1 Purpose

This document provides guidance on how to effectively carry out a weather and climate change risk assessment for Design, Construction and Maintenance projects and activities. This supports:

- The requirements set out in the Level 2 Environment and Social Minimum Requirements (ESR) standard NR/L2/ENV/015,
- Further assessment of risks and opportunities identified through use of the Environment and Social Appraisal (ESA) Tool, and
- The Environment and Social Performance Policy NR/L1/ENV/100 which states;
  We will adapt at construction and at asset renewal to provide resilience in the most cost-effective manner by designing schemes to be resilient to future weather conditions and/or with a view to providing passive provision for future weather conditions.

This document should be used in conjunction with the Climate Change Projections Guidance Note (NR/GN/EDS23).

The document is also applicable to any projects and activities that fall outside the scope of NR/L2/ENV/015, but which have the potential to be vulnerable to current and/or future weather impacts.

This guidance and its actions should be applied by the person accountable for the delivery of the project or the role that they have designated as responsible for managing the risks to the project and asset.

The consideration of current and future adverse and extreme weather in projects and activities is necessary, as there are existing impacts on the reliability of our assets and the performance and safety of the railway which will be altered by climate change.

Weather risks and the effects of climate change should be considered in any project or activity that will design, create, or maintain an asset. This should also occur when planning operational regimes or undertaking activities that will influence the operation of an asset.

2 Weather and climate change impact assessment basics

Adverse and extreme weather already create safety, performance and financial risks for the railway and our projects and day to day operations and activities. Understanding the vulnerabilities your project or activity has too current and future weather events and the risk that these pose to its capability to provide/contribute to the desired performance and safety outcomes of the railway is essential to identifying and delivering successful adaptation.
The bullets below provide a basic summary of the process that should be used to identify, quantify and mitigate the weather and climate change risks that a project or activity may encounter.

This applies to projects progressing under any framework. For projects or activities subject to the Project Acceleration in a Controlled Environment (PACE) framework this document indicates the relevant step to which each aspect of the guidance applies. Projects and activities outside of the PACE framework should seek to apply the guidance at the equivalent steps in their delivery frameworks (for example, need identification/scope development, option development and selection, detailed design and construction/delivery). During their progress from inception to delivery projects or activities should:

- **Identify projects** that will require a weather and climate change impact assessment – A high-level conversation with stakeholders to understand how the asset or activity may respond to current and future weather. PACE stage A,

- **Identify impacts** - Identify the weather and climate change vulnerabilities of and risks to the project of the asset/activity planned and how these will affect the capacity of the asset/activity to maintain its function and the performance and safety of the railway over its lifespan. PACE stage 1,
- **Quantify vulnerabilities** - Determine the risk and level of the impacts and their timings under climate change and understand if any could affect the feasibility of the project. PACE stage 1,
- **Set requirements -** Use the findings above to develop client requirements which require levels of current and future resilience that are appropriate to the needs of our stakeholders. PACE stage 1
- **Develop (an) option(s)** - Determine an option or options that address these requirements through appropriate adaptation actions. This should explore the full range of on/off-site, physical and operational solutions. PACE stage 1,
- **Project design** - Set design standards that will meet the adaptation and resilience client requirements by seeking to reduce the risks and impacts identified to acceptable levels in a whole life cost beneficial manner. Any additional/'novel' maintenance or operational requirements associated with the design should be agreed with the appropriate teams. PACE stage 2, and
- **Project delivery** - The project delivery should satisfy the weather and climate change adaptation/resilience requirements in the client requirements in accordance with the design and specification set. Construction activities, temporary facilities and operational activities should consider the potential impact of adverse and extreme weather events with appropriate task risks assessments and health and safety plans put in place. Before the asset enters service, the owner should be fully briefed on the operation and maintenance requirements of any weather and climate change design aspects. PACE stage 3.

