Network Rail Third Adaptation Report

December 2021

Contents

Acronyms and abbreviations

Acronym	Definition
ALT	Asset Leadership team
ARC	Audit and risk committee
ARP	Adaptation Reporting Power
CCC	Climate Change Committee
CIRIA	Construction Industry Research and Information Association
COVID19	Coronavirus
CRI	Composite reliability index
CP	Control Period
CRAM	Corporate risk assessment matrix
Defra	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
EA	Environmental Agency
ERR	Enterprise risk record
EWAT	Extreme weather action teleconference
GBR	Great British Railways
GRAI	Governance, risk, assurance and improvement
ICT	Information and communications technology
IOAF	Infrastructure operators adaptation forum
IPCC	Intergovernmental panel on climate change
KPI	Key performance indicators
LiDAR	Light detection and ranging
NERC	National Environment Research Centre
NRW	Natural Resources Wales
OLE	Overhead line equipment
ORR	Office of Rail and Road
PACE	Project acceleration in a controlled environment
PPM	Public performance measure
RAIB	Rail accident investigation branch
R&D	Research and development
RCM	Remote condition monitoring
RDG	Rail Delivery Group
RSSB	Rail Safety and Standards Board
SAF	Service affecting failures
SEPA	Scottish Environment Protection Agency
SCSG	Seasonal Challenge Steering Group
SHEC	Safety health, environment committee
TA	Technical authority
TCFD	Task Force on Climate-Related Financial Disclosures
TRaCCA	Tomorrow's Railway and Climate Change Adaptation
UIC	Union Internationale des Chemins de fer - International Union of Railways
UK	United Kingdom
UKCP	United Kingdom Climate Projections
WISP	Whole Industry Strategic Plan
WRCCA	Weather Resilience and Climate Change Adaptation

Foreword

We've already seen the devastating impact that climate change can have on the railways, and we know that it will only get worse in the coming years, so we must continue to do all we can to better understand the risks and impact it can have on our infrastructure. And we have a responsibility to our passengers, freight customers, lineside neighbours and those we serve to make sure the railway is more resilient and ultimately safer.

We know that rail is already the greenest form of public transport in the UK and we're determined for it to stay that way, which means there's no room for us to rest on our laurels. In recent years we've made some great progress including our routes updating their weather and climate change plans, publishing our long term climate change adaptation roadmap, and forming of the **Weather Risk Task Force**. All these activities help the railway become more resilient to climate change. We were also the first railway in the world to set science based targets that will help limit global warming to 1.5 degrees. We are committed to responding to the climate change challenge.

I am pleased to share our third Adaptation Report. It summarises our progress in understanding and managing the impact of climate change and sets out how we are implementing actions to increase our resilience.

Andrew Haines
Chief Executive

Executive summary

Adverse and extreme weather is accelerating deterioration of our assets

Climate change is already causing more frequent and more severe extreme weather events and we are experiencing its impacts on the railway. The weather over the past few years shows clear trends towards an increased frequency of extreme drier periods followed by prolonged and extreme wet weather. These factors accelerate deterioration of our earthworks and put pressure on drainage systems and other assets, increasing the likelihood of critical coping thresholds being exceeded and prompting increased levels of intervention. 'Good' management of climate change risk involves improved 'on the ground' resilience, which will come at significant cost and will take many years to achieve.

We are investing significant resources to better understand and manage the impact of weather on the railway, with a step change in effort following the tragic incident at Carmont in 2020. We have established the Weather Risk Task Force which is improving data and processes to support our operational response to weather events and our understanding of asset condition and vulnerability.

Whilst our planning for climate change adaptation is well advanced, as recognised by the Climate Change Committee (CCC) in their **2021 Progress Report**, our key challenge will be implementing these plans and improving resilience on the ground.

Network Rail and the Adaptation Reporting Power

Climate change is one of the biggest challenges facing our society and in particular infrastructure operators like Network Rail. We operate an extensive and complex network of assets across Great Britain which are exposed to a wide range of adverse and extreme weather events. These can disrupt our operations with the safety, performance and economic impacts being felt by both our customers and the wider economy. As we move into the future, climate change will alter the frequency of weather disruptions and increase many of their impacts.

The Climate Change Act (2008) empowers the Secretary of State to request that key organisations report on how they are preparing for climate change impacts and the measures they are taking to adapt and improve their resilience. We recognise the importance of participating in this process to aid the assessment of the United Kingdom's (UK's) adaptation status and as an opportunity for us to review our progress and plans and communicate our experience to others.

Our second Adaptation Reporting Power (ARP) submission outlined our planned actions to prepare for future climate impacts and details of our progress are included in this third (ARP3) report. Our strategic business plan for 2019 – 2024 has been developed to ensure that regions include and identify appropriate investment in weather and climate resilience and that resilience actions are resourced for delivery. Asset policies now include reference to climate change and long-term route studies have been developed for a number of areas on our network. We recognise that we need to extend the coverage and work is ongoing to achieve this through the development of long-term regional strategies.

Actions speak louder than words

In addition to those actions which were outlined in ARP2, we have developed a Weather Resilience and Climate Change Adaptation (WRCCA) Strategy which has helped improve governance, knowledge and practices throughout our business across our five workstreams or 'pillars of resilience' as outlined further below. We have also developed a Seasonal Weather Management Strategy and the recently established Weather Risk Task Force which are aimed at improving the way we manage extreme weather and seasonality from an operational and asset management perspective – these activities are highlighted in this report but not included in detail.

Strategies and programmes

We have developed strategies which underpin our activities to improve the railway's weather and climate change resilience. We have worked to improve our response to the seasonal and short-term weather challenges facing the railway through the development of our 10-year Seasonal Weather Management Strategy.

Looking to the longer-term adaptation is now a core priority within our **Environmental Sustainability Strategy** which outlines our adaptation roadmap. This contains our key adaptation milestones up until 2050 and how we plan to achieve them. In addition, we are a key stakeholder in the development of the 30-year Whole Industry Strategic Plan (WISP) which will recognise that addressing weather resilience and adapting to the future climate is integral to the long-term sustainability of the railway.

To continue to drive progress within our business and the wider industry, several key programmes have been established. These include the Seasonal Challenge Steering Group (SCSG) and the industry weather resilience programme focussing on improving operational weather performance, and the Weather Risk Task Force created to deliver the recommendations made in the Lord Robert Mair and Dame Julia Slingo reports following the tragic incident at Carmont in 2020.

Risk management and action plans

We have made significant progress in developing the understanding of the current weather risks that our network is subject to and how these will shift as the climate changes into the future. There are a number of mechanisms through which we identify, record and control our risks, including our corporate level enterprise risk registers (ERR), the updated Control Period 6 (CP6) **Route WRCCA Plans** and our recent **Asset Management WRCCA Plan**. For this ARP3 submission we have taken the opportunity to create an Integrated ARP3 Climate Risk Assessment and have presented the key risks identified, see **Appendix A**.

Standards and guidance

To support our people in their work to understand our climate risks and deliver adaptation actions, we have produced two climate change guidance notes. The **Weather Resilience and Climate Change Impact Assessment Guidance Note** provides the framework for users to identify rail asset and project vulnerabilities to climate change. This is complimented by the **Climate Change Projections Guidance Note** which provides the data and support to navigate and apply climate change projections to asset planning and design.

The guidance notes are embedded into the Environment and Social Minimum Requirements Standard (ESR) ensuring that our asset creation process considers the risks of climate change. They were also used in the creation of the Asset Management and Route WRCCA Plan risk assessments. Going forward, they will be used to update a wide range of our existing asset management standards.

Collaboration and engagement

We are recognised as one of the leaders in climate change adaptation planning for infrastructure in the UK. Whilst we have delivered much of our activity internally, collaboration with organisations across infrastructure sector and with academic institutions has played a key part in providing us with the knowledge to achieve this.

As we are only as strong as our weakest links, we will continue to enhance our current relationships and, following recent work to understand our interdependencies, we will seek to extend our activity to cover the new relationships discovered.

Research and analysis

Since we submitted ARP2 we have conducted a wide range of research aimed at improving our understanding of how weather affects our network and the impact of future climate change. We have accounted for the updated United Kingdom Climate Projections (UKCP18) within our work and identified the most robust climate scenarios to inform our adaptation actions with reasonable confidence through to 2050 and beyond. In addition, we have improved our technical knowledge of weather impacts on our assets and developed analysis tools to better understand our risks.

We have also begun looking beyond our boundaries to consider the interdependencies we have with others. Those that we rely on, those that rely on us and those organisations where there is a co-dependency. Whilst this is a complex challenge, we hope to further develop our understanding of our interdependencies with others so that we can improve our resilience whilst also contributing to the resilience of the wider economy, communities and other strategic infrastructure networks.

Planned actions for ARP3

In this ARP3 submission, we have outlined how we intend to develop our capability within our five pillars of resilience and the actions we will take to deliver weather and climate resilience in accordance with the adaptation roadmap in our 2020 Environmental Sustainability Strategy.

Moving forward, we will build this into the WISP as we transition to the Great British Railway (GBR) and we will continue to develop and hone the capability of our assets, network and people to address the impacts of weather and climate change. Embedding climate resilience in everything that we do will enable us to deliver a ‘reliable railway that is resilient to climate changes’, part of our vision to deliver a sustainable railway ‘serving the nation with the cleanest, greenest mass transport’.

TCFD cross-reference

The reporting requirements for the 'Task Force on Climate-Related Financial Disclosures' (TCFD)[1] are addressed in the following ARP3 chapters and sections.

Acronym	Definition	ARP3 section
Governance	Describe the Board's oversight of climate-related risks and opportunities	3
	Describe management's role in assessing and managing climate-related risks and opportunities	3, 5
Strategy	Describe the climate-related risks and opportunities the organisation has identified over the short, medium and long term	6, 7
	Describe the impact of climate related risks and opportunities on the organisations business, strategy and financial planning	4, 7
	Describe the resilience of the organisation's strategy, taking into consideration different climate related scenarios including a 2°C or lower scenario	4, 8
Risk management	Describe the organisation's processes for identifying and assessing climate-related risks	5
	Describe the organisation's processes for managing climate-related risks	3, 5, 7
	Describe how processes for identifying, assessing and managing climate-related risks are integrated into the organisation's overall risk management	3, 5
Metrics and targets	Disclose the metrics used by the organisation to assess climate-related risks and opportunities in line with its strategy and risk management process	3
	Describe the targets used by the organisation to manage climate related risks and opportunities and performance against targets	3, 4

[1] TCFD (2021) Proposed Guidance on Climate-related Metrics, Targets, and Transition Plans [online]. Available at: https://assets.bbhub.io/company/sites/60/2021/05/2021-TCFD-Metrics_Targets_Guidance.pdf Last accessed: 23/08/2021.

Introduction

Adaptation Reporting Power

Climate governance at Network Rail

Strategies and plans

Our approach to assessing climate change risk

Interdependencies

Our climate change risks

Adaptation actions and progress

Conclusions

1

1.1 Who is Network Rail? What do we do?

Network Rail owns, operates and develops Britain's railway infrastructure including approximately 20,000 miles of track, 30,000 bridges, tunnels and viaducts and thousands of signals and level crossings. We are also responsible for managing twenty of the UK's largest railway stations. We exist to get people and goods where they need to be and to support Britain's economic prosperity. We do this by running a safe, reliable and efficient railway that serves our customers and communities.

Our 'putting passengers first' vision is grouped around six strategic priorities **(Figure 1-1)**, each of which is materially impacted by the weather that we experience in the UK and will be affected by the longer-term changes to our climate.

Figure 1-1 – Putting passengers first strategic priorities

Safety | **Train service delivery** | **Efficiency** | **Sustainable growth** | **Customers & communities** | **People**

We are a public sector, arms-length body of the Department for Transport (DfT). As a devolved organisation we have five regions responsible for the operation, maintenance and long-term planning of the railway, supported by 14 routes as illustrated in **Figure 1-2**. Our regions also are supported by a number of national functions as explained further in **Table 1-1** and **Section 3**.

Table 1-1 – Region and route functions

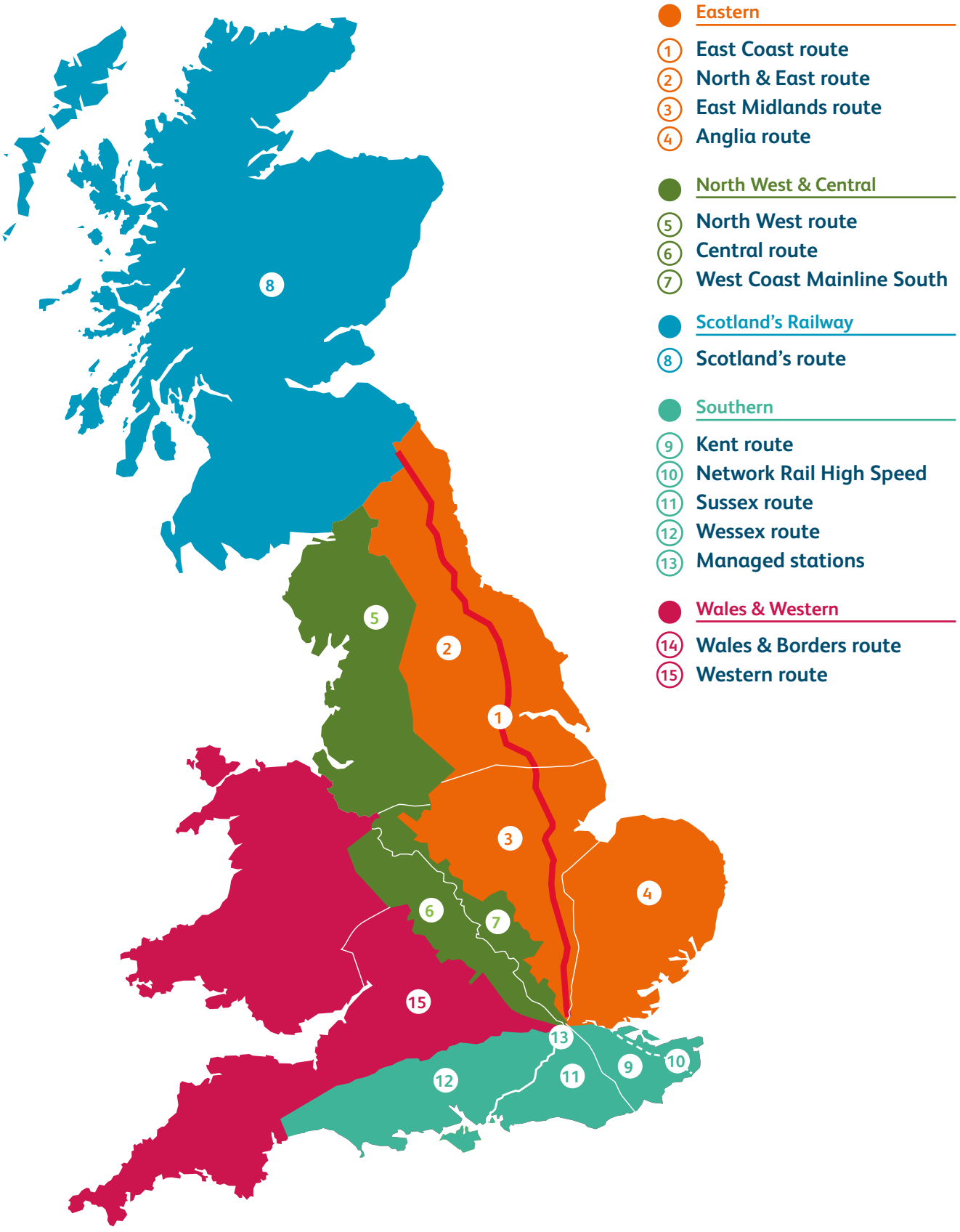
A region...

