary principle it is considered that there is very low certainty that prevailing rainfall would get heavier and more frequent over the Proposed Scheme's construction period. While emissions scenario RCP8.5 suggests that a central estimate of mean winter precipitation change is an increase of 1.9 mm by 2071-89 changes on a shorter timescale, when construction occurs, would be significantly less. Although the prevailing climate is not expected to change during construction extreme weather is still possible but is assessed as being of a low likelihood.	Large adverse - Without mitigation a landslide event during construction working hours has the potential to cause loss of life of the construction workers – a very large impact. With mitigation, the risk to life will be reduced, but a landslide could still have impacts on the construction schedule and so cause a large amount of traffic disruption.	Not Significant (without mitigation: Significant)

Table 17.4 - Potential operational impacts on asset receptors (including their operation, maintenance, and refurbishment)

Potential Impact (PI) and reference ID (PIX)	Embedded mitigation and reference ID (CV-EmbedX)	Additional mitigation and reference ID (CVX)	Likelihood	Consequence	Significance
PI2: In the future, wetter winters and extreme weather, particularly heavier rainfall and increased intensity of rainfall, will increase the risk of landslides and other geohazards occurring which could damage Proposed Scheme assets. The Proposed Scheme itself would reduce consequences of landslide impacts on assets such as the A83. This potential impact addresses the risk on new structures, including landslide impacts on debris flow shelters, i.e. ensuring they are adequately protected against boulder rock falls, gravel, slurry and water movements.	CV-Embed2 - A number of measures are proposed to be in place for protection of the major structure of the project, the Debris Flow Shelter (DFS) and Debris Flow Wall (DFW): • A catchpit up to 6m wide with a protection wall between the road and catchpit of up to around 7.5m in height. • Stabilisation measures such as soil nails in superficial deposits, and rock dowls/bolting in localised areas of bedrock instability will be used. • A minimum 1m depth of fill will be provided on the roof to dissipate energy from boulders as part of rockfall events. • A 1m thick layer of gabions (or other suitable protection measures) will also be provided at the rear of the hillside wall to dissipate energy from lateral boulder load as part of rockfall and debris flow events. • Two Debris Flow Protection Walls, in a staggered arrangement, and adjacent catchpit are proposed to the north of the DFS. These provide the necessary protection to the A83 from potential debris and rockfall events between the DFS and B02 Burn Bridge Where the alignment is not protected by the DFS, stabilisation measures such as soil nails in superficial deposits, and rock dowls/bolting in localised areas of bedrock instability will be used. The B02 Burn Bridge comprises of a 30m single span bridge skewed at 12-degrees to the A83. The primary function of this bridge is to convey debris flows under the A83 at this location and into the base of the glen.	None	Medium - Following Transport Scotland's DMRB guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is medium certainty that rainfall would get heavier over the Proposed Scheme's lifetime. Emissions scenario RCP8.5 suggests that a central estimate of mean winter precipitation change is an increase of 1.9 mm by 2071-89. Changes to extreme rainfall are likely to increase in frequency on a long-term scale, however large variation across years is expected.	Minor adverse – Overall the Proposed Scheme will reduce consequences of landslide impacts on assets. The DFS and DFW will reduce the length of exposed road surface and additional embedded mitigation will protect these structures as well as the remaining exposed road surface. Emergency repairs and maintenance interventions may be required in response to increased landslide occurrence and risk of larger landslides as a result of climate change. These would create associated traffic delays (minor adverse). Without mitigation the consequences would be Very large.	Not Significant (without mitigation: Significant)

Potential Impact (PI) and reference ID (PIX)	Embedded mitigation and reference ID (CV-EmbedX)	Additional mitigation and reference ID (CVX)	Likelihood	Consequence	Significance
PI3: Hotter summers and increased ultraviolet exposure could directly damage assets. For example, over expansion, fading of facades, all of which could increase maintenance requirements and may cause traffic disruption.	CV-Embed3 - The design will ensure assets can adapt to expected future variations in temperature. For example, the Eurocodes used for bridges in the Proposed Scheme stipulate design to a temperature range which is adjusted to take account of altitude, material type and depth of surfacing thickness, etc. As part of Transport Scotland's on-going maintenance of the trunk road network, the Proposed Scheme structures will be monitored throughout the life of the Proposed Scheme.	None	Medium - Following Transport Scotland's DMRB Guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures would increase over the Proposed Scheme's lifetime (by 2071-89 summer mean daily maximum temperatures could be up to +3.0ºC warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place the likelihood of impact is Medium. There is still potential for some damage to assets during the lifespan of the Proposed Scheme.	Minor adverse – In response to climate change impacts on deterioration rates, emergency repairs and increased maintenance interventions may be required. These would create associated traffic delays (minor adverse). Under extreme temperature, certain maintenance activities may be required to be undertaken at night, to keep work to schedule, thus incurring higher programme costs (e.g. labour and illumination) but causing less traffic disruption (negligible). Without mitigation the consequence would be Moderate.	Not significant (without mitigation: Significant)