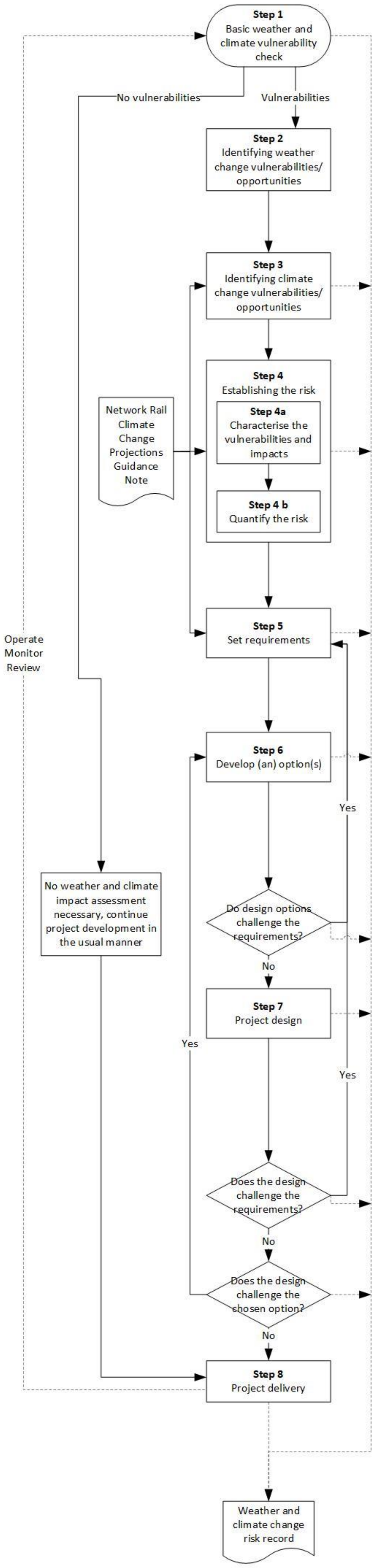
At each stage of the project or activity a record should be kept of the findings of the weather and climate impact assessment, any decisions that these are used to inform and the results of those decisions. This document should live and evolve throughout the development and delivery of the project or action, with amendments and additions made to incorporate any new or changed decisions, actions or data that arise as the project/activity progresses. This will ensure that the reasoning behind the risk, and impact assessments, the setting of client requirements the design decisions taken and the levels of adaptation/resilience and the residual risk are transparent and made available to the asset/activity owners and for future interventions. This could either be a standalone report (for suggested content see Section 4.8) or incorporated into the standard project/activity recording processes.

3 The weather and climate change impact assessment process

Figure 1 is a flowchart that defines the process recommended to successfully carry out the basic steps outlined in Section 2. It indicates the order in which the assessment steps should be undertaken, illustrates key questions that should be asked at each step, provides examples of relevant data sources and for projects or activities subject to PACE it shows the link to the relevant PACE stage.

For those requiring further information the remainder of the document beyond Figure 1 provides additional guidance on each of the steps in the flowchart.

Figure 1: **Weather and climate change impact assessment process**



What weather events could affect the asset(s) or activities of the project from inception to operation and could the impacts get better or worse under climate change? This is a high-level process to identify if weather events or climate change have the potential to affect the asset or activity planned by the project and if the requirements documents should include further assessment work. It does not seek to characterise or quantify the risks at this stage and does not require modelling. it should ask simple questions such as; Is the asset or activity in a flood zone? Is the driver for this project a weather event e.g. an OLE failure in hot weather? Have there been past weather related failures? Would the general climate trends laid out in Section 4.1 make the impacts better or worse? **Data sources** could include: Asset owners, Schedule 8/4 and delay minutes data, the relevant Route WRCCA plan, Environment Agency/Scottish Environment Protection Agency/Natural Resources Wales flood maps. For projects using the PACE framework this should be in PACE A. See Section 4.1 for further guidance.

What weather events could affect the construction, operation and maintenance of the asset(s) or the planning and delivery of an activity? This should asses the weather vulnerabilities and opportunities of the asset/activity, how it may affect/be affected by its surroundings, site access, lineside neighbours, safety, workforce welfare and any interdependencies it may have such as power supplies, etc.). **Parameters for consideration** include: temperature ranges (internal/external), solar gain, snow, ice, wind, scour, coastal erosion, flooding (river, coastal, surface water and groundwater), drought/desiccation, lightning and combined and cumulative events (storms. droughts followed by intense rain etc.). **Potential weather related data sources** could include: Asset owners, Schedule 8/4 and delay minutes data, the relevant Route WRCCA plan, Environment Agency/Scottish Environment Protection Agency/Natural Resources Wales flood maps, Network Rail Weather Service. For projects using the PACE framework this should be in PACE 1. See Section 4.2 for further guidance.

Will changes in the severity and frequency of weather events under climate change alter current weather vulnerabilities or add new ones? This assessment should use the **Network Rail Climate Change Projections Guidance Note (NR/GN/ESD23)** to identify the change trends and values for the available weather parameters across the whole of the expected lifespan of the project or activity. The data gathered should be used to re-assess the vulnerabilities identified or discounted in the first step. Do the changes increase, decrease, remove or add a vulnerability? **Additional information** on the potential vulnerabilities can be found in the relevant Route WRCCA plan and the TA Asset Function Climate Risk Assessment Gaps and Action Plan. For projects using the PACE framework this should be in PACE 1. See section 4.3 for further guidance.