- Supports one or more routes
- Plans and responds to what passengers want and need from the railway

The routes...

- Deliver local operations, maintenance and renewals
- Are responsible for day-to-day delivery of train performance

Figure 1-2 – Our regions and routes[2]



[2] Source: https://www.networkrail.co.uk/running-the-railway/our-regions/

1.2 How does the weather affect our railway?

Britain's railway operates in a wide range of weather conditions and is one of the safest in Europe[3]. It is our responsibility to deliver assets that serve our passenger and customer needs in an efficient, safe and punctual way. The increasingly frequent severe and prolonged weather events due to climate change make maintaining our high level of performance a constant challenge.

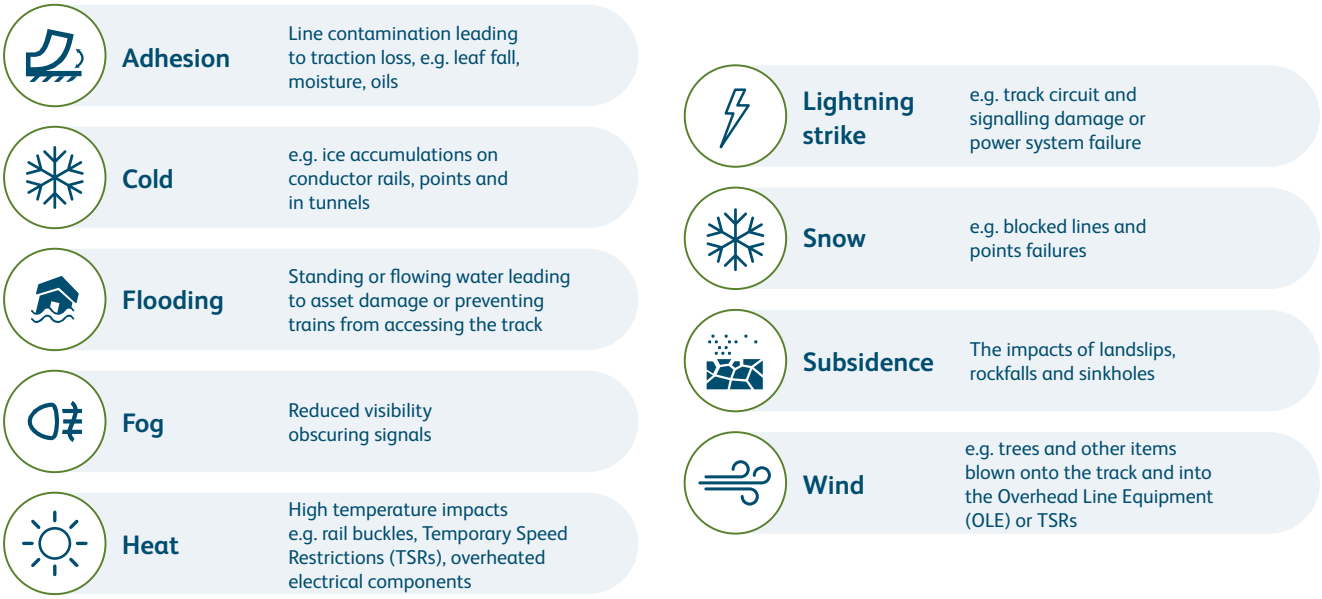
We recognise that these changes are already affecting our assets and systems, causing significant disruption to our network with impacts felt by our customers, staff and the communities in which we live and work. For instance, heavy rainfall may require us to delay the arrival or departure of trains or respond to slippery conditions on platforms. In more challenging cases, trains can be stopped from running, and railway infrastructure may be obstructed and damaged resulting in costly repairs.

In rare more extreme cases, we see a much bigger effect, with wide-spread delays, the need for more substantial repair work and the potential for very serious safety consequences most recently demonstrated by the tragic events at Carmont in Scotland in 2020.

1.2.1. Effects from weather events

In order to understand the weather-related impacts on the performance of our network we have been collating and analysing data on Schedule 8 delay compensation costs and the associated delay minutes since 2006/07. We have been able to attribute these data to specific weather types and events and have recorded the cost and minute values for weather related incidents under the nine categories shown in Figure 1-3. While adverse and extreme weather impacts significantly vary year-by-year, this 15-year dataset has enabled us to identify some general trends.

Figure 1-3 – Schedule 8 attribution categories for weather impacts



[3] RSSB (2020) Annual Health and Safety Report 2019/2020 [online] Available at: **https://www.rssb.co.uk/safety-and-health/risk-and-safety-intelligence/safety-performance-reports** Last accessed: 23/08/2021

Between 2006/07 and 2020/21, weather related incidents caused over 322,000 delay events, around 26 million delay minutes and over £1 billion of Schedule 8 compensation payments. In addition, weather related Schedule 4 cancellations cost more than £170 million since 2013/2014. However it should be noted that not all incidents are correctly attributed to weather and these figures are likely to be conservative, with the actual cost being much higher.

Figures 1-4 to 1-7 show the cumulative costs for each of the impact categories from 2006/07 to 2020/21 across our whole network and for England, Wales and Scotland respectively. Nationally, it can be seen that the two biggest challenges to our service come from wind and flooding incidents costing £275 million and £223 million each. However, there are also significant impacts associated with adhesion and snow, each costing more than £100 million over the same period.

When we analyse the data for our assets in the separate nations, we start to see important differences attributable to the varying national climates. While wind, flooding and snow remain the top impacts across all three, flooding becomes the top impact in Wales. In Scotland, snow, cold and adhesion are greater challenges than elsewhere, while England and Wales see relatively more issues related to heat, with England predictably seeing the greater impact. Of the three nations, Wales shows the greatest impact from lightning.

Figure 1-4 – Cumulative Schedule 8 weather category costs 2006/07 to 2020/21 (Great Britain)

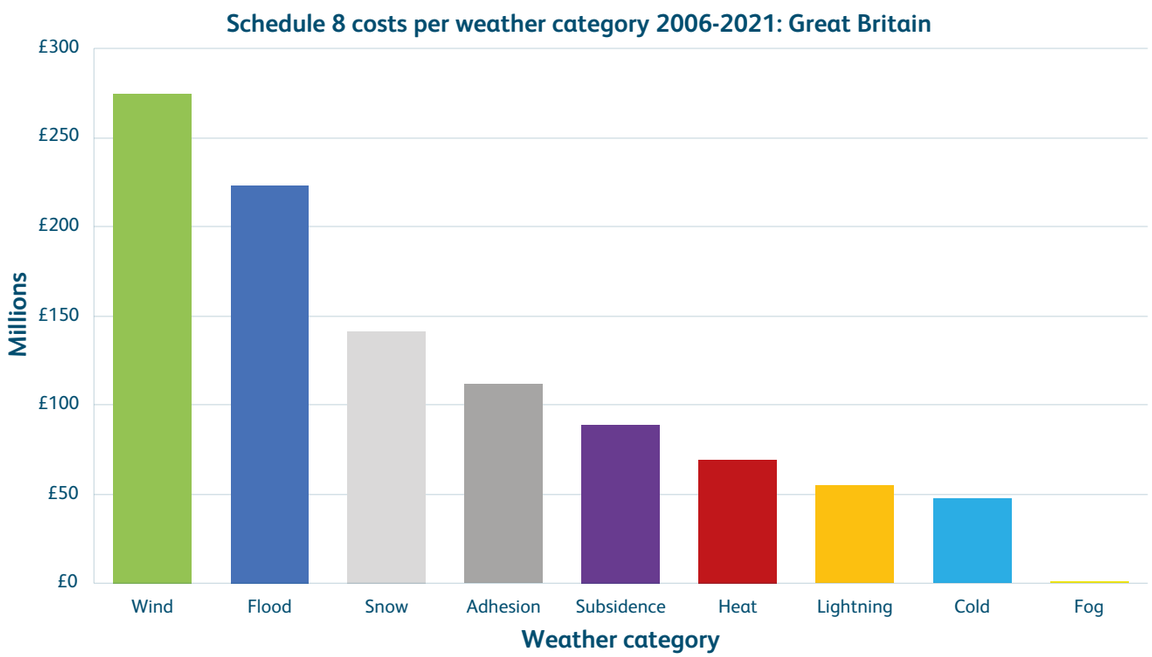


Figure 1-5 – Cumulative Schedule 8 weather category costs 2006/07 to 2020/21 (England)

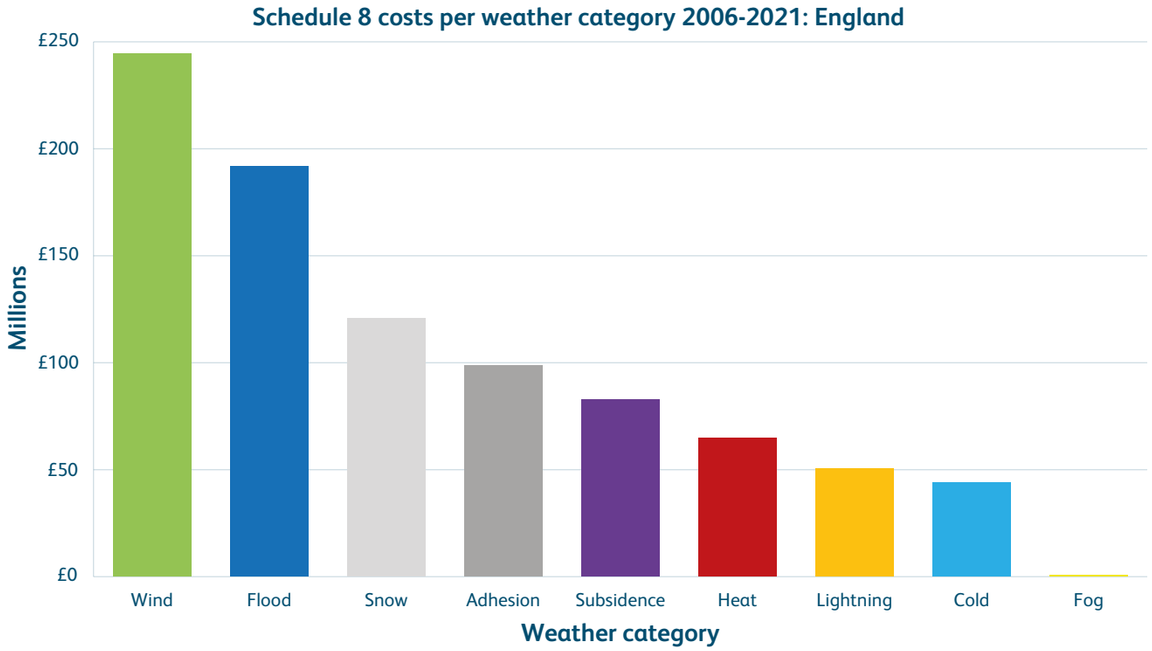


Figure 1-6 – Cumulative Schedule 8 weather category costs 2006/07 to 2020/21 (Wales)