Potential Impact (PI) and reference ID (PIX)	Embedded mitigation and reference ID (CV-EmbedX)	Additional mitigation and reference ID (CVX)	Likelihood	Consequence	Significance
PI4: Drier summers and wetter winters could adversely affect soil stability, impacting structures. This could affect physical assets (e.g. foundations) as well as semi natural features (e.g. embankments) and natural structures (e.g. trees). Impact pathways include: • the expected reduction in summer average rainfall is likely to intensify and extend soil moisture deficits and impact groundwater levels. This could impact soil stability, for example causing subsidence or increasing earth pressures • wetter winters could cause soil instability as heave causes the upward movement of the ground; usually associated with the expansion of clay soils which swell when wet • wetter winters and heavier rain could cause weakening or washout of structural soils and • wetter winters may increase regularity of soil saturation and increase risk of embankment collapse.	CV-Embed4 - Risk will be managed by best practice design and construction. The geotechnical design will be in accordance with BS EN 1997-1:2004 Eurocode 7 Geotechnical Design Part 1 General rules. For example, • undertaking appropriate ground investigations and • collecting appropriate groundwater level data • cuttings and embankment works will be designed based on slope-stability analysis using site specific soil parameters • stability assessments will be completed as part of design. Including analysis and modelling to predict maximum and permittable magnitude of settlement • where foundations extend below the existing groundwater table or could extend below the future groundwater level, they are designed in accordance with industry standards • high friction, free draining materials will be specified for embankment construction to mitigate the risk of collapse To avoid waterlogging around embankments appropriate drainage will be included so that carriageway runoff is collected and stored and natural catchment runoff is collected and conveyed before being released to local watercourses after a rainfall event, see DMRB, CG 501 - Design of highway drainage systems and DMRB, CD 522 – Drainage of runoff from natural catchments. The geotechnical construction will be in line with Standards for Highways (MCHW Series 0600 - Earthworks). Soil stability risks will be controlled, for example, by providing appropriate soil compaction. The Proposed Scheme will have an operational maintenance plan which will include regular inspection of vulnerable assets in the study area to assess movements for the lifetime of the Proposed Scheme.	None	Medium - Following Transport Scotland's DMRB guidance and in line with UKCP18 projections and the precautionary principle it is considered that there is medium certainty that summers would get drier over the Proposed Scheme's lifetime. The central estimate of change in mean summer precipitation by 2071-89 is -0.7mm under RCP 8.5. However, the uncertainty around this estimate ranges from a 0.3mm increase to a 1.6mm reduction (represented by the 10th and 90th percentile respectively). Winter precipitation change is an increase of 1.9mm by 2071-89, following the same precautionary principle, it is considered there is also a medium certainty that winters would get wetter.	Minor adverse - Drier summers and wetter winters could damage assets and increase maintenance and upgrade works causing associated traffic disruption (minor adverse). Without mitigation consequences would be Large.	Not significant (without mitigation: Significant)

Potential Impact (PI) and reference ID (PIX)	Embedded mitigation and reference ID (CV-EmbedX)	Additional mitigation and reference ID (CVX)	Likelihood	Consequence	Significance
PI5: Hotter and drier summers could damage the Proposed Scheme's landscaping. More regular maintenance may cause traffic disruption. Hotter and drier summers will increase soil moisture deficits in the future which could negatively impact the Proposed Scheme's landscaping. The landscaping has aesthetic benefits but also prevents excessive aeolian soil erosion and protects structures from surface water runoff scour.	CV-Embed5 - The proposed landscape design will futureproof the Proposed Scheme in terms of climate change as well as in terms of pests/diseases (which can be exacerbated with climate change) by adhering to best practice. This will include diversifying planting species as much as possible, whilst still having regard to the local character, and generally planting only native species, which will mitigate impacts from soil moisture deficits. It will also adhere to best ecological practice.	None	Medium - Following Transport Scotland's DMRB Guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures would increase over the Proposed Scheme's lifetime (by 2071-89 summer mean daily maximum temperatures could be up to +3.0ºC warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place the likelihood of impact is Medium. There is still likely to be some damage to assets during the lifespan of the Proposed Scheme.	Negligible – Proposed planting is unlikely to be impacted by hotter and drier summers due to selection of species and adhering to best ecological practice. Any additional maintenance would cause minimal traffic disruption as it is unlikely to require lane closures. Without mitigation the consequence would be Minor.	Not Significant (without mitigation: Not significant)