What is the nature of the vulnerability(ies) and what are the impacts? For the vulnerabilities established in Step 1 identify the nature of the weather event(s) that caused past impacts on the asset/activity and establish the threshold at which an unacceptable impact is experienced e.g. a rainfall event of 33mm/day or a minimum daily temperature of -12°C. For vulnerabilities identified in step 2 or for those with no past data use proxies from similar assets. For all events characterised identify the current/possible impacts, such as repair costs and safety or performance impacts and any associated costs, and identify if/how these may change under future conditions. **Data sources:** NR/GN/ESD23, previous failure/impact investigations, existing asset design data and the Network Rail Weather Service.

What is the current and future risk? For all events characterised establish the current and future occurrence frequency(ies) of the event threshold(s) for the relevant time periods over the expected asset/activity lifespan. Then combine these with the impact data from the step above to evaluate the current and future risk levels using Network Rail's likelihood x consequence assessment method. Record the risk changes identified, particularly those that become acceptable or unacceptable, and use these in setting the design requirements. **Data sources**: NR/GN/ESD23 gives data on some current and future event frequencies, where this is not provided modelling may be necessary.

Note: Combined risks may have more than one threshold or climate change modifier (e.g. a storm, a heatwave, coastal erosion or soil moisture deficit). For projects using the PACE framework this should be in PACE 1. See Section 4.4 for further guidance. **Any weather or climate change risks that may impact the feasibility of the project should be noted at this stage**

Do the weather and climate change risks affect the desired performance level of the asset/activity? Identify operational activities and design parameters (e.g. maintenance) influenced by the above risks and impacts (e.g. OLE tension systems or drainage capacity). Determine if rising risks may lead to unacceptable performance (e.g. more speed restrictions) and if decreases could allow reduced designs(e.g. less points heating). Use this assessment to set requirements that enable asset/activity to deliver appropriate performance levels under the challenges and opportunities across it's lifespan. This should; be done in a cost beneficial manner, consider on and off site solutions and explore all risk positions e.g. accepting the risk, partial risk reduction, full mitigation in phases over the lifespan of the asset/activity or full mitigation now. Any requirements set should not prejudice the ability to adapt the asset/activity in the future. **Data sources:** NR/GN/ESD23 (climate change adjustments), modelling as necessary. For projects using the PACE framework this should be in PACE 1. See Section 4.5 for further guidance.

How can the project be designed to meet the weather resilience and climate change adaptation elements of the requirements? This should consider both on/off-site and design/operation options across the railway system that could influence weather and climate resilience. The aim should be (an) option(s) that provide(s) current and future resilience that, do(es) not lock in risk or prevent future adaptation, account(s) for other requirements (e.g. safety or carbon emissions) and is/are cost beneficial and deliverable within project constraints that may affect the risk appetite (e.g. technical, space or budgetary). The option(s) should mitigate unacceptable risks as far as possible, for example by moving design elements out of flood zones, specifying designs/equipment tolerant to increased ambient temperatures. **You should agree the extent to which the option design(s) can manage the threats to the feasibility of the project identified in Step3 and if residual risks would continue to constitute a threat**. However it/they should attempt to allow design flexibility later enabling detailed design to address the specific mitigation solutions/set residual risks. The option should also seek to identify cost beneficial opportunities to mitigate other performance and safety issues as a part of its core design e.g. does flood mitigation for an electrical kiosk also mitigate a wet bed? **Data sources**: NR/GN/ESD23 (climate change adjustments), modelling as necessary. For projects using the PACE framework this should be in PACE 1. See Section 4.6 for further guidance.

During this step the ability to meet the requirements may be challenged by; the discovery of new risks, changes to the profile of any of the previously characterised risks or the identification of new construction or operational constraints. If this happens the new information should be used to review and if necessary change the requirements or option(s).

How can the design of the option components/activities (including operational aspects) and their interactions with other railway systems and the wider surroundings influence the weather and climate change resilience of the project outputs? Design should identify; 1) Which parts of the option are going to be most vulnerable to the increases in risk, or benefit from the decrease in risk? 2) Which are the 'critical' components that could create the biggest performance and safety risks or cost implications on failure or degradation? And 3) how do these data sets interact. This will enable prioritised decisions to be made on how and where resource should be applied to the design to achieve the most cost beneficial adaptation outcomes. Design decisions as a result of this should explore asset/ equipment specification/construction, landscape management, operation/maintenance/event recovery solutions and how these could combine to achieve the most cost effective response to the risks, managing them to acceptable levels. The asset owner, relevant operations teams and appropriate 3rd parties (e.g. the Environment Agency) should be involved here to identify the best use of operational solution, to understand any implications such as novel maintenance and to make best use of partnership solutions (e.g. flood defences). The opportunity should be taken to identify if the design co-incidentally contributes to, or could cost beneficially contribute to other targets, for example does, or could the design of drainage to protect signalling equipment reduce the risk/impact of a wet bed, contribute to our net biodiversity target by creating a SuDS which may also have a lower carbon footprint? The nature and scale of the project and the risks/benefits to be addressed should influence the level of further work undertaken (detail, cost etc.). **Data sources**: NR/GN/ESD23 (climate change adjustments), modelling as necessary. For projects using the PACE framework this should be in PACE 2. See Section 4.7 for further guidance.