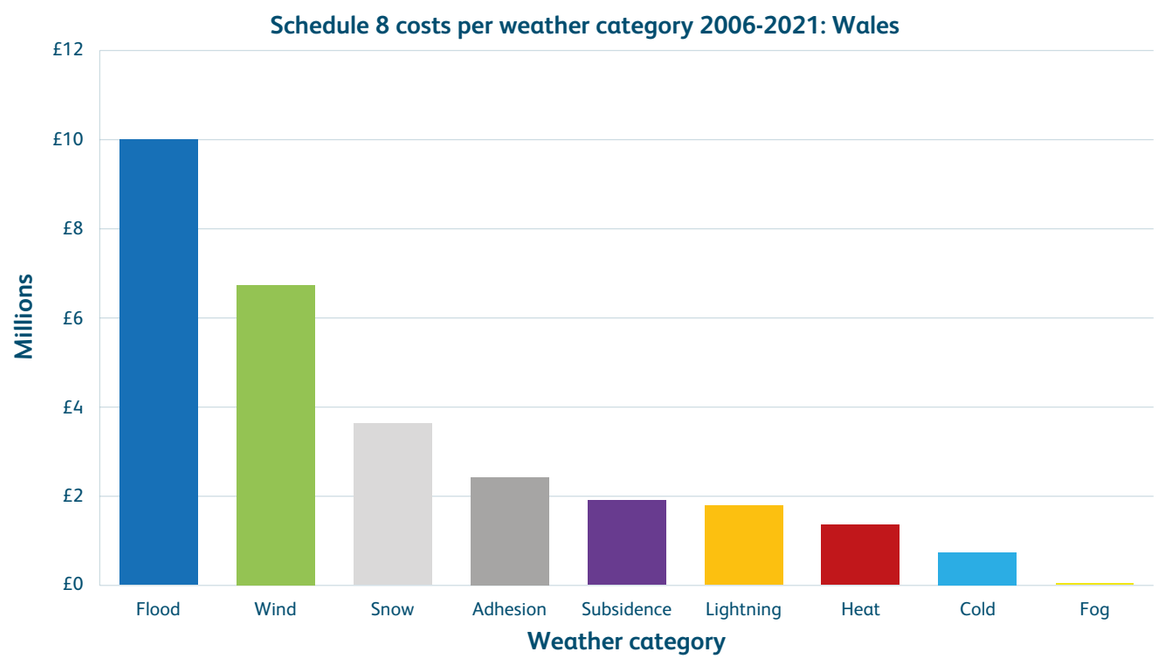
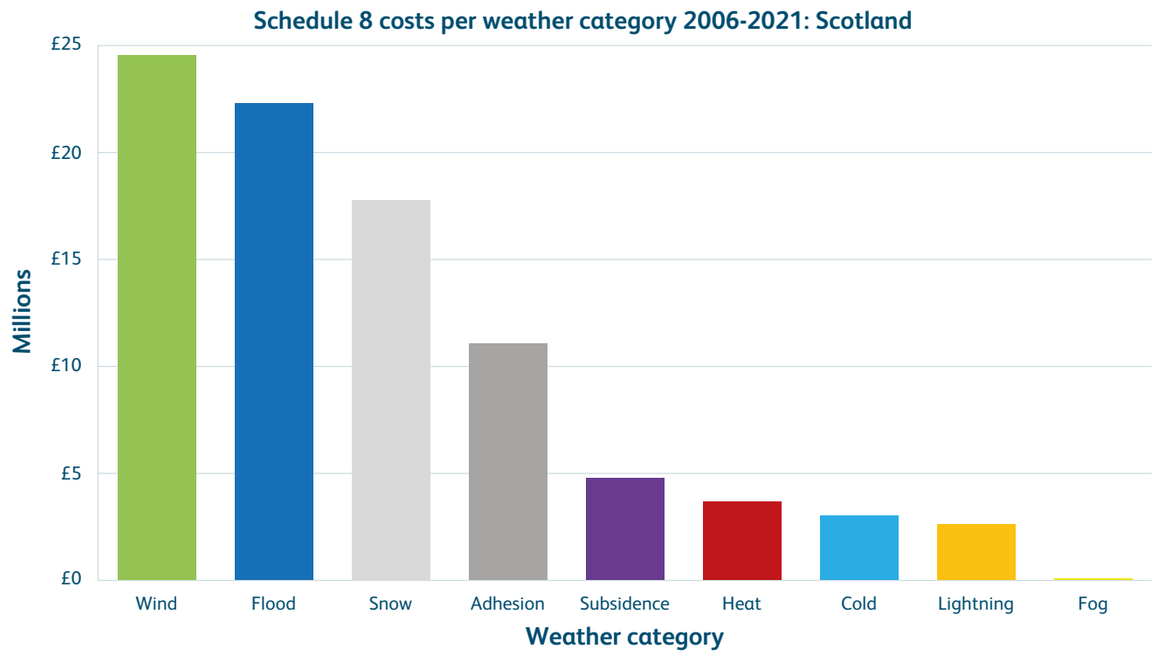
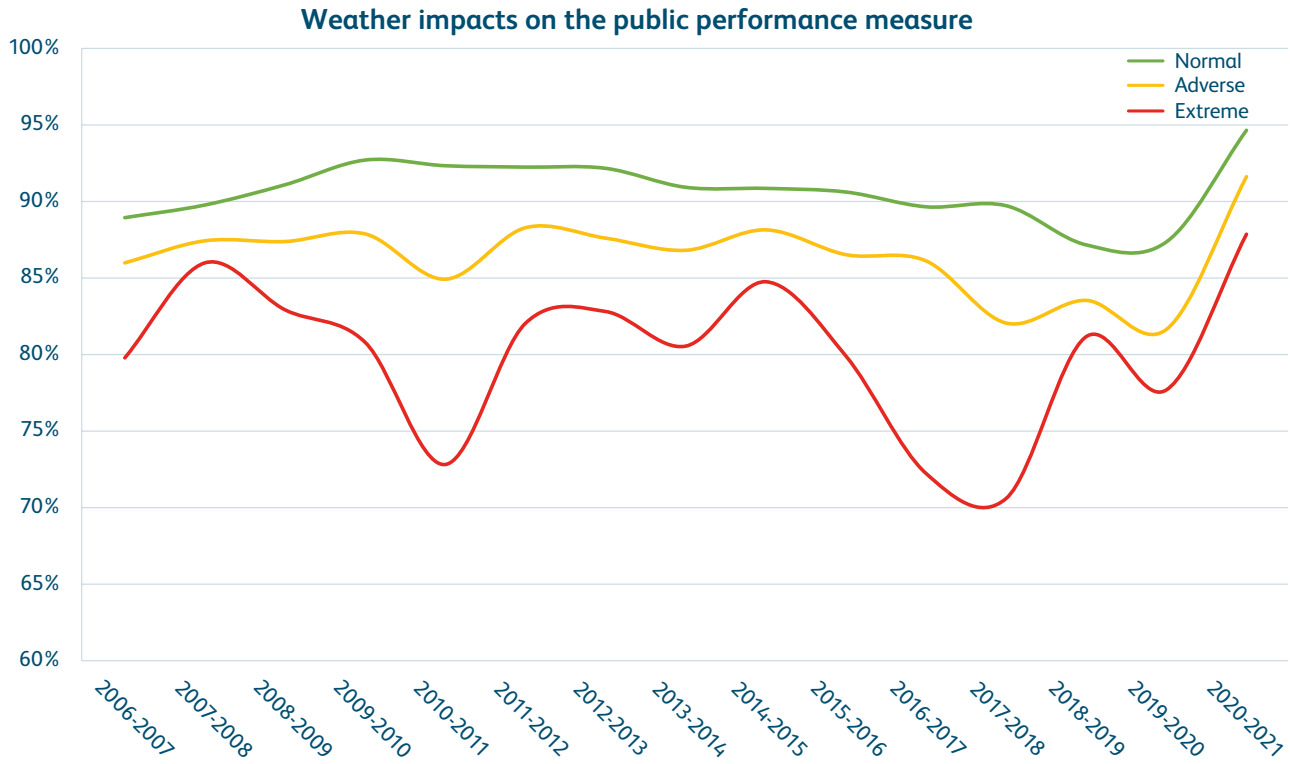


Figure 1-7 – Cumulative Schedule 8 weather category costs 2006/07 to 2020/21 (Scotland)



Across our network the average cost of all weather-related schedule 8 payments ranges from £50-100 million per year and the inclusion of missed targets, repairs and socio-economic costs raises this to an estimated £200-300 million per year. In the last 15 years, weather has cost us at least £3 billion and during adverse weather days our performance, measured by the public performance measure (PPM), has been 2-4 % lower than on normal weather days **(Figure 1-8)**.

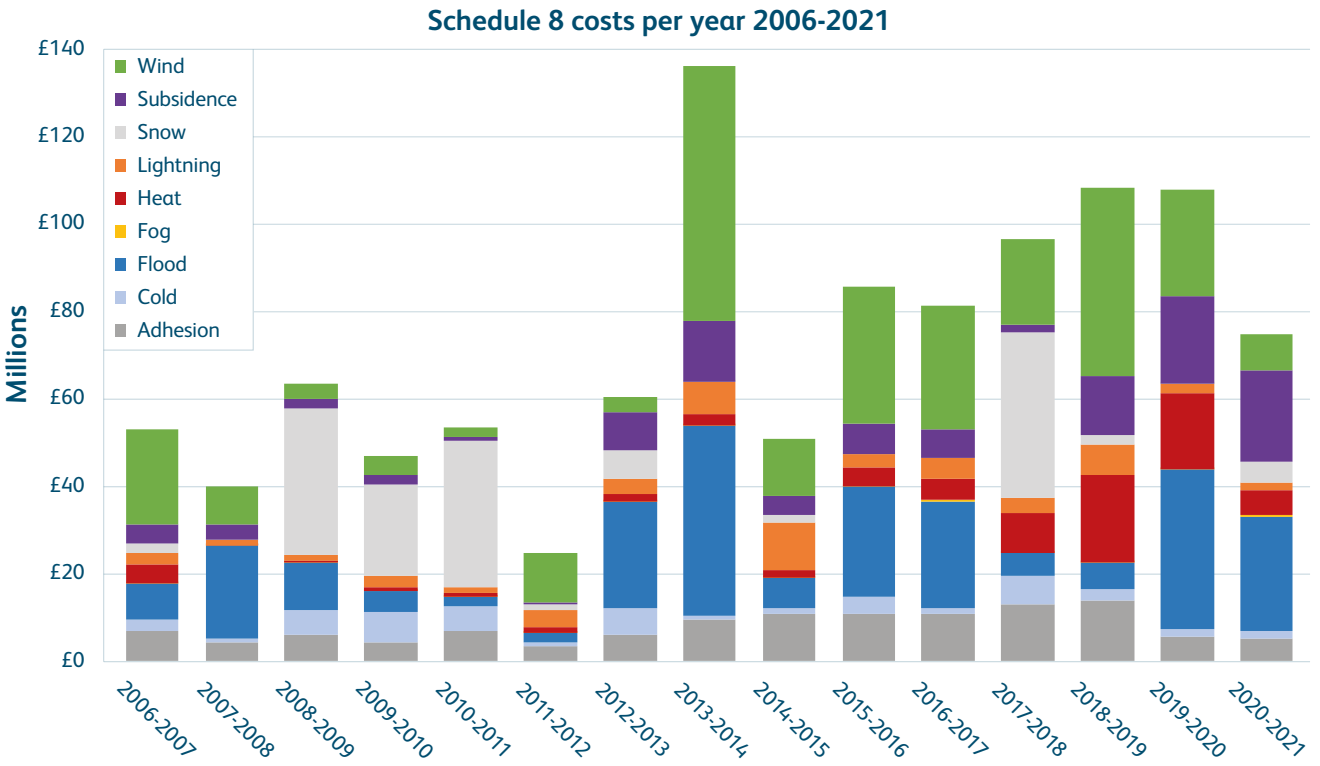
Figure 1-8 – Service performance (PPM) under normal, adverse and extreme weather



On extreme days the average delay minutes (approximately 6,500 minutes) are much higher than on normal days (2,500 minutes) with adverse days on average reaching 3,500 minutes. There is also a clear impact of seasons on PPM and on average there is a 1.5 % drop in summer, 3.5 % in winter and 5 % drop in autumn. Cumulative costs per year can be seen in **Figure 1-9**.

We continue to analyse this data to improve our understanding of the cost and impacts of weather events on our assets and services, and how best to identify and prioritise actions across our network.

Figure 1-9 – Annual cost of weather impacts



In addition to the analysis work on our delay and Schedule 8 data, a large amount of effort is being put into developing our understanding of the day to day and location by location impacts of weather on our assets, and to improving our operational response. Much of this work is being undertaken by our National Weather team and their stakeholders and it is used in:

- Setting and improving our weather planning and response policies and operational standards
- Improving our weather and impact forecasting tools and capabilities
- Improving our operational planning and responses
- Developing performance resilience metrics

This work improves the understanding of our current weather resilience, with the data collected and the knowledge generated also forming the baseline necessary for us to build our understanding of how the projected climate changes will affect our future resilience.

An example of this has been the work we have done with our chief engineer's teams over the last two years to assess the current and future climate risks to our whole range of assets and asset systems. This has created a risk assessment, and action plan which have been summarised in our Network Rail Asset Management WRCCA Plan report. The detail of this is discussed in **Section 4.3.2**.

1.2.2. Climate change impact

The Intergovernmental Panel on Climate Change (IPCC) have identified, in their latest climate science synthesis report[4], that it is certain that global temperatures will continue to increase until at least 2050. Therefore the risk to our network from a changing climate over the coming decades will remain.

Climate change is often viewed as a future problem, however, it is already causing more frequent and severe extreme weather events, with our network and services already suffering its impacts. Historic and current weather shows clear trends towards an increased frequency of extreme drier periods, followed by prolonged and extreme wet weather. Very hot summers such as 2018 are '30 times more likely than would be expected from natural factors alone'[5]. 'Extreme regional rainfall such as Storm Desmond in 2015 has a return period of about five years (20 % chance in any given year) and is at present roughly 60 % more likely due to human-caused climate change.'[6]

These factors accelerate our earthworks deterioration and put pressure on drainage systems, increasing the likelihood of critical coping thresholds being exceeded and leading to more interventions. Adverse weather can also impact other assets, with accelerated scour increasing risk at bridges over rivers for example. Some assets can be replaced more quickly/easily with current technology (e.g. track/signalling), but others, such as earthworks, cannot be future-proofed quickly. These assets require progressively rising investment accompanied by transformational change in how we manage the network and deploy technology. 'Good' management of climate change risk involves improved 'on the ground' resilience which will come at significant cost and will take many years to achieve.

Impacts from weather and climate change represent some of the most serious risks to our organisation, and to the people and businesses who rely on us. It materially influences our ability to safely and efficiently operate our services, buildings and infrastructure.

Trends in the UK climate and the UKCP18 data indicate, there has, and will continue to be, a shift to a warmer climate. We therefore need to focus on the effect that climate change will have on our performance and resilience. With many adverse and extreme weather events becoming more frequent and intense, without adaptation we will see more damage and greater disruption to our network, making it more challenging to retain existing levels of resilience with current levels of investment.

Our ongoing work to determine how changing weather patterns and events will alter the impacts that we experience is essential for planning the continued safe, reliable and efficient operation of our network. **Section 4** and **Section 8** provide more detail on our work to plan for and address weather and climate risk and resilience.

[4] IPCC (2021) Sixth Assessment Report Climate Change 2021: The Physical Science Basis

[5] Madge G (2019) Study examines drivers of 2018 UK summer heatwave. **https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2019/drivers-for-2018-uk-summer-heatwave** viewed 27 October 2021

[6] World Weather Attribution (2017) **https://www.worldweatherattribution.org/uk-storm-desmond-revisited-december-2017/** viewed 27 October 2021

1.3 How are we responding to our changing climate?

Since our second adaptation report we have developed strategies and detailed action plans that have enabled us to embed climate change consideration into key areas of our business.

We have also developed our Seasonal Weather Management Strategy and the recently established Weather Risk Task Force which are aimed at improving the way we manage current extreme weather and seasonality from an operational and asset management perspective. As this report focusses on climate change adaptation these activities are highlighted but are not covered in detail.

The first key piece of adaptation work was the development of a **WRCCA Strategy** in 2017 which set the framework for the weather resilience and adaptation work detailed throughout this report. It was also used as the backbone of our updated strategy included as one of the four core themes of our 2020 Environmental Sustainability Strategy. This sets out our ambitions for achieving 'a reliable railway that is resilient to climate change', part of our wider aim to deliver a sustainable railway 'serving the nation with the cleanest, greenest mass transport'. Detail on these strategies can be seen in **Section 4.2**.

An essential part of achieving current and future resilience is developing an understanding of the scale and nature of the issues we face so that we can identify appropriate responses. In 2018/19 we carried out research to identify the most appropriate climate change scenarios for use in our climate change planning, and published two guidance notes that provided our business with a methodology and data for assessing the current and future risks and planning actions. These are our; **Weather Resilience and Climate Change Impact Assessment Guidance Note** and **Climate Change Projections Guidance Note** and further information can be seen in **Section 8.2**.

Using these guidance notes we have carried out strategic risk assessments to update the Route WRCCA Plans for CP6 in 2020 and to create a new Network Rail Asset Management WRCCA Plan for our TA's chief engineer's teams in 2021. Both of these include weather and climate change risk assessments using UKCP18 and detail the actions that they intend to take over CP6. Details of the plans are included in **Section 4.3**, their risk assessments in **Sections 5.3** and **5.4** and their actions in **Section 8**.