Potential Impact (PI) and reference ID (PIX)	Embedded mitigation and reference ID (CV-EmbedX)	Additional mitigation and reference ID (CVX)	Likelihood	Consequence	Significance
PI6: Wetter winters and extreme weather could increase the risk of landslides in the future which could directly damage landscaping.	CV-Embed6 - There is no landscaping in areas where the Proposed Scheme is designed to contain and/or direct boulder rock falls, gravel, slurry and water movements. See embedded mitigation in PI2 for further details.	None	Medium - Following Transport Scotland's DMRB guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is medium certainty that rainfall will get heavier over the Proposed Scheme's lifetime. Emissions scenario RCP8.5 suggests that a central estimate of mean winter precipitation change is an increase of 0.5 mm by 2071-89. Changes to extreme rainfall are likely to increase in frequency on a long-term scale, however large variation across years is expected.	Negligible –Landscaping is not proposed in areas where landslide activity is expected. Consequence is unchanged without mitigation.	Not Significant (without mitigation: Not significant)

Table 17.5 - Potential operational impacts on end users

Potential impact and reference ID (PIX)	Embedded mitigation	Additional mitigation and reference ID (CVX)	Likelihood	Consequence	Significance
PI7: Hotter summers increase vehicle breakdowns and so could increase the traffic disruption they cause, and associated accidents. This could intensify road traffic impacts especially given that the Proposed Scheme removes two existing laybys to allow construction of the DFS and the B828 Glen Mhor local road junction.	CV-Embed7 - The Proposed Scheme is 2.4km long and the road carriageway has a 1m hard strip where it passes through the DFS. The Rest and Be Thankful viewpoint car park is immediately adjacent to the A83 and will be accessed via the improved B828 Glen Mhor local road junction. The overall lay-by provision still meets the requirements of DMRB CD 169 'The Design of Lay-bys, Maintenance Hardstandings, Rest areas, Service Areas and Observation Platforms. The DFS will be open so there is no need for ventilation, e.g. to dissipate smoke or car exhaust fumes. CCTV and emergency telephones will be within and outside the DFS. An external walkway for maintenance and emergency egress is also included to limit potential consequences of an event.	None	Medium - Following Transport Scotland's DMRB Guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures would increase over the Proposed Scheme's lifetime (by 2071-89 summer mean daily maximum temperatures could be up to +3.0 °C warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place the likelihood of impact is Medium.	Minor adverse - Breakdowns can have the following adverse effects: • cause drivers to lose control of their vehicle - e.g. in the event of a tyre blowout or brake failure (both can be associated with warmer weather) • increase the likelihood of vehicle fires and associated risks for road users • be dangerous for drivers stranded in a live traffic lane and • cause secondary accidents involving other road users. All the above can cause minor adverse traffic disruption consequences (due to obstruction of traffic or as traffic slows to pass). Without mitigation consequence would be Large.	Not Significant (without mitigation: Significant)

Potential impact and reference ID (PIX)	Embedded mitigation	Additional mitigation and reference ID (CVX)	Likelihood	Consequence	Significance
PI8: Extreme weather (snow and ice) could affect driver experience. Although winters are forecast to be warmer, extreme weather could still affect the study area in the future; snow and ice could create a hazard during operation, particularly at the entrance and exit of the flow debris shelter.	CV-Embed8 - Roads will be salted and ploughed as needed, based on forecasts and road conditions, in line with the Transport Scotland winter service procedures. The Proposed Scheme design will include drip checks, which ensure that no water flows into the DFS that could result in icicle formation. Microclimate models are being developed to understand the risk from driven rain/snow coming into the DFS and any identified adverse risk would be addressed at a later design stage.	None	Low – Following Transport Scotland's DMRB Guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that on average, snowfall and heavy snowfall will decrease over the Proposed Scheme's lifetime (Regional (12km) and Local (2.2km) projections show a decrease in both falling and lying snow relative to the 1981-2000 baseline [under emissions scenario RCP8.5]). Climate projections for extreme weather events that may result in snow and ice, however, have low certainty.	Minor adverse - Accidents could occur during extreme cold weather creating traffic disruption (minor adverse). Without mitigation the consequence would be Large.	Not Significant (without mitigation: Not significant)