During this step it is possible that the ability to meet the requirements set in Step ,4 or to produce a design that achieves the option developed in Step 5, may be challenged. This could be due to; the discovery of new risks, changes to the profile of any of the previously characterised risks, design/component limitations or the identification of new construction or operational constraints. If this happens the new information should be used to review and if necessary amend the requirements or the option as appropriate.

What planning, processes and steps are necessary to ensure the safe and successful delivery of the project to the adapted design and specifications? All contractors and staff should be fully briefed on the design to ensure that adaptation measures are enacted, particularly if aspects of the design, delivery or operation are novel or differ from standard designs. Appropriate liaison structures should be set up where necessary (for example with stakeholders in a flood protection scheme). Planning the timing and siting of activities should take into account the season and the potential impacts of extreme and adverse weather events (e.g. flood vulnerability or heatwaves) on equipment and workforce welfare. Upon entry into service the asset or activity should have a planned schedule of maintenance that meets the needs of the adapted asset and that has also accounted for the impacts of weather on the workforce welfare. Any maintenance regime should require activities that will result in the refurbishment , renewal or replacement of assets or parts (with a lifespan of 30+ years) to consider climate change in their selection or design. Data sources: Network Rail Weather service and NR/GN/ESD23 (climate change adjustments). For projects using the PACE framework this should be in PACE 3. See section 4.8 for further guidance.

Recording of Weather and climate change impact assessment results and related design/operation decisions.
The project should record: 1) the risks and impacts considered, 2) the risk and design decisions taken, their rational and the residual level of risk that the asset/ activity carries, 3) the range of options discounted and the rational, 4) limitations to the impact assessment and the impact on design decisions, 5) changes to the project requirements and the rational, 6) the nature of any operational requirements and 7) Key adaptation design parameters/limitations, e.g. this design is adapted to surface water flooding based on EA peak rainfall central allowances of 10% for the 2050s. Recording of this information is essential so that future projects or decisions related to the asset or activity can understand the designs, their rational and limitations.
Recording could either be through the standard decision logging and reporting processes and documents within the project process or through the creation of a dedicated weather and climate change report. If the former route is chosen it is suggested that dedicated weather and climate change sections are created in the relevant documents and that a summary be considered within the handover documentation. See section 4.9 for further guidance.

4 Additional guidance

4.1 Basic weather and climate vulnerability check

This should be a high-level discussion between the project sponsor and the project team to identify if there are any aspects of the weather which could affect the design, delivery, and operation of the asset or activity. This step should ask simple questions as laid out in **Step 1** in Figure 1, it should not involve modelling or quantification of the risks or impacts. Only projects that are found to have vulnerabilities should carry out more detailed assessments as required by flow chart.

When considering the possible climate change impacts the following general climate change trends should be used: Warmer minimum, average and maximum summer and winter temperatures, wetter winters, drier summers, more and worse storms, more and longer droughts and heatwaves, possible increases in wind speed, lightning and humidity or reductions in frost days and snow days and volumes.

4.2 Identifying weather vulnerabilities

This is **Step 2** in assessing how your project or activity may be impacted by weather and climate change and as shown in Figure 1 it should be carried out in the initial phases of activity to ensure that the risks and their mitigation are accounted for in the setting of the delivery requirements.

Particular attention should be paid to local conditions that may change broader regional and national assumptions or bring bespoke challenges. Local asset knowledge will be key here.

The bullets below provide additional example questions that could be asked and further possible data sources.

Additional questions:

- Is the activity vulnerable to the effects of flooding (coastal, river, surface water/rainfall and groundwater)?
- Could extreme weather pose a risk to the workforce?
- Does the asset have a temperature threshold after which its operation is impaired, or it fails?
- Can successive weather events reduce the lifespan of the asset?
- What severity of weather event causes a problem for example a heatwave or an intense rainstorm? and
- Will the failure of the drainage system affect lineside neighbours?

Further data sources:

- Flood maps can be found at:
  - Environment Agency - Environmental management : Flooding and coastal change - detailed information - GOV.UK (www.gov.uk)
  - Scottish Environment Protection Agency - Flooding | Scottish Environment Protection Agency (SEPA)
  - Natural Resources Wales - Natural Resources Wales / Flooding
- The Network Rail Weather Service (www.nrws.co.uk),
- Incident or Rail Accident Investigation Branch (RAIB) reports or other analysis of related activities in the area for example the Safety Management Information System (SMIS) database,
- Local/anecdotal evidence – stakeholders familiar with locations can provide information which may not be captured in the incident data e.g. maintenance teams, lineside neighbours, landowners and utilities,
- Met Office – weather data, including past adverse and extreme weather events, past weather station records and UK extremes for some variables, can be found on the Met Office web site, and

- Media reports for extreme weather events around the project or activity location,

4.3 Identifying climate change vulnerabilities

Climate change will alter the severity, frequency and impact of weather events. This will alter the risks and impacts of asset failures increasing many to unacceptable levels and reducing some. Examples are:

- Increased severity and frequency of flooding, storms and heatwaves leading to more washouts and track buckles making the maintenance and improvement of our resilience increasingly challenging, or
- Reduced severity of winters leading fewer frozen points or snow blockages making maintenance and improvement of our resilience easier[1].