As part of the process of generating this report we have taken the opportunity to amalgamate our route and asset management WRCCA risk assessments into one integrated risk assessment using the Department for Environment, Food and Rural Affairs (Defra) ARP3 template as a common format. This has enabled us to drive more detail into the route risk assessments, allowed the two business areas to sense check each other's work and iron out discrepancies and given us 'one version of the truth'. This work is presented in **Section 5.4**.

Allied to our work in the climate adaptation arena, the Seasonal Challenge Steering Group (SCSG) has issued a 10-year Seasonal Weather Management Strategy which looks to address short-term tactical improvements to operational weather management, response to and recovery from adverse and extreme weather events (see **Section 4.2**). The recently established Weather Risk Task Force will implement 19 action plans to deliver the recommendations from reviews by Lord Robert Mair and Dame Julia Slingo to improve our use of data to manage our operational response and understand our assets (**Section 8.3.1**).

Collectively the above work has built our adaptative capacity creating the awareness, tools and space that is enabling us to enhance our 'on the ground' resilience activity. An example is the move from the unfunded, aspirational adaptation actions included in the CP5 Route WRCCA Plans, to the fully funded adaptation actions included in CP6 and the subsequent **Route WRCCA Plans**.

Under the guidance of these strategic activities, we have done and are continuing to do a considerable amount of work to meet the challenges of the weather and future climate change. This ranges from research to further improve our governance and understanding through to investment in our assets to improve their resilience. Particular focusses have been in the areas of earthworks and drainage and water management. Details of our actions can be found throughout this report with a wide range of examples. **Sections 3**, **4** and **5**, describe our approach to governance, strategy and risk assessment in greater depth and **Sections 7** and **8** detail our risks and climate adaptation actions and progress.

1.4 Resilience and adaptation in a post-COVID world

Throughout its history, the railway has played a vital role in supporting and enabling the growth of the UK's economy by providing mass transport services for freight and passengers. Over this time, it has seen and adapted to many changes in the structure of the industry and the needs of its customers and other stakeholders.

The COVID-19 pandemic has been one of the biggest challenges to date causing large reductions in passenger numbers over the last two years, with uncertainty remaining over how these will recover, both in terms of total volumes and usage patterns. **The Great British Railways: Williams-Shapps Plan for Rail** (published in May 2021) took this into account in its conclusions regarding the need for fundamental changes in the structure and funding of the railway to improve its performance and efficiency and to make it more economically sustainable.

Our strong environmental credentials already mean that we and the railway are uniquely positioned as a sustainable and low carbon transport mode to help the Government to achieve its target of net zero emissions by 2050. However, the continuing reduction in passenger revenues has placed a great strain on the public purse meaning that funding will be constrained over the coming years and the delivery of the Williams-Shapps plan is likely to cause fundamental shifts in how the railway operates.

Meeting the challenge of climate change is likely to require a combination of increased investment in resilience action and changes in operating practices. The uncertainties posed by the funding challenge and the Williams-Shapps plan mean that committing to investment levels beyond those already agreed and/or specifying process or structural changes too far into the future is not possible. In this report we have therefore included currently funded and planned actions up to 2024 and sought to set our adaptation aims and pathway for future years in line with the climate change adaptation roadmap in our Environmental Sustainability Strategy (see **Figure 4-2**).

By improving resilience and being adaptable to change, we will continue to improve our efficiency, safety and operational performance. This will increase our ability to deliver positive outcomes for customers, the communities in which we work and the environment. We will also help create a transport function and value chain that is stronger and better able to cope with disruptions.

In short, weather resilience and climate change adaptation will help us and the rail transport sector 'build back better'.

1.5 Structure of this report

This report has been prepared in line with sector specific guidance provided by Defra and is broadly aligned with the common surface transport report structure that was agreed in collaboration with National Highways, Transport for London (TfL), HS2 and HS1.

To help you navigate through this report, it is structured as follows.

- **Section 2: Adaptation Reporting Power** – provides an introduction to adaptation reporting, a review of our ARP1 and ARP2 reports and an indication of what to expect from this report
- **Section 3: Climate governance at Network Rail** – outlines our business and corporate governance structure, demonstrating ownership at the highest levels within the organisation and our engagement with internal and external stakeholders
- **Section 4: Strategies and plans** – presents our vision for a climate resilient railway, our strategic priorities, action plans and our approach to ensuring the robustness of our activities
- **Section 5: How do we assess climate change risk** – details our approach to risk assessment at a corporate level, how climate change is managed through the enterprise risk process, how we have undertaken the risk assessment which is the foundation of this report and presents the methodology for scoring risks
- **Section 6: Interdependencies** – provides an overview of our key interdependencies with other infrastructure sectors and third parties
- **Section 7: Our key risks from climate change** – gives an overview of the 'moderate', 'major' and 'severe' risks that extreme weather and climate change present to our business
- **Section 8: Adaptation actions and progress** – outlines the considerable work that has been undertaken over the past five years and our progress in addressing the adaptation challenge since ARP2 and sets out our planned actions for APR3

2

2.1 Introduction to ARP reporting

Defra has requested that Network Rail produce this report under the ARP requirements in the Climate Change Act (2008). The purpose of ARP is for key organisations in different market sectors to report on the steps they are taking to identify and adapt to climate risks. We are included as a vital part of the transport industry.

To ensure that we are reporting in line with best practice, we have worked closely with Defra, the Office of Road and Rail (ORR), National Highways, TfL and many other stakeholders. Together we have developed a risk assessment and reporting framework that provides a standardised approach for the land transport sector, enabling Defra to easily draw comparisons and conclusions from across our reports.

The ARP reporting framework for the land transport sector is also in general accordance with the TCFD guidelines. The TCFD approach is structured around four interlinked thematic areas that represent core elements of how organisations operate, and we have structured this ARP report, accordingly: governance; strategy; risk management; and metrics and targets.

2.2 ARP1 and ARP2: A retrospective

Our first formal adaptation report (ARP1) was submitted 10 years ago in 2011 and was considered best practice at the time. It used research from Tomorrow's Railway and Climate Change Adaptation (TRaCCA) to build a largely qualitative picture of our approach to managing climate impacts.

ARP2, published in 2016, significantly advanced our work in ARP1. For example, it described the step change we had made in the way we assess climate risks across the organisation, using the 'bow-tie' methodology described in **Section 5**. As part of a suite of activities and actions, this methodology allowed us to analyse the short and long-term weather resilience of rail assets in much greater detail. ARP2 also:

- Described how the bow-tie risk assessment process had provided a basis for the weather resilience and climate change programme being run at the time
- Detailed climate governance arrangements more comprehensively than ARP1
- Based its findings on much more refined climate data
- Demonstrated the growing and advancing systems we had put in place to manage the causes and consequences of climate impacts

2.3 What can you expect from this ARP3 report?

This ARP3 report is an opportunity to communicate how we have honed and refined our approach to climate resilience, further advancing the work we reported in ARP2 five years ago.

Specifically, this report:

- Provides an updated assessment of the climate change risks and impacts on our organisation
- More comprehensively sets out our governance structure following restructure of the organisation
- Describes the way that we have further embedded climate risk consideration into our strategies, plans and processes through the use of research and tools
- Sets out more clearly the interdependent relationships we have with other organisations, and their roles in helping us manage climate risks
- Focusses further on the metrics and targets we are using to measure our performance
- Reports how our work aligns with TCFD's non-financial requirements

This report allows us to take stock of our progress, communicate it to the external world, and describe how we will continue to deliver meaningful actions for a resilient railway.

2.4 What is not included?

This report aims to report our physical risks in line with TCFD. There are two key requirements of the TCFD which have not been included in this report, namely:

- **Financial disclosure** – we are not currently able to provide detailed **financial analysis** of our risks and opportunities. We are working hard to improve our understanding of the cost of weather to the railway and how this might change in the future though a number of research projects and hope to be able to provide more information in due course
- **Carbon and transition risks** – this report also focuses on physical rather than **transition risks**. Transition risks consider the way in which, in the move to a more sustainable and low carbon economy, changes in legislation, markets and technologies can impact our organisation. These are more closely aligned with our work on decarbonising the railway and have not been considered here in depth. If you want to know more about our work on reducing carbon as part of our commitments to net zero, you can read our plans **here**

We have conducted a review of our current risk assessment and reporting against TCFD with a view to producing a full report in a few years' time.

3.1 Laying strong foundations

We are committed to building a railway that is resilient to the impact of extreme weather and climate change. This means taking positive and proactive action to ensure our customers (passengers and freight), people, operations, and the infrastructure they rely on, are resilient and adaptable to long term climate changes.

Climate change is governed through the implementation of our Environmental Sustainability Strategy which covers climate change mitigation through our low emissions railway and decarbonisation ambitions and adaptation through our weather resilience and climate change adaptation ambitions discussed further in **Section 4**.

Our strategies and plans have been approved by our Board and the DfT and are governed as set out in **Section 3.2** below.

3.2 Our business structure

Network Rail is a devolved organisation with five regions supported by 14 routes as illustrated in Figure 1-2. The managing director of each region is responsible for long-term planning and asset management plans and overseeing route directors who are responsible for delivery of operations, maintenance and renewals. The routes are responsible for day-to-day delivery of train performance and work closely with their local train operating partners.

National functions provide support and strategic direction to the work in the regions:

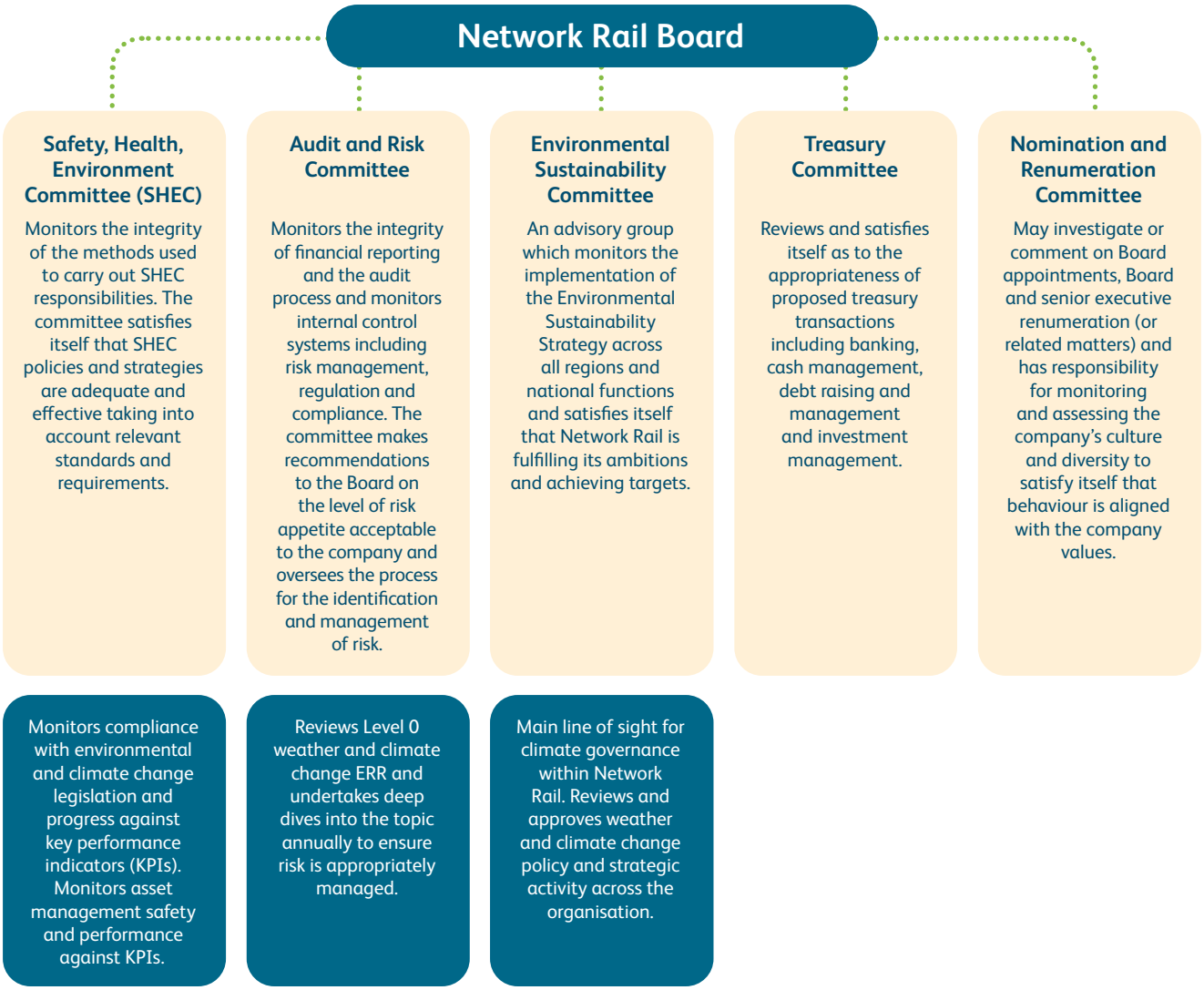
- **Technical Authority (TA)** – provides technical leadership and specialist expertise for safety, engineering, asset management, security, environment and sustainability and manages the national control and competence framework. The TA defines and discharges network accountabilities for policy, strategy and the control framework (including assurance against it) in the areas above. Our WRCCA team sits in the Environment and Sustainability team and is responsible for the development, oversight and implementation of our WRCCA policy and strategy and the production of this report
- **System Operator** – works with the regions and routes to support delivery of high levels of safe and efficient operational performance, contributing to an excellent experience for passengers, freight and customers. Their focus is on improving what the network is capable of by planning for the future, providing high quality analysis and advice, producing the timetable and managing industry-wide relationships. The National Weather team in System Operator is responsible for managing the short-term impacts of weather on the railway as discussed further below
- **Route Services** – provide a wide range of services to all parts of the organisation including asset information services, business services, commercial and procurement, engineering services, IT services and supply chain operations
- **Central Functions** – provide a wide range of support to the business including Finance (covering the group financial controller, risk and internal audit, planning and regulation) and Human Resources and Communications

3.3 Corporate governance

Our Board of Directors report to the Secretary of State for Transport and are responsible for ensuring our actions support the strategic policies of the Secretary of State and the Scottish and Welsh Ministers through the committees illustrated in Figure 3-1. We are subject to independent regulation by the ORR as set out in our framework agreement with the DfT.

The Executive Leadership team, including the chief executive, the chief financial officer and senior executives from each of the regions and functions outlined above, manage these relationships to oversee the day-to-day running of Network Rail. Together the Executive Leadership team and the Board are responsible for ensuring our strategies and plans are compliant with regulations and controls and that we have the funding to deliver our services.