Potential impact and reference ID (PIX)	Embedded mitigation	Additional mitigation and reference ID (CVX)	Likelihood	Consequence	Significance
PI9: Wetter winters and extreme weather could increase the risk of landslides in the future which could affect end users (drivers). The Proposed Scheme itself will reduce consequences of landslide impacts on end users.	CV-Embed9 - The Proposed Scheme design reduces the risk of landslides impacting the road. See embedded mitigation in PI2 for further details.	None	Medium - Following Transport Scotland's DMRB Guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is medium certainty that rainfall will get heavier over the Proposed Scheme's lifetime. Emissions scenario RCP8.5 suggests that a central estimate of mean winter precipitation change is an increase of 1.9mm by 2071-89. Changes to extreme rainfall are likely to increase in frequency on a long-term scale, however large variation across years is expected.	Minor adverse – The consequence is an improvement from the baseline, however it is acknowledged here that there could still be some minor impacts. These impacts relate to the potential for accident rates to increase, particularly during wet weather, creating more traffic disruption (minor adverse). Without mitigation the consequence would be Very Large.	Not Significant (without mitigation: Significant)

Potential impact and reference ID (PIX)	Embedded mitigation	Additional mitigation and reference ID (CVX)	Likelihood	Consequence	Significance
PI10: Wetter winters and extreme weather could increase landslide risk in the future impacting maintenance work. Increased rainfall intensity resulting from climate change could create dangerous environments for maintenance workers, e.g. when clearing debris pits, by increasing landslide risk.	CV-Embed9 - A maintenance track is to be constructed to allow maintenance vehicles to access the roof directly to conduct inspections and safely clear the proposed catchpit or roof of any debris after a debris flow or landslide event. Crews should therefore not need to enter the catchpit. A 1m high pedestrian fence is proposed along the perimeter of the roof of the DFS with the exception of the ends of the structure where a solid reinforced concrete upstand is proposed.	CV2 - Health and safety measures would be implemented as part of maintenance plans, that would monitor forecasts and stability in the area of work.	Medium - Following Transport Scotland's DMRB Guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is medium certainty that rainfall will get heavier over the Proposed Scheme's lifetime. Emissions scenario RCP8.5 suggests that a central estimate of mean winter precipitation change is an increase of 1.9mm by 2071-89. Changes to extreme rainfall are likely to increase in frequency on a long-term scale, however large variation across years is expected.	Minor adverse - Maintenance may be delayed to avoid bad weather. This might extend maintenance work periods. Delayed and / or extended inspection and debris removal after a landslide may create traffic disruption (minor adverse). Without mitigation the consequence could be Very large.	Not Significant (without mitigation: Significant)

17.6. Additional Mitigation

17.6.1. Table 17.6 summarises the additional mitigation measures set out in Table 17.3, Table 17.4 and Table 17.5. These are presented here as they are in addition to the embedded mitigation incorporated in the design of the Proposed Scheme.

Table 17.6 – Additional mitigation identified

Mitigation Reference	Mitigation Measures
CV1	Health and Safety protocols will be included in the CEMP, for example weather forecasts, severe weather plans and stability observations and protocols to protect the safety of the construction workers.
CV2	Health and safety measures would be implemented as part of maintenance plans, that would monitor forecasts and stability in the area of work.

17.6.2. In addition to the mitigation set out in Table 17.6, the Scottish Government provides resilience in the event of a climate emergency through organisations such as the Scottish Government's Resilience Room (SGoRR) and the Multi Agency Response Team (MART).