Past records of weather event return periods, asset and system performance records, asset lifespans and asset deterioration and failure rates and will become unreliable for planning future assets and activities. We must; understand the future changes in climate, the effects that these will have on the vulnerabilities of our assets and activities and account for these in our desired outcomes. This is **Step 3** in Figure 1.

The asset/activities whole life should be explored to understand if and when any of the current vulnerabilities will change. Vulnerabilities discounted in step 2 should be re-assessed to see if climate changes will elevate their severity and or frequency beyond coping thresholds, for example flooding:

- Will there be any changes in rainfall (patterns, intensity or frequency), river flows or sea level?
- Did Step 2 identify a flooding vulnerability (river, coastal, groundwater, surface water), if so, will the changes make it worse? and
- If flooding was discounted as a current issue will the changes cause future impacts to become unacceptable at some point? Is the flood zone bigger, is the flood depth higher or is the flood frequency increased?

Climate change data for this task should be sourced from (NR/GN/EDS23) on Safety Central. This guidance should be used in conjunction with the relevant Route WRCCA Plan to ascertain what the future climate changes will be for the location of the project or activity in the short, medium and long term. This should then form the basis of a reassessment of the current weather vulnerabilities identified in Section 4.2.

4.4 Establishing the risk

Step 4 (Figure 1) is essential to account for the risks when setting the design requirements needed to provide an appropriate level of resilience and performance. Steps 4a and b set layout a process to establish; the thresholds at which current and future weather evets will impact our assets, the degree of impact that output of the project may face and the risk of this happening. The box at the bottom of this section contains a worked example of the how to achieve this.

The level of resource and the degree of detail employed in assessing and evaluating the weather and climate risks should be related to the scale and nature of the project, its risks and its criticality.

It is possible that future changes in the risks/impacts may be significant enough to challenge the feasibility of the project and these should be noted and addressed at this stage. Examples include flooding of a depot or its access route becoming so frequent and severe that any further investment at that location becomes unviable, temperature extremes in buildings and cabinets exceeding the existing/planned operational tolerance of electrical equipment, or a significant reduction on frost days/snow falls reducing the need for points heating. Under such circumstances you should consider:

[1] Climate change is projected to change the frequency of severe winters, but not the severity.

- Adjusting the scope of the project to consider the additional risk to avoid delivering investment that becomes redundant or stranded before the planned lifespan ends,
- Reassessing what an acceptable level risk is. Reducing the threshold for benefits or increasing it where there are no alternatives and the project or activity is critical to our operations, performance or safety, and
- Reassessing the need for the investment.

Maximum/minimum daily temperature issues for replacement of an electrical panel:

1) Determine if the existing panel has failed in low or high temperatures and at what temperature this occurred. Identify how this threshold relates to the ambient temperature. If it has not failed, understand if similar panels have and at what temperature. If you can find no failure records, note the design tolerance within which the panel is expected to operate, note if this temperature has occurred at the planned location in the past and establish a relationship to ambient temperature.
2) Identify the past or potential impacts of exceeding the threshold (e.g. repair costs, safety and performance impacts and associated costs) and quantify them. Use NR/GN/EDS23 to identify the future temperature range projected for the timescale appropriate to the panel's expected lifespan and identify if this would change the scale or nature of the impacts.
3) Establish a baseline risk for comparison with future risks, by identifying the frequency with which the threshold has been/would be exceeded) under current conditions and combining this with the current impact data from 2) using Network Rail's likelihood x consequence assessment method.
4) Establish future levels of risk by identifying the frequency with which the threshold would be exceeded under the projected climate changes for the timescale appropriate to the lifespan of the asset/activity and combining this with the future impact data from 2) in the same manner as 3).
5) Use these findings in setting the design requirements.

Notes: 1) NR/GN/ESD23 provides data on some current and future weather event frequencies, but modelling may be necessary for others. 2) Combined risks or some parameters may need more than one threshold or climate adjustment factor e.g. a heat wave may need both maximum temperature and duration.