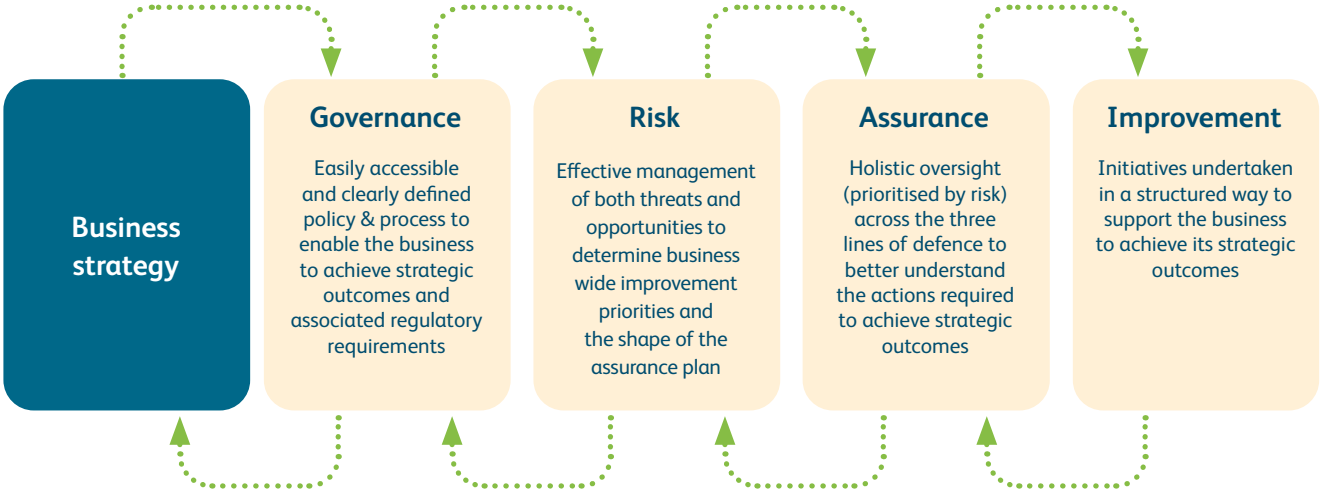
Figure 3-1 – Network Rail Board committees



The Executive Leadership team maintains oversight of the business through strategy committees aligned to the six strategic priorities within our 'putting passengers first' vision. Each of these strategic areas: safety, train service delivery, efficiency, sustainable growth, customers and communities and people, are materially impacted by the weather that we experience in the UK and will be affected by the longer-term changes to our climate. The primary focus of our work on climate change adaptation is on sustainable growth and this is the route for governance of our activities.

We use the governance, risk, assurance and improvement (GRAI) process to ensure that a consistent and auditable approach is taken across different governance systems. This helps us manage our work effectively, learn as an organisation, improve safety, and become a more efficient and dependable partner. We are better able to understand if the business strategy is being achieved by using the steps shown in **Figure 3-2**.

Figure 3-2 – GRAI process



3.4 Weather resilience and climate change adaptation governance

Delivery of our goal of 'a reliable railway service that is resilient to climate change' is the responsibility of multiple teams and business units across Network Rail and the wider rail industry.

The TA Environment and Sustainability team owns the national strategy and corporate risk register for managing weather and climate change risk, with its WRCCA team leading collaboration with teams across the organisation falling into the following broad categories.

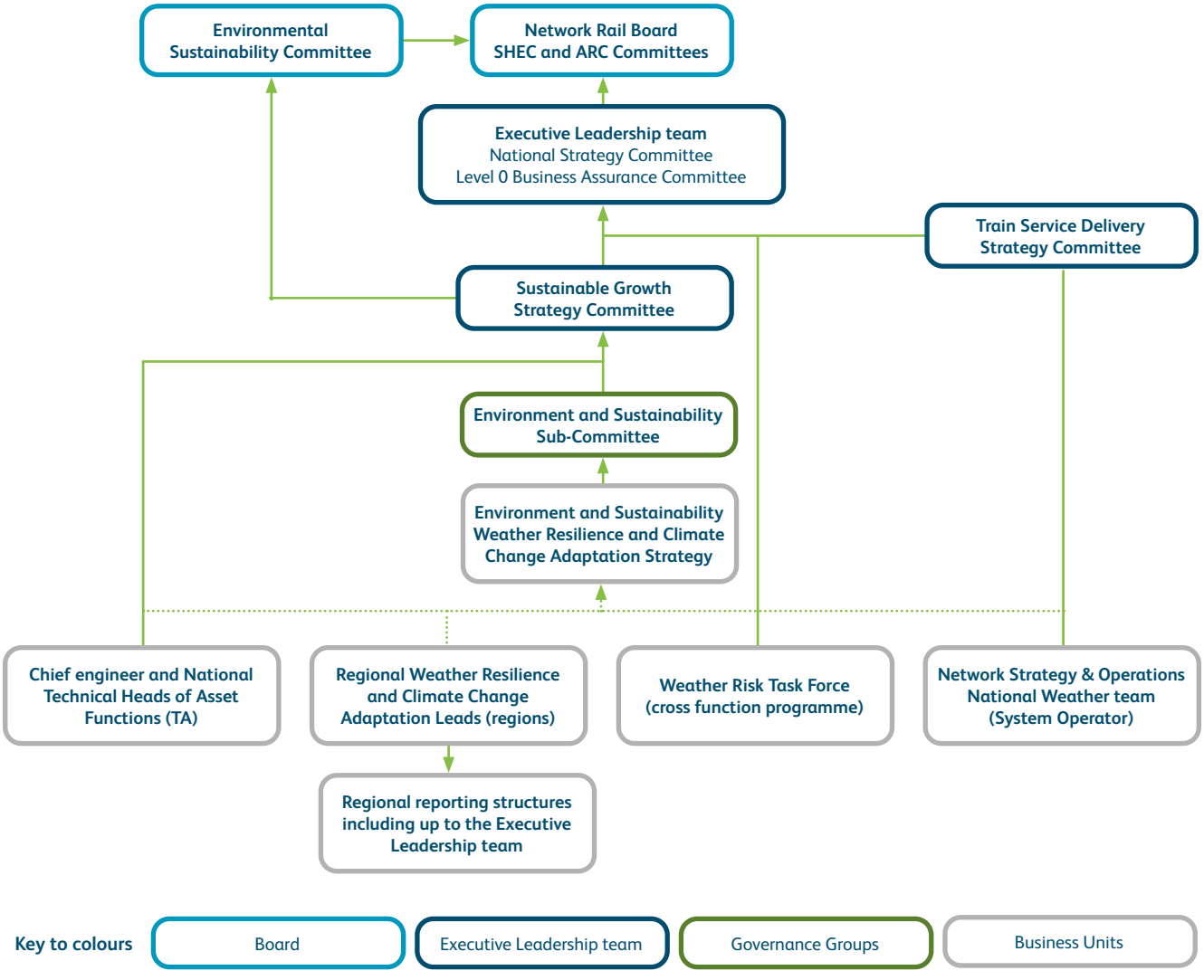
- **Strategy and planning** – network level strategic direction, policy and investment planning – led by the TA Environment and Sustainability team supporting regional delivery
- **Asset management** – inclusion of climate change in asset policies, standards and specifications, regional and route asset management and capital delivery projects – led by the TA chief engineer

- **Operational weather management** – network level standards, tools and programmes supporting the smooth running of the railway in all seasons – led by the System Operator Network Strategy and Operations team
- **Weather Risk Task Force** – delivery of the recommendations from the Lord Robert Mair Earthworks task force, Dame Julia Slingo Weather Advisory Task Force and the operational response to weather review. Action plans have been developed from these reports and will be led by a dedicated programme delivery team, with some actions led by regional teams
- **Research, analysis technology and tools** – a wide range of activity delivered across the business by multiple teams responsible for different elements of analysis to support the work of the teams above

The teams in each group are governed through GRAI and report to the Executive Leadership team and Board through channels relevant to their function.

Figure 3-3 shows the core governance channels for the WRCCA workstreams. Within this structure a wide range of teams and business units contribute to the workstreams, with national oversight provided by the TA WRCCA team.

Figure 3-3 – WRCCA governance structure



The key accountabilities for each of the core contributors to the workstreams are shown in **Figure 3-4** and further detail on the activities that they take to deliver these are detailed in the paragraphs below.

Figure 3-4 – Core adaptation contributor roles

Environment & Sustainability WRCCA team TA	• Lead network level activities in relation to climate change resilience and adaptation • Corporate weather and climate change vision and strategy • Governance and assurance against national control framework • Competence and capability (national level) • Provide specialist expertise
Chief engineer TA	• Stewardship of Network Rail asset and maintenance standards and policies • Management of the product approval process • Provision of technical expertise and network analysis, led by professional heads • Reliability analysis and reporting
Network Strategy & Operations	• Lead network level activities in relation to operational and seasonal weather management • Weather management through appropriate responses to weather forecast alerts and seasonal preparation • Delivery of year on year seasonal planning and the 5 year operational weather strategy
Regional engineering and asset management	• Asset management at regional and route level

Weather Resilience and Climate Change Adaptation team – This team defines the company vision, strategy and policy for the management of weather and climate change resilience within Network Rail and is accountable for the oversight and governance of it and the activities to deliver it. As part of this it owns and manages the Level 0 industry-wide weather and climate change ERR (see **Section 5**) monitoring controls and improvement actions across the business in collaboration with the System Operator.

It provides assurance against the National Control Framework and progress reporting; internally through our Climate Change Collaboration Forum and national WRCCA Plan and ERR reporting to the TA, the Executive Leadership team and the Board and; externally though liaison with our regulators (ORR, DfT, Defra, Welsh Government, Transport Scotland etc). A key activity allied to this is being Network Rail's national representatives on the subject in liaison with our regulators, the Rail Industry Climate Change Adaptation Working Group and key external stakeholder groups, such as the Infrastructure Operators Adaptation Forum (IOAF) and the CCC.

Internally it acts as a centre of excellence undertaking weather and climate change research and analysis and providing specialist technical advice, data and training to support the business in understanding climate change impacts and developing strategies at region, route and other levels.

Chief engineer's team – This team comprises five asset groups and 14 asset functions. They define our asset strategies and policies for making our assets resilient to extreme weather and climate change and manage their weather and climate related risks through Level 1 and 2 ERRs. They set asset standards and component specifications and develop and implement plans to increase asset resilience delivering performance, safety, financial and reputational benefits considering the interdependencies between our assets and the wider railway system. This is underpinned by detailed analysis of the weather-related impacts on our assets and the use of deterioration modelling and other decision support tools to understand their vulnerability, allowing informed investment prioritisation.

They are responsible for ensuring that all of their activities appropriately consider the impacts of the current and future climate and they have recently published their Asset Management WRCCA Plan which sets out the actions they will take to achieve this.

They have committed to reviewing their activities to embed climate change adaptation thinking and action, where appropriate, in line with the overarching WRCCA strategy. For example, developing and implementing weather and climate change resilience plans and including future climate consideration into their whole life costing tools and using these in investment planning and prioritisation. The key actions can be seen in **Section 4.3**. They will report progress against these actions and their effectiveness to the WRCCA team and this will be tracked through the Level 0 weather and climate change ERR controls.

Network Strategy & Operations – This team lead on operational and seasonal weather management. They are the co-owners of the Level 0 industry-wide weather and climate change ERR with the WRCCA team and monitor the relevant controls and improvement actions across our operations. They deliver our Seasonal Weather Management Strategy on behalf of the SCSG.

They are responsible for the development and review of operational weather management standards and seasonal preparedness procedures and the national management and reporting of weather-related incidents in line with national strategy and action plans. Within this role they are tasked with convening extreme weather action teleconferences (EWAT). They also manage and maintain the Network Rail Weather Service as a key input into the operational weather management and response process. In addition, they are responsible for responding to revisions recommended by the Weather Advisory Task Force.

Assurance and reporting of weather-related incidents and activities is a key accountability, they; deliver third line independent assurance for seasonal preparation and leading indicators based on asset condition and provide a tactical overview of operational and seasonal weather management to the Executive Leadership team. They also represent Network Rail in operational weather resilience liaison with external stakeholders, including DfT, National Performance Board and SCSG.

Analysis of weather-related impacts on performance and the use of this data in improving our weather impacts knowledge and responses is a core activity allied with a role facilitating research and the trialling of new technologies, products and materials both train and non-train borne through the Rail Safety and Standards Board (RSSB) and Rail Delivery Group (RDG).

Regional engineering and asset management – The Regional Asset Management teams support the development of asset strategies and plans in compliance with Network Rail standards through Asset Leadership teams (ALT) and engagement with the chief engineer's teams, for example through discipline collaboration forums. They develop and implement action and investment plans for the short to medium term feeding into strategic business planning Control Periods and guiding the work for asset teams. Going forward these plans will include any actions linked to the Weather Risk Task Force and the Route and Asset Management WRCCA Plans reported to the ORR.

They will develop long term adaptation pathway strategies and investment plans for enhancing the resilience of their regions to identify key investment pathways and points of transformational change required. These will be used to create a sequenced plan of action to manage and renew assets to enhance resilience to climate change whilst delivering performance, safety, financial and reputational benefits. Within these they will identify and develop resilience schemes which address risks to all assets, land and third parties and are designed to be resilient to future weather conditions as a result of climate change.

When developing schemes they will also need to embed a wide range of sustainability considerations (e.g. habitat creation, social value, carbon reduction etc) and address interdependencies and cascade impacts with other infrastructure operators, train and freight operators and neighbouring regions.

They will report progress in implementing their WRCCA plans and against the ERR controls.

3.5 Collaboration and stakeholder engagement

3.5.1. Within Network Rail

We have nominated WRCCA 'leads' in those business units with a core role in delivering our strategic ambitions on weather and climate change adaptation. These representatives act as the focal point for our interactions into and out of their business units. As such they play a key role in developing our work streams, providing data and reviews, undertaking research and exchanging best practice.

These leads meet in a monthly 'collaboration forum' which enables the sharing of information and best practice across teams. In addition to this, the TA WRCCA team and the System Operator National Weather team meet twice a month to review risks and align work programmes. Both teams are members of the SCSG which is tasked with improving the management of operational weather performance.

Our asset management teams have well established engagement and collaboration through ALTs for each asset function and the National Asset Management Review Group which feeds into the Sustainable Growth Committee. The ALTs involve representatives from routes and regions around the business. These will form the structure within which each asset function will develop strategies to respond to the risks identified in this report and put plans in place to adapt the railway to climate change.

3.5.2. Government and regulators

We hold regular liaison meetings with the DfT and ORR within the structure of the environment and sustainability programme as well as on weather resilience specific issues. These meetings are used to share updates on activities, discuss expectations and report on progress in delivery against commitments in our Route WRCCA Plans and strategic milestones.

We also work closely with the Welsh and Scottish Governments, Defra, the CCC, National Infrastructure Commission, Environment Agency (EA), Natural Resources Wales (NRW) and the Scottish Environment Protection Agency (SEPA) to ensure we are meeting policy and regulatory goals in all nations and to share data and collaborate on projects including flood defence and coastal erosion schemes.