17.7. Residual Effects

Residual Effects – Construction

17.7.1. No receptors have been identified as having likely significant residual effects during the construction period.

17.7.2. Table 17.7 summarises the potential impacts detailed in Table 17.3.

Table 17.7 - Residual Effects Construction

Reference (Potential Impact ref PIX)	Pre-Mitigation Effect Likelihood & Consequence	Pre-Mitigation Effect Significance	Mitigation Measures	Post-Mitigation Effect Likelihood & Consequence	Post-Mitigation Effect Significance
PI1	Low & Very Large adverse	Significant	Embedded mitigation such as the design removing the need for earthworks on the downhill side of the A83 (PI1) and health and safety protocols in the CEMP (CV1) reduces the significance of this impact.	Low & Large adverse	Not Significant

17.7.3. Justification for the categorisations shown in Table 17.8 along with full descriptions of the proposed mitigations can be found in Table 17.4 and Table 17.6.

Residual Effects – Operation

17.7.4. No receptors have been identified as having likely significant residual effects for the operation of the Proposed Scheme. Table 17.8 summarises the potential impacts detailed in Table 17.4 and Table 17.5.

Table 17.8 - Residual Effects Operation

Reference (Potential Impact ref PIX)	Pre-Mitigation Effect Likelihood & Consequence	Pre-Mitigation Effect Significance	Mitigation Measures	Post-Mitigation Effect Likelihood & Consequence	Post-Mitigation Effect Significance
PI2	Medium & Very large adverse	Significant	Embedded mitigation is in place for protection of the DFS and DFW. Stabilisation measures are in place where the alignment is not protected by the DFS. PI2 details these measures. The significance of this impact is reduced by this mitigation.	Medium & Minor adverse	Not Significant
PI3	Medium & Moderate	Significant	Embedded mitigation as part of the design and structure monitoring as detailed in PI3 reduces the significance of this impact.	Medium & Minor adverse	Not Significant

Reference (Potential Impact ref PIX)	Pre-Mitigation Effect Likelihood & Consequence	Pre-Mitigation Effect Significance	Mitigation Measures	Post-Mitigation Effect Likelihood & Consequence	Post-Mitigation Effect Significance
PI4	Medium & Large adverse	Significant	Best practice design and construction e.g. in accordance with BS EN 1997-1:2004 Eurocode 7 Geotechnical Design Part 1 General rules and as detailed in PI4, reduces the significance of this impact.	Medium & Minor adverse	Not Significant
PI5	Medium & Minor	Not Significant	Diversifying plant species and generally planting only native species, while adhering to best ecological practice (PI5) reduces the consequence, but not the overall significance of this impact.	Medium & Negligible	Not Significant

Reference (Potential Impact ref PIX)	Pre-Mitigation Effect Likelihood & Consequence	Pre-Mitigation Effect Significance	Mitigation Measures	Post-Mitigation Effect Likelihood & Consequence	Post-Mitigation Effect Significance
PI6	Medium & Negligible	Not Significant	Embedded mitigation in PI6 does not reduce the significance of this impact as no landscaping is planned in areas designed to carry landslide debris.	Medium & Negligible	Not Significant
PI7	Medium & Large adverse	Significant	Embedded mitigation in the design of having a 1m hard strip, the Rest and Be Thankful car park (PI7), reduces the significance of this impact.	Medium & Minor adverse	Not Significant
PI8	Low & Large adverse	Not Significant	Embedded mitigation in PI8, including drip checks, reduces the consequence of this impact, but does reduce the significance as it was already not significant.	Low & Minor adverse	Not Significant

Reference (Potential Impact ref PIX)	Pre-Mitigation Effect Likelihood & Consequence	Pre-Mitigation Effect Significance	Mitigation Measures	Post-Mitigation Effect Likelihood & Consequence	Post-Mitigation Effect Significance
PI9	Medium & Very large adverse	Significant	Embedded mitigation in the design of the Proposed Scheme reduces the risk of landslides impacting the road (PI9). This reduces the significance of this impact.	Medium & Minor adverse	Not Significant
PI10	Medium & Very large adverse	Significant	Embedded mitigation includes a maintenance track and pedestrian fence as detailed in PI10. Additional health and safety mitigation monitoring forecasts and stability in the area of work (CV2) reduces the significance of this impact.	Medium & Minor adverse	Not Significant

17.7.5. Justification for the categorisations shown in Table 17.8 along with full descriptions of the proposed mitigations can be found in Table 17.4 and Table 17.6.

Compliance with Planning Policy

17.7.6. Effects remaining after mitigation is in place are termed residual effects. It is not anticipated that any non-compliance with policy (as identified in in Volume 4, Appendix 17.1: Climate Vulnerability Legislation, Policy, and Guidance) would result based on the assessment.