4.5 Setting requirements

Once current and future risks are quantified **Step 5** (Figure 1) assesses the implications. Suggested questions are:

- Do currently acceptable risks worsen, possibly becoming unacceptable?
- Do existing risks improve?
- What design parameters or operational activities are susceptible to the increased risks or able to take advantage of reducing risks?
- What do the changes in risk profile mean for the acceptable outcomes of the project over the lifespan of the asset/activity? and
- What is our risk/performance appetite - should we; seek to fully mitigate the risks now or over time, accept a degree of risk or accept all the risk?

After investigating the range of possible business impacts and benefits of the changing risks (for the outcomes of the project financial, safety, performance etc.) you should agree on the key weather and climate risks to it over the asset/activities lifespan and identify how this interacts with your risk appetite. You should then consider how incorporate this into your requirements enabling you to set ones that a) have realistic levels of asset performance that are viable over the lifespan of the asset/activity, b) lay out design and operational requirements that accommodate the projected changes or require the design to do so, c) that allow/encourage or at least do not block the use of off-site/3rd party solutions. Questions could include:

- What level of risk are we willing to accept/what level of risk mitigation do we want and how does this translate to requirements that are viable over the lifespan of the asset/activity?
- What risks are solely within our control and what risks could be influenced by 3rd parties?
- Should we seek to control the risks ourselves or should we include alternative solutions such as catchment management?
- What design parameters or operational activities have the capacity to influence/respond to the changes in the risks and impacts? and
- Could changes in these reduce the increased risks to acceptable levels/take advantage of risk reductions? If so, what project requirements would be necessary to achieve these and are they practicable/cost beneficial?

When setting the viable long-term requirements, a key question to ask is if weather and climate risks be woven into all the requirements, if there should there be a single weather resilience and climate change adaptation requirement, or both? An example of single requirement could be 'the project should understand the risks and impact/opportunities posed by current weather and the effects of climate change and deliver an outcome that is adapted to these to ensure that the asset/activity is fit for purpose over its lifespan?

4.6 Develop (an) option(s)

Step 6 (Figure 1) should use the risk and impact information to review our 'normal' ways of doing things and consider design options that enable the desired performance under future weather conditions. You should seek to avoid locking in current and future vulnerabilities and improve the resilience of the asset/activity by; avoiding the risks/impacts where able, mitigating those that remain as far as possible, enabling continued operation under residual impacts and promoting rapid recovery from weather related events. They should also seek to maximise any benefits from projected reductions in vulnerability (e.g. fewer frost days) and to integrate adaptation actions with other outcomes and goals such as safety, sustainability, and service performance. Key considerations include:

- Project footprint - asset/activity and associated infrastructure, size, location and orientation during construction and operation can significantly influence the level of weather and climate risk exposure,
- Design specifications - specifications should account for current and future weather event variability (e.g. operating temperatures, drainage system design storms, wind speeds, soil moisture and sea level, flooding) and consider a range of controls including hard/traditional engineering methods, soft engineering (landscape solutions) and operational/administrative solutions,
- Dependencies - is the cost or security of supply of our external supplies vulnerable e.g., logistics (deliveries/availability) of materials, plant and equipment, power and water? Are others dependent on us?
- Engagement with communities - What effects may the project have outside of its footprint? Benefits could be flood protection, improved access routes, service improvement or economic opportunities. Negatives could be noise, dust and other emissions, increased flooding or access restrictions, and
- Links to other Network Rail Targets - Will any adaptation design decisions maximise/contribute to, benefit from or hinder the delivery of other targets (e.g., decarbonisation, biodiversity, waste management, air quality, safety, performance)?

You should agree the extent to which the option design(s) can manage the threats to the feasibility of the project identified in Step4 and if residual risks would continue to constitute a threat.

In developing a design it is possible that new data/evidence may be identified that challenges the ability to meet the project requirements, for example; new risks, changes to the profile of any of the previously characterised risks or the identification of new construction or operational constraints. If this happens the new information should be used to review the requirements and consider changes to them or the option(s) being considered.

All design decisions that address the weather and climate change risks and impacts should be subject to cost benefit analysis across the lifespan of the project. This should compare an un-adapted option with different adaptation measures/levels of resilience to support the selection of the optimal design to take forward into project design.

4.7 Project Design

Although **Step 6** will have addressed some of the risks/impacts and opportunities, where this was not possible or only partially so **Step 7** (Figure 1) should include work to; identify and select designs to optimise option delivery, take advantage of opportunities from projected risk reductions and manage any remaining unacceptable risks.

Before making design decisions the project should understand and evaluate the full range of solution options available covering the full range of on/off-site, design/operation and hard/soft solutions. Asset owners and operational teams should be involved here to ensure that the optimum balance of solutions is chosen and that operational impacts such as novel maintenance are understood and agreed.