3.5.3. Rail industry

Network Rail is a founding member of the Rail Industry Climate Change Adaptation Working Group which now sits under the RSSB Sustainability Programme. This group brings people from all parts of the rail industry including other infrastructure owners, train and freight operators and rolling stock owners and designers with a view to developing holistic, industry wide solutions to support the long-term resilience of the railway.

We are also involved with the newly formed task force on weather resilience coordinated by the International Union of Railways (UIC) which formally brings together discussion on this topic across the global rail industry. This will build on initial discussions and engagement we have had over the past few years with other national rail organisations such as ProRail (Netherlands), SNCF (France) and Metrolinx (Canada).

3.5.4. Infrastructure operators, academics and other external stakeholders

The IOAF and Transport Adaptation Steering Group are our key routes to engaging with external stakeholders. We place high importance on collaboration through these groups as the opportunity to share experiences, best practice and to work together on research projects. This has delivered significant value to our work and will continue to do so. Of particular value has been discussion with National Highways, TfL, HS2 and HS1 to develop the common ARP3 approach for the surface transport sector. The broad structure of this report and the template for the risk assessment was developed and agreed with this group.

We regularly engage with academics, consultants and other expert service providers through the groups above as well as work with our wider research and development (R&D) portfolio and through the delivery of specific consultancy projects (e.g. guidance and methodology for adaptation pathways, UKCP18 climate projections updates etc).

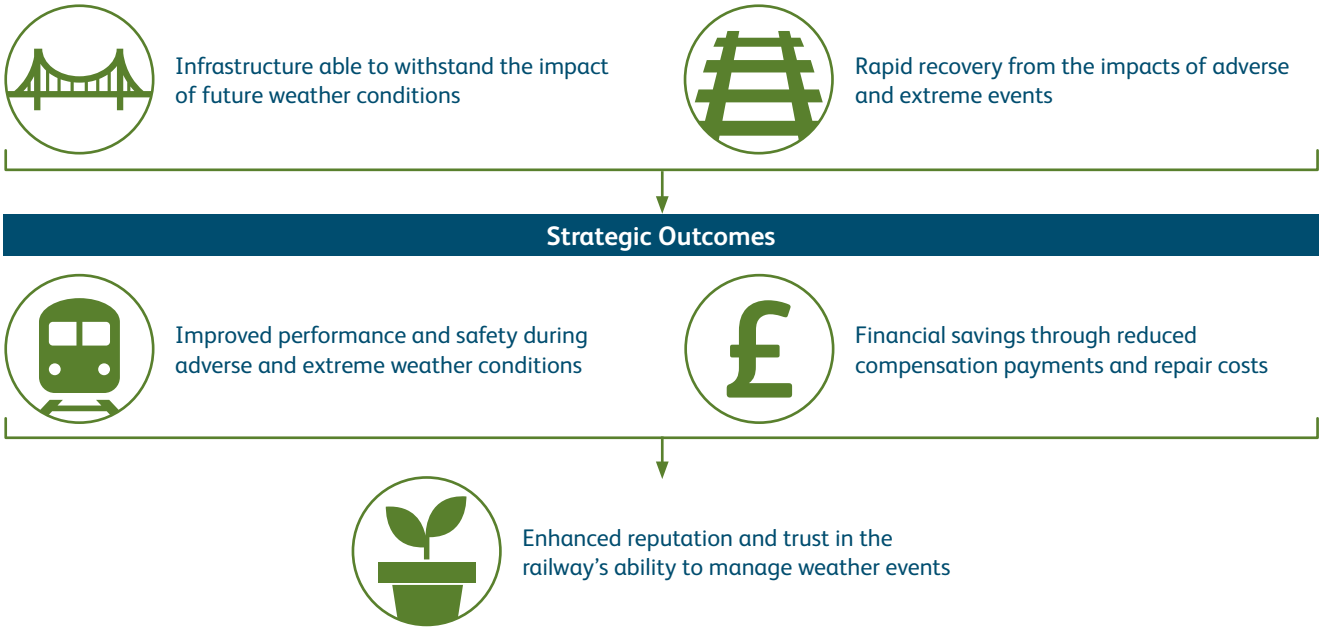
We will continue to actively engage with a wide range of stakeholders across the rail industry, the communities we serve, the research community and the wider infrastructure sector to advance climate change adaptation at Network Rail, in the UK and globally.

4

4.1 A vision for a weather and climate resilient railway

Our vision is for a railway that is safe and more resilient to the effects of weather and climate change now and in the future. The desired outcome for our journey to resilience is presented in Figure 4-1.

Figure 4-1 – Strategic vision and outcomes for enhancing resilience of the railway



Short-medium-term operational and seasonal resilience

Vision

- To deliver a safe and seasonally agnostic railway by putting passengers and freight users first

Goals

- Minimising the seasonality bump
- Excellently implementing key route strategies
- Avoiding or excellently managing major incidents

Long-term weather and climate change resilience

Vision

- A reliable railway service resilient to climate change

Goals

- Replace like for better rather than like for like
- Adapt at construction and at asset renewal
- Climate change considerations are embedded in business as usual through updated policies, standards, and procedures
- Interdependencies are understood and managed in collaboration with the rail industry, infrastructure operators, government and other stakeholders

4.2 Our vision and strategic priorities for climate adaptation

We published our first WRCCA strategy in 2017 and this set the framework for all of the work described in this report. Our overarching strategic ambition for climate change adaptation was updated in 2020 when it was made a core theme of our new Environmental Sustainability Strategy. Since then, we have developed a Seasonal Weather Management Strategy and established the Weather Risk Task Force, both of which contribute to the short, medium and long-term resilience of the railway.

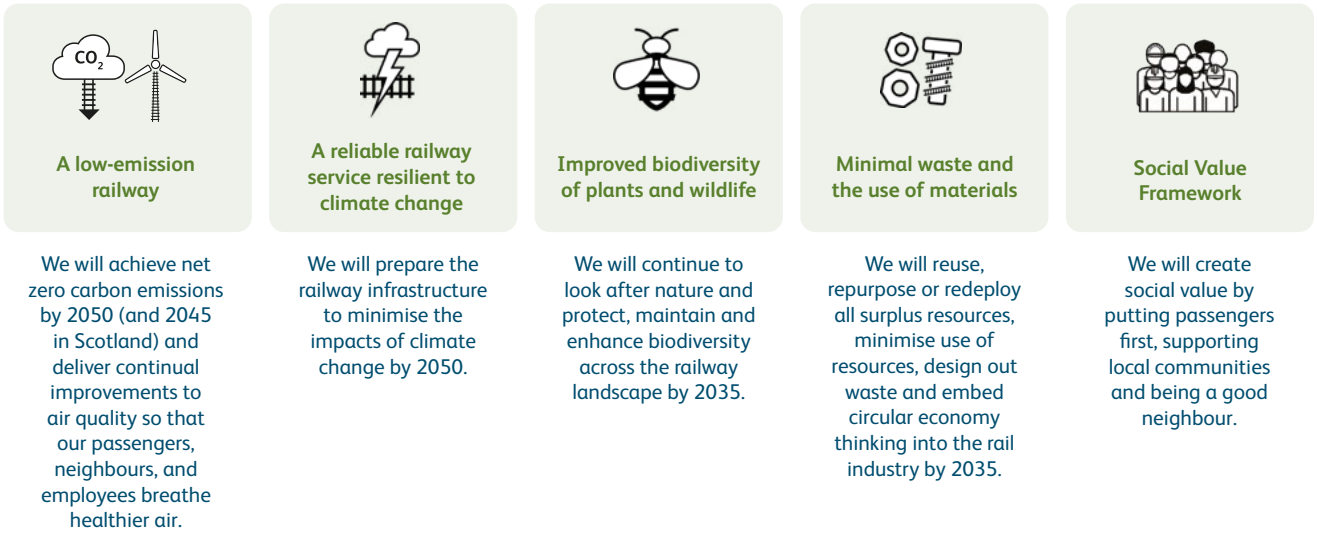
In addition, work has begun on the sustainable rail strategy as part of the WISP for the railway over the next 30 years and climate change resilience forms a core element. Our 2017 WRCCA Strategy will shortly be updated in light of these developments to provide the overarching framework for operational weather management and longer-term climate change resilience. In the meantime, this section provides an overview of our current strategy and action plans.

4.2.1. Environmental Sustainability Strategy

Our vision for a sustainable railway is **'To serve the nation with the cleanest, greenest mass transport. We want to put passengers first, help passengers and freight users to make green choices, support local communities and be a good neighbour.'**

Climate change adaptation is one of the four core priorities in our Environmental Sustainability Strategy (**Figure 4-2**) with an ambition to 'prepare the railway infrastructure to minimise the impacts of climate change by 2050.' In addition to this strategy we have a fifth priority relating to enhancing our social performance in line with our **Social Value Framework**.

Figure 4-2 – Network Rail Environmental Sustainability Strategy core priorities

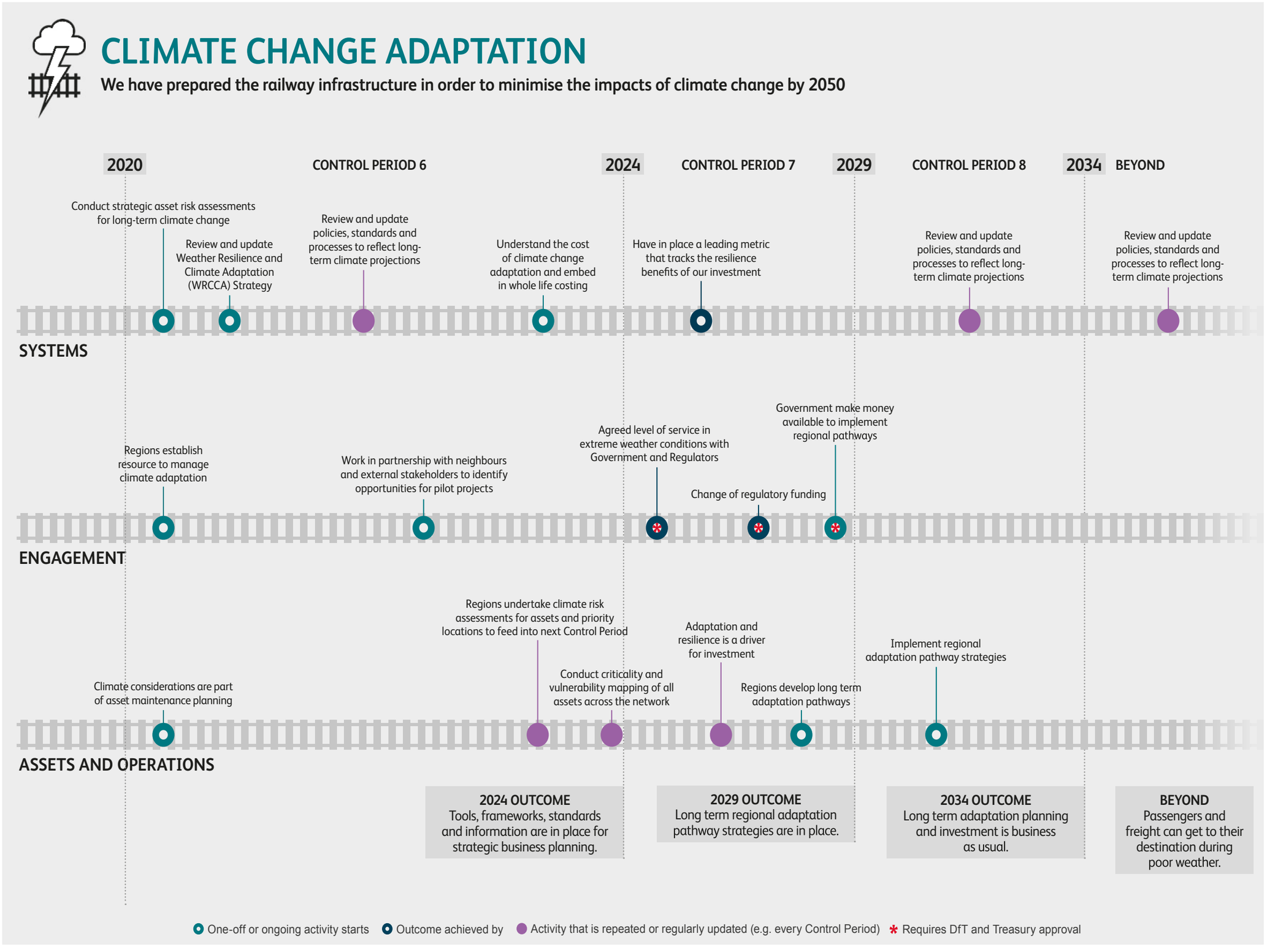


Critical to our plans for minimising safety and performance reliability impacts caused by climate change is embedding resilience into the way that we design, build, operate, maintain and replace our railway assets. Our key milestones include:

- Asset policies and standards updated to reflect long-term climate change projections by 2024
- Review criticality and vulnerability mapping of all assets for climate change across the network by 2024
- Agree level of service in extreme weather conditions with Government and regulators by 2027
- Regions develop long-term adaptation pathway and investment strategies by 2029

The roadmap to achieving this ambition as set out in our Environmental Sustainability Strategy is presented in **Figure 4-3**.

Figure 4-3 – Environmental Sustainability Strategy climate change adaptation roadmap



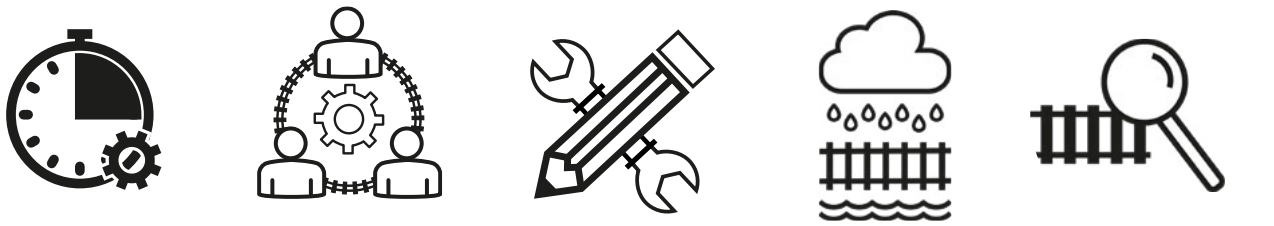
4.2.2. Weather Resilience and Climate Change Adaptation Strategy

Our current **WRCCA Strategy** was created in 2017 to set out our framework for developing a sound understanding of the weather and climate impacts for our business and the actions we would need to take to address them. The core commitments in it are:

- Integrating climate change in our 'business as usual' activities
- Taking action on climate change risks based on robust planning and investment
- Analysing and reporting on both our successes and opportunities for improvement
- Streamlining and enhancing our ability to respond to, and recover from, seasonal and extreme weather events
- Engaging with stakeholders across the regions and the wider rail industry, to ensure we really understand our relationships with others and how interdependent risks (those that could impact or require a response from a number of parties) are effectively managed

Our work falls into five strategic workstreams which enable us to deliver these commitments, improve our understanding and management of weather and climate change impacts and to integrate climate change considerations into business as usual. An overview of the workstreams is provided in **Figure 4-4**.

Figure 4-4 – Network Rail's five pillars or 'key workstreams' for resilience



Strategy and planning

- Long term resilience strategies guide investment and transformation of the railway
- Risk assessment, action and investment plans control weather and climate resilience
- Knowledge and information to enable people to fulfil their roles and make accurate and robust decisions

Operational weather management

- Operational weather management can handle increasingly frequent and severe weather events
- Minimise the seasonality bump
- Excellently implement Key Route Strategies
- Avoid or excellently manage 'out-of-control' events

Asset management & engineering

- Assets and projects designed to be climate resilient
- Climate resilience embedded in policies, standards and processes, and guidance and tools support business
- Investment supports resilience from a sustainable growth and train service delivery perspective

Weather Risk Task Force

- Co-ordinated implementation of the recommendations from the Lord Robert Mair and Dame Julia Slingo task forces and the earthworks sprint

Research and analysis

- Common understanding of current and future weather risks, impacts on the railway system, existing and future vulnerability and the economics and benefits of different resilience levels
- Systems, technology and tools to facilitate prediction and minimisation of weather and climate change impacts

4.2.3. Seasonal Weather Management Strategy

Our ambition to deliver 'a safe and seasonally agnostic railway by putting passengers and freight users first' will be delivered through the 10-year Seasonal Weather Management Strategy to improve operational and seasonal weather management. This strategy has been led by the SCSG, a cross industry group which seeks to improve the management of weather-related performance in the short to medium-term. The SCSG focusses on tactical, operational measures to improve resilience on a daily, seasonal and annual basis and the strategy aims to dampen the variability in seasonal performance and create a 'seasonally agnostic' railway through the achievement of the following three goals:

- Minimising the seasonality bump
- Excellently implementing key route strategies
- Avoiding or excellently managing 'out-of-control events'

The National Weather team works with the SCSG to implement the Seasonal Weather Management Strategy across industry and to deliver the industry weather resilience programme designed to improve our understanding and response to the short-term weather impacts to our systems.

Both the SCSG and the National Weather team will continue to work closely with the WRCCA team to ensure that their strategies and plans are aligned with the longer-term climate change strategy and actions.

4.2.4. Looking to the future – Sustainable Rail Strategy

The Williams-Shapps Plan for Rail published in May 2021 outlines plans to reform Britain's railways. It will create a new public body, GBR which will integrate the railways, owning the infrastructure, collecting fare revenue, running and planning the network, and setting most fares and timetables. It will bring together elements of the DfT, Network Rail, the RDG and others under a single, familiar brand with united, accountable leadership. The aim is to support delivery of a financially sustainable railway as the country recovers from the impact of the coronavirus (COVID19), with new contracts focused on punctuality and improved efficiency, making it easier and cheaper to plan maintenance, renewal and upgrades.

Building a resilient and sustainable railway is key to the delivery of this plan. A 30-year WISP is being developed and this will provide the framework for development of the rail industry into the future. Climate change resilience is a key priority in this and we are fully engaged with ensuring that the right information goes into it.

We are also supporting the RSSB with the development of the Sustainable Rail Strategy which forms part of the WISP. It will provide a long-term plan to establish rail as the backbone of a cleaner future transport system. The climate resilience element is being developed through collaboration in the Rail Industry Climate Change Adaptation Working Group and is closely aligned with Network Rail's strategic roadmap (See **Figure 4-3**).

4.3 Action plans

4.3.1. Route weather resilience and climate change adaptation plans

We have assessed the vulnerability of our network to extreme weather and climate change and have developed action plans setting out planned activities to improve resilience. The first set of Route WRCCA Plans covering CP5 (2014–2019) were published in 2014 (as reported in ARP2).

In 2019/20 new updated plans were produced to cover the **CP6 period (2019–2024)**. In the update of the plans, we took the opportunity to accommodate changes in our organisational structure and to enhance the climate change risk assessment in terms of the scope of the data provided. This was done using data from our **Climate Change Projections Guidance Note** based on the UKCP18 projections. These changes are summarised in **Figure 4-5**.

Since the update the organisational structure of Network Rail has changed again, moving from eight routes to five regions containing 14 routes. However the Route WRCCA Plans still cover the full geography of Great Britain and therefore capture the key risks and investments within the new regional borders.

In addition to the technical updates the CP6 WRCCA plans represent a significant step forward in increasing the deliverability of, and accountability for, the adaptation actions that they contain. In the CP5 plans the actions included by the routes were generally not supported by funding from the CP5 business plans and so were not enforceable, and no mechanism was put in place to monitor progress against them.

In the new CP6 WRCCA plans all of the actions committed to in the action tables are supported by funding allocated from the CP6 business plan, and a six-monthly reporting process has been put in place with the regions. This enables us to track progress for internal assurance through our governance structure and to meet a need to report progress twice yearly to the ORR.

The regional directors of Engineering and Asset Management are the owners of the plans and they are accountable to the ORR for their delivery.

Figure 4-5 – Key changes and improvements to our Route WRCCA Plans

Our Route WRCCA Plans analyse past weather impacts and likely future changes in extreme weather events. For past events, the Schedule 8 cost and the related delay minutes recorded are attributed to one of the categories in **Figure 1-3**. Having assessed the significance of the risks, and classified them, each plan then considers what annual performance impacts they might cause and identifies high risk locations within their route.

Preparing a plan for each route means we can account for the current weather and the projected climate conditions specific to each one, for example, changes to the climate in the Southern region will be very different to those for Scotland's Railway. This is important as these variations may require different approaches to managing the risks across our network such as different design standards and/or operational responses like alert levels or maintenance schedules. Periodically updating the plans means that we can review our performance against past plans and assess our adaptation progress. This enables us to continue to evolve our knowledge and approach to make positive progress.

Key actions to manage the risks, for which funding is available, are outlined and include activities such as:

- Programmes of drainage renewal and refurbishment to reduce the risk of flooding
- Slope stabilisation and renewal of earthworks to reduce the risk of landslips
- Investment to reduce the risk of bridge scour
- Coastal, estuarine and river defence improvements
- Enhanced maintenance of vulnerable track locations and overhead line equipment (OLE) systems to combat high temperature impacts
- Vegetation management plans to mitigate wind impacts
- Funding of research to better understand the weather impact risks and prevention
- Installation of remote condition monitoring (RCM) to improve proactive asset management and operational responses

Regular monitoring of action delivery in the plans enables us to track and report our regions' progress on current and future weather resilience and is used in updating our corporate risk register. Individual regions track their progress against the route plans appropriately. Progress updates are provided twice a year to the TA and via them to the Executive Leadership team and the ORR.

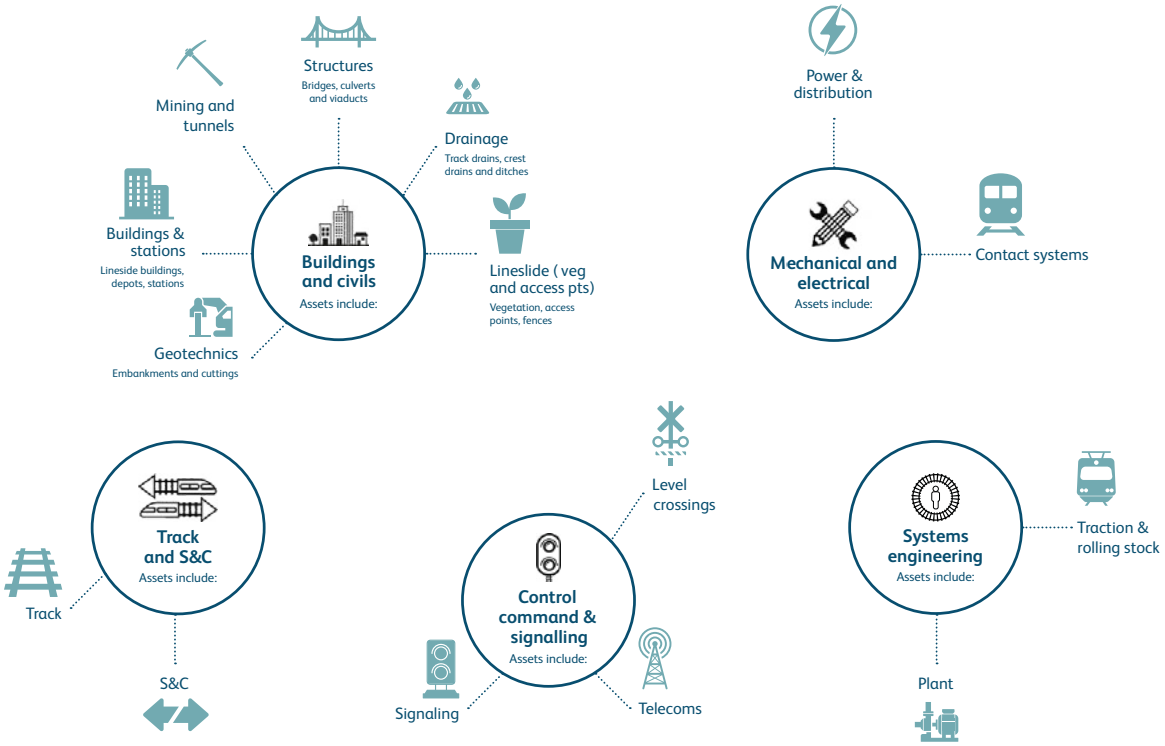
Details of the key risks identified in these plans, the CP6 actions planned to address them and our progress against the CP5 and CP6 Route WRCCA Plan actions can be found in **Sections 7 and 8** of this report.

4.3.2. Network Rail Asset Management Weather Resilience and Climate Change Adaptation Plan

Throughout 2019/20 the TA's chief engineer's team and the WRCCA team have developed a climate change risk assessment and action plan for our assets.

The work covered all of the asset types managed within our five core asset groupings (see **Figure 4-6**) and used our climate change guidance notes to assesses the current weather risk and the future risk for the 2050's and the 2080's under our primary climate change planning scenario (RCP6.0 90 %).

Figure 4-6 – Core asset groups and functions



The risk assessment results were used to identify knowledge gaps and formulate actions for each asset type collated into an action plan for the TA chief engineer's teams which includes activities such as:

- Updating all asset function policies to reflect the need to manage climate change risks through justification and prioritisation of available funding
- Identifying critical standards and specifications which require update to incorporate climate change, as appropriate, in line with Network Rail climate change guidance notes
- Reviewing the effect of adverse and extreme weather on assets including adjacent or dependant asset classes and developing common strategies for management
- Evaluating and improving asset inventory and condition knowledge and monitoring
- Developing whole life cycle models to include weather and climate change in asset sustainability models to measure degradation
- Reviewing the existing drainage strategy to develop a catchment-based water management strategy considering current and future flood risks
- Cyclical review and update of the risk assessment and plan, for example completion of a risk assessment and plan for the telecommunications function which has recently joined the chief engineer's team
- Monitoring and reporting of progress against the actions in the plan

The actions broadly fall into the following 4 categories.

- **Management** – review of the risk assessment process and plan and progress reporting
- **Strategy** – reviewing policies, strategies and processes and updating them to require WRCCA consideration in their implementation
- **Standards** – reviewing and updating standards and technical specifications as necessary to embed climate resilience in the design, construction, maintenance and operation of assets
- **Interdependencies** – identifying interactions between the assets and the development of an integrated planning process using a system-based approach
- **Research** – filling knowledge gaps which are preventing adaptation action and/or to identify more resilient technologies, working practices etc.

In October 2021, we published the Network Rail **Asset Management WRCCA Plan report** which summarised the results of the risk assessment and the subsequent action plan. The intention is for this work to form the foundation of detailed climate change adaptation strategies for each asset function which are to be developed in collaboration with regions through the ALTs over the next few years.

Full detail of the risk assessment and action plan can be found in the appendices that have been published with the Asset Management WRCCA Plan report on our website **here**. In addition, **Section 7** of this report includes discussion of selected key risks and **Appendix A** contains our full Integrated ARP3 Climate Risk Assessment.

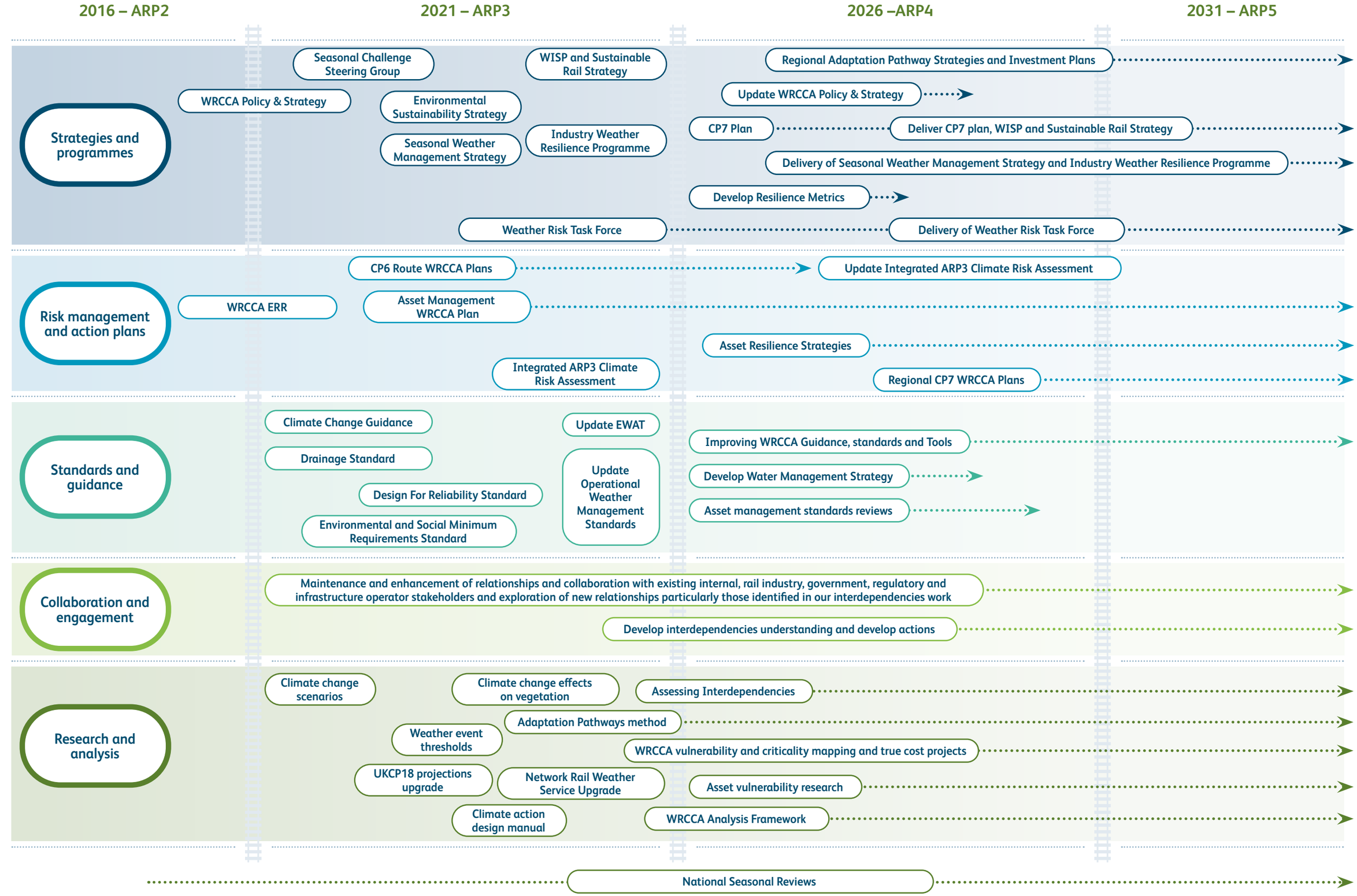
Delivery of these actions will be core to embedding weather and climate resilience into the asset functions, policies, standards and processes and enabling the delivery of adaptation by the regions. The risk assessment and action plan are owned by the chief engineer who will be responsible for delivery and the monitoring of progress. As with the Route WRCCA Plans progress updates will be provided twice a year to the TA WRCCA team and via them to the Executive Leadership team and the ORR.