As a minimum technical design studies should be undertaken to test different solution options and product specifications against varying current and future weather extremes such as increased temperatures, changing precipitation patterns, higher wind speeds, combined and cumulative events etc. For example, assessing different flood protection products or methods (water proofing, elevation, operational options such as powering down). Examples of additional studies or modelling that could be undertaken to inform the range of solutions options and the technical design studies could also include:

- Detailed current and future flood risk assessments,
- Coastal erosion modelling for current and projected rates,
- Soil moisture records analysis and projections modelling,
- Land use maps analysis,
- Identification of partnership opportunities e.g. flood protection or habitat enhancement schemes, and
- Adoption of novel/best practice designs from other infrastructure organisations and publications.

The level of resource and the degree of detail employed in undertaking additional studies and assessments should be related to the scale and nature of the project, its risks and its criticality.

Mock examples of adaptation options for installing an electrical kiosk at the bottom of a cutting slope with projected temperature problems in 2030 and current surface water flood issues from above the slope that will increase through the century are below. Other options could be explored in the design space between these examples.

Option	Design	Pros and cons
One	Crest and face drainage piped to watercourse 500m away. Sized for flows to 2050. Maintenance schedule set accounting for frequency of system use. Dark green GRP kiosk at toe of slope fitted with air conditioning capacity fit for 2050. Monitor drainage performance and review design in 2045 for upgrade to 2070s design. Monitor failures of electrical	Pros – Built and maintained under our control/to our standards. Known efficacy based on past schemes. Cons – More work on our land increasing possession time and safety risks. Construction and maintenance costs, safety risks and carbon and resource

	components in kiosk and upgrade air conditioning as necessary.	footprints likely to be higher and. Habitat damage/disruption. Less design flexibility.
Two	Partnership fund habitat creation on land above the cutting that will divert sufficient flows up to 2070s away from the slope and with a habitat strip at the top of slope as buffer to absorb additional flows. Passively vented waterproof white kiosk located in shade if possible (consider dwarf wall). Site on slope above projected flood levels. Specify cleaning to keep albedo. Monitor flooding and review performance/design in 2045 and 2065 or as necessary. Move kiosk further up slope/place on a plinth or consider drainage as necessary. Monitor temperature related failures and review kiosk design as necessary. Shade if not installed/available in phase 1. Explore kiosk materials e.g., silvering, increasing electrical component temperature tolerance or installing air conditioning if no other option.	Pros – Meets the resilience needs, reduced work on our land lowers possession time and safety risk, partnership approach could reduce costs, reduced costs of ongoing maintenance, reduced carbon and resource footprint, reduced habitat damage/disruption of construction, habitat creation of drainage solution, higher design flexibility. Cons – less control of drainage solution design, delivery and maintenance. Novel design may give less certainty of performance.

4.8 Construction and maintenance

Although construction and maintenance are temporary phases they can range from hours/days to years and can occur in any season and may be impacted by a range of weather events. They also have a key role in ensuring that the final design is delivered as intended and that aspects relating to adaptation in the operational phase of the asset/activity are effectively communicated. These phases should:

- Ensure that all internal and external stakeholders are fully briefed on the weather and climate change adaptation aspects of the project design for both phases. This is particularly important if novel or non-standards designs have been developed,
- Assess impacts and include their consideration into health and safety risk assessments and control procedures for the planning and execution of both phases, for example, heatwaves, drought, snow, ice, heavy rainfall, flooding, high wind, lightning and combined/cumulative events,
- Inform risk avoidance measures such as locating facilities (warehouses, stockpiles, maintenance depots, site offices, parking, welfare facilities etc.) outside flood risk areas, and
- Where avoidance is not possible; guide protection measures appropriate to the risk level and the project length or activity. For example, flood barriers, alternative water supplies, specification of welfare facilities.

Whilst the short-term nature of these phases means that they should focus on their safe and efficient delivery under current weather conditions they generally do not need to consider climate change beyond implementing and enabling any adaptation actions included in the asset design.

One exception to this is where a maintenance activity will result in the refurbishment, renewal or replacement of assets or asset parts with a lifespan of over 30 years. In these cases the need for a climate change risk assessment should be noted in the appropriate maintenance specification and/or schedule and it should be carried as per Sections 4.1 to 4.77. The level of resource and detail employed should be related to the criticality of the asse and the scale and nature of the project or activity.

4.9 Weather and Climate Change Risk Reporting

A record of the weather and climate change impact assessment process and outcomes should be produced so that the evidence and reasoning behind the design and operational adaptation decisions are transparent and available for any future operation or intervention/investment. This should include, but not be limited to:

- The results of the weather and climate change impact assessment detailing the identified and discarded current and future opportunities and risks e.g., temperature threshold of failures, frequency and impact scores/evidence, case study,
- A record of the project/activity element(s) that could be impacted,
- A description of the safety and performance impact(s) and consequence(s) for the project/activity and its operation (including indicative costs where available),
- A record of the use of this information in setting the project requirements and rationale,
- A record of the adaptation measures considered during the option development and design detailing those discarded and those incorporated into the design and operation of the option including the rationale,
- A log of any changes to the project requirements due to the design work and the rationale for these,
- Any unmitigated or residual risks
- Any maintenance and operation requirements resulting from the adaptation aspects of the design, and
- Assumptions in the project or recommendations from it that future projects should take into account.

The record could be kept as part of the normal project documentation process or as a standalone document. If the former route is chosen it is suggested that dedicated weather and climate change sections are created in the relevant documents and that a summary be considered within the handover documentation.

The record should be updated throughout the project/activity development and delivery, with updates made (as necessary) to incorporate any new or changed decisions, actions or data that arise across the project/activity delivery. When completed it should be kept in the project files and appended to the relevant asset register to ensure that future operation of and investment in the asset or activity can be informed by the findings.

5 Glossary

Adaptation	Climate change adaptation is action taken to improve the resilience of assets, networks and systems to future weather conditions, avoiding, minimising or mitigating the impact of more severe or frequent adverse and extreme weather events and gradual or erratic changes in weather patterns due to climate change.
Climate	Average weather over a longer time period (months to many years), but commonly 30 years, as defined by the World Meteorological Organisation.
Climate Change	A change in global or regional climate patterns, attributed to changes in levels of atmospheric greenhouse gases.
Climate Projection	Modelled response of the climate system to a future greenhouse gas emissions (or atmospheric concentration) scenario. For example, the UKCP18 RCP2.5 scenario assumes a rapid decarbonisation of the world economy and shift to renewable energy.
Climate Scenario	A projection of future greenhouse gas emissions used by analysts to assess future vulnerability to climate change using future population levels, economic activity, the

	structure of governance, social values, and patterns of technological change. Economic and energy modelling can be used to analyse and quantify the effects of such drivers.
Coastal Flooding	Where high tides and/or storm surges raise the sea level and/or wave height above that of the natural coastline or defences causing over topping.
Environment Agency	English environmental regulator.
Greenhouse Gases	The main greenhouse gases are water vapour, carbon dioxide, methane, ozone, nitrous oxide are chlorofluorocarbons.
Groundwater Flooding	When snow melt or rainfall soaking into the ground raises the level of the water table until it is above ground level.
Natural Resources Wales	Welsh environmental regulator.
RCP	Representative Concentration Pathways are the current IPCC climate projection scenarios There are four: RCP2.6, RCP4.5, RCP6.0 and RCP8.5. These scenarios have been used in the UKCP18 climate projections.
RCP6.0	Representative Concentration Pathway 6.0 - emissions peak around 2080, then decline.
RCP8.5	Representative Concentration Pathway 8.5 - emissions rise throughout the 21st century.
Resilience	The ability of assets, networks and systems to anticipate, absorb, adapt to and rapidly recover from disruptive events. This includes the adaptive capacity gained from understanding current and future risks to our assets.
River Flooding	Also known as fluvial flooding. Caused by the migration of snowmelt or rainfall into watercourses raising their flows to the point where they exceed the channel capacity and overtop the banks and/or flood defences into the flood plain.
Scottish Environmental Protection Agency	Scottish Environmental Regulator.
Storm Surge	An increase in sea level under storm conditions, beyond the normal tidal maximum, due to low atmospheric pressure and gale force winds forcing water towards the coastline.
Surface Water Flooding	Also known as pluvial, rainfall or flash flooding. The result of rapid snowmelt or intense or prolonged rain falling onto land and accumulating at low points in the topography.
Threshold	Value of a climate variable that causes significant increases in asset failures/daily disruption if exceeded. Thresholds may change if asset design or operation changes.
UKCP09	National climate projections for the UK produced in 2009.
UKCP18	National climate projections for the UK produced in 2018.
Vulnerability	The propensity or predisposition to being adversely affected by, in this case by weather events or impacts.
Weather	The occurrence of weather variables such as temperature, precipitation and humidity, in the short term, as opposed to the long-term definition of climate. See above.

Weather resilience	Weather resilience is the ability of assets, networks and systems to anticipate, absorb, adapt to and/or recover from disruptive weather events.

APPENDIX 1 – Version Control

Date	Change description	Change owner	New document version
14/08/19	**1st published**	**David Quincey, Climate Change Adaptation Manager**	**Issue 1**
06/11/20	**Updated to UKCP18**	**David Quincey, Climate Change Adaptation Manager**	**Issue 2**
05/03/21	**Issue 3 removal of reference to NR/GN/ESD33**	**David Quincey, Climate Change Adaptation Manager**	**Issue 3**
31/10/21	**PACE and Region feedback update**	**David Quincey, Climate Change Adaptation Manager**	**Issue 4**