4.4 Actions speak louder than words

In setting our visions, strategies, priorities and ambitions we understand that actions speak louder than words. Over time, delivering meaningful action will help us continue to demonstrate that our strategy and governance on climate resilience and adaptation is being implemented effectively.

Our work over the last five years has seen us make significant steps in improving our adaptive capacity and has seen investment in resilience. The next five years will continue this progress with greater integration into our asset management processes across our regions enabling further adaptation investment. A summary of these activities is illustrated in **Figure 4-7** and further detail can be found in **Section 8**.

Figure 4-7 – Key Adaptation Actions in Since ARP2



4.5 How robust is our approach?

Our approach to managing climate change is broadly aligned with the international standard for adaptation (ISO14090) and our comprehensive risk management and governance structure ensures that issues are considered at the highest levels within the organisation.

The CCC has recognised our adaptation planning as well advanced in their **2021 Progress Report**. Whilst we believe this to be true, our key challenge will be implementing these plans and improving resilience 'on the ground'.

The ORR commissioned an independent review of our CP6 route plans which found that:

'There are many strengths to the current WRCCA plans, and they should be considered an example of good practice, globally. Network Rail demonstrates a relatively high maturity in climate resilient planning in comparison to other rail operators internationally, and other sectors. The WRCCA plans are consistent in their approach across the different route regions and provide an evidence-based understanding of current risk to operational performance'[7].

This gives us confidence that we are taking the right path towards delivering appropriate adaptation, but we continue to monitor and review activity to ensure our approach is robust. Specifically, we:

- Have senior leadership support for our strategy and roadmap
- Liaise with our regulators to ensure they are aware of and endorse our approach
- Access best practice and current information from key stakeholders and academics
- Seek to develop metrics and targets to measure and direct our adaptation action
- Take a 'plan-do-check-act' risk assessment approach and report progress to stakeholders
- Invest in tools, resources and systems to improve our knowledge of and response to weather and climate risks
- Are working to better understand; the financial impacts of climate change, links to TCFD and stakeholder requirements and the development of the adaptation business case
- Recognise that the pace of change in climate science, industry understanding and stakeholder needs requires that we continually review and update our approach

We know that there is still a considerable volume of work to be done in our work to adopt and embed weather resilience and climate change activity as 'business as usual'. The following sections of this report describe some of the more detailed processes and methodologies we have (and will) adopt to ensure we become fully resilient and adaptable to changes in the climate.

[7] ORR Review of Network Rail's Weather Resilience and Climate Change Adaptation Plans July 2021 - **www.orr.gov.uk/media/22602**

4.6 Monitoring impacts and progress

The performance of our network, the service we deliver and the investment and operational activities we undertake to maintain these are monitored in a number of ways by our regulators and internally. This enables us to understand the effectiveness of our operational weather response, the delivery of our adaptation plans and the effectiveness of our actions in improving our service to passengers. The paragraphs below summarise our key activities in this area.

Public Performance Measure – The PPM is used to record and report the percentage of trains which have run their entire planned journey calling at all scheduled stations and arriving at their terminating station within 5 minutes (for London & South East and regional services) or 10 minutes (for long distance services) of their scheduled arrival time. On the 1st April 2019 new measures were added to report cancellations and the proportion of trains arriving at the scheduled stations within one minute of the timetable. We report this data to the ORR every 4 weeks.

Within this data set each entry is allocated to a cause category, one of which is extreme weather. This allows us to analyse and track the impacts of weather on performance as illustrated in **Figure 1-8**.

Delay minutes and Schedule 8 compensation payments – As outlined in **Section 1.1.1** we have data going back to 2006/07 which has been analysed to help us understand the weather-related impacts on the performance of our network. It allows analysis of the trends in performance and the annual variability from a national to an asset location scale and is used to inform our weather and climate change risk and cost modelling activities.

Our Environmental Sustainability and WRCCA Strategies – These set out our goals and milestones for climate change adaptation as outlined in **Section 4.2**. Delivery progress is monitored by our Board through regular reports to our Environmental Sustainability Committee.

Route and Asset Management WRCCA Plan Actions – Delivery of these action plans (see **Sections 4.3** and **8**) is core to our adaptation success. The regions report their Route WRCCA Plan progress to the TA WRCCA team every six months, with a summary of the findings being reported to the ORR. The target is for 80 % of actions to be completed on time. A parallel mechanism is being set up for the Asset Management WRCCA Plan.

Operational weather performance – The National Weather team in our System Operator is currently undertaking a programme of research and analysis to develop a series of metrics and leading indicators designed to better monitor how our service levels respond to weather. These will be used to track the effectiveness of our operational responses and investments in resilience.

Climate change resilience metrics – At the time of writing, we are working on development of leading resilience metrics to help us better understand and manage our assets. Two strands of work are underway with:

- Internal analysis of asset condition and weather-related failure data looking to develop a Network Rail specific metric for resilience
- Engagement with our regulators, the rail industry, the transport sector and the wider infrastructure operators to identify and develop climate change specific metrics across sectors to support comparison of risk and resilience

5.1 Our risk assessment process

Safety, health, performance, wellbeing, sustainable development and climate risks are a very present and ongoing reality for all our work across the short, medium and long-term.

Our approach to managing these risks is to deploy both strategic and project-level management to:

- Provide safety assurance for our passengers, workforce and members of the public that may be affected by our work
- Garner all the information we need to take risk-based decisions
- Create systems that ensure we comply with the relevant rules and regulations

All enterprise risks in Network Rail are managed in accordance with the enterprise risk management standard and framework (based on HM Treasury's Orange Book management of risk guidance). This sets out how to identify, assess and manage our risks including defining corporate level risks such as the weather and climate change.

5.1.1. The corporate risk assessment matrix

In Network Rail we have a corporate risk assessment matrix (CRAM) (**Figure 5-1**) which is used as a standard risk assessment methodology and matrix for all risk assessments in our business.

CRAM assessments evaluate the likelihood of the risk occurring, and the impact if it occurs. The likelihood assessment must account for any previous instances of the risk occurring. By evaluating the historic event data in conjunction with current controls, an estimated likelihood can be determined. Impact is the effect of a risk occurring and is assessed using both financial criteria and nonfinancial criteria such as reputational, performance and safety impacts.

Use of one standardised CRAM allows for cross-functional comparison and prioritisation of risks.

Figure 5-1 – Our CRAM

Version 3.1 04 July 2019

Impact area	Subcategory	1	2	3	4	5
Safety/Health/ Environment	Safety	Event with the potential for less than 20 'any other injuries' or a single specified injury (less than 0.1 FWI).	Event with the potential of a single specified injury to 5 specified injuries (between 0.1 and 0.5 FWI).	Event with the potential of between 5 specified injuries and 2 fatalities (between 0.5 and 2 FWI).	Event with the potential of between 2 and 10 fatalities (between 2 and 10 FWI).	Event with the potential of over 10 fatalities (greater than 10 FWI).
	Health	An event causing health effects which could potentially require short-term modifications and adjustments or redeployment e.g. workrelated stress.	An event causing health effects which could potentially require long term modifications and adjustments or redeployment e.g. HAVS.	An event causing health effects leading to a potential of between 1 and 2 fatalities e.g. silica and asbestos or an event which results in permanent incapacity to work e.g. severe HAVS.	An event causing health effects leading to a potential of between 2 and 10 fatalities e.g. silica and asbestos.	An event causing health effects leading to a potential of over 10 fatalities e.g. silica andasbestos.
	Environment	A temporary but reversible event which causes negligible impact to an on-site area of low environmental value, managed immediately by internal control procedures.	Minor reversible short-term (<1 month) event which impacts the local environment (i.e. onsite and beyond site boundary).	Moderate reversible medium-term event (< 6 months) which causes impact to the wider environment (i.e. up to district area), requiring mitigation or restoration works.	Major reversible impact to the environment where longer term remediation is required (> 6 months), or irreversible impact to small numbers of animals or small areas of habitat of environmental significance.	Major, permanent (or very long-term > 5 years) and irreversible environmental damage and/or destruction of nationally or internationally important sites or legally protected species.
	Energy & Carbon	No increase in operational energy use and greenhouse gas emissions.	Slight increase (<5 %) in operational energy use and greenhouse gas emissions.	Moderate increase (5-10 %) in operational energy use and greenhouse gas emissions.	Significant increase (10-20 %) in operational energy use and greenhouse gas emissions.	Very significant increase (>20 %) in operational energy use and greenhouse gas emissions.
Performance	Network Disruption	Un-planned passenger or freight disruption for up to a day on any one route.	Unplanned passenger or freight disruption (for >1 day and <3 days) on any one route.	Unplanned passenger or freight disruption (>3 days and <1 week) on any one route or up to a day on multiple routes.	Unplanned passenger or freight disruption for over a week on multiple routes and limited access to station facilities.	All passenger or freight users experience prolonged and unplanned disruption to key routes. Access to major station facilities likely to be severely restricted.
	Service Delivery	Poor performance or non-performance of noncritical activities with negligible /very minor customer disruption.	Poor performance or non-performance of noncritical activities causing moderate customer disruption as a result which may continue intermittently for up to 1 week.	Poor performance or non-performance of some critical activities with moderate customer disruption to one or more customers for up to 1 week.	Poor performance or non-performance of some critical activities leading to significant disruption to one or more customers, impacting critical service provision for up to 1 week.	Poor performance or non-performance of many critical activities leading to prolonged major disruption to multiple customers severely impacting critical service provision.
	Asset Reliability	<2 % of asset reliability CP6 targets missed (including Composite Reliability Index (CRI) and Service Affecting Failures (SAF) or <2 % decline from previous year's performance.	2-5 % of asset reliability CP6 targets missed (including Composite Reliability Index (CRI) and Service Affecting Failures (SAF) or 2-5 % decline from previous year's performance.	5-10 % of asset reliability CP6 targets missed (including Composite Reliability Index (CRI) and Service Affecting Failures (SAF) or 5-10 % decline from previous year's performance.	10-15 % of asset reliability CP6 targets missed including Composite Reliability Index (CRI) and Service Affecting Failures (SAF), or 10-15 % decline from previous year's performance.	>15 % of asset reliability CP6 targets missed (including Composite Reliability Index (CRI) and Service Affecting Failures (SAF) or >15 % decline from previous year's performance.
Finance	(£)	£0 – £2m.	£2 – 10m.	£10 – 50m.	£50 – 250m.	Over £250m.
	Budget	Less than 3 % of allocated budget.	Between 3 % - 5 % of allocated budget.	Between 5 % and 7 % of allocated budget.	Between 7 % and 10 % of allocated budget.	Greater than 10 % of allocated budget.
	Efficiency	Efficiency target 100 % deliverable.	Efficiency target >90 % deliverable.	Efficiency target 80-90 % deliverable.	Efficiency target 60-80 % deliverable.	Efficiency target <60 % deliverable.
	Asset Sustainability	<£25m renewals deferred.	£25-100m renewals deferred.	£100-500m renewals deferred.	£0.5-1.5b renewals deferred.	>£1.5b renewals deferred.
Satisfaction & Reputation	Media and Stakeholders	Short-term adverse local stakeholder reaction.	Adverse local media reports over a period. Localised stakeholder concern.	Significant local and / or regional reports including social media. National media interest creating public concern. Negative national stakeholder statements from both government departments, devolved governance bodies and/or TOC/FOCs.	Extensive prolonged adverse national reporting and public disputes with key stakeholders or devolved governance bodies.	Extensive and prolonged negative reporting nationally or public disputes with devolved governance bodies, key stakeholders, including political and/or TOC/FOCs. Escalation to external bodies inevitable & impossible to contain in medium term.
	Legal	Minor legal issues, non-compliance or breach of regulation. Legal challenge minor out of court settlement limited to parties involved and expected outcome known.	Breach of regulation with investigation or report to authority with prosecution and/ or moderate fine possible. Limited to parties involved but outcome uncertain.	Serious breach of regulation. Major litigation/ Class action/criminal prosecution/prohibition notice. Local profile and outcomes uncertain.	Significant prosecution and fines. Very serious litigation including class actions. National profile, impact on current/future business operations.	National profile, major impact on current and future business operation. Prosecution likely. Potential prison terms for executives and/ or high fines for organisation.Multiple litigations.
	Regulatory	No ORR action.	Risk scores 1 – 2 on the ORR regulatory escalator.	Risk scores a 3 on the ORR regulatory escalator.	Risk scores a 4 on the ORR regulatory escalator.	Risk scores 5 on the ORR regulatory escalator.
	Government			DfT / Transport Scotland / Transport for Wales interest.	DfT / Transport Scotland / Transport for Wales intervention.	Risk scores 5 on the ORR regulatory escalator.
	Internal	Short-term loss of morale with poor performance of non-critical activities.	Minor disengagement. Effectiveness/Efficiency compromised with service Failures in non-critical activities.	Some disengagement leading to effectiveness/efficiency compromised in some critical activities.	A major downturn in company-wide engagement leading to service failures within some critical activities.	A significant downturn in companywide engagement. Serious failings across most services. Potential for significant changes imposed on NR, its responsibilities and structure.
		1	**2**	**3**	**4**	**5**
Likelihood Criteria		<5 % Very Low likelihood the risk will occur. Risk would occur less than once in 25 years.	5 – 20 % Low likelihood the risk will occur. Risk would occur between once in 25 years or up to once in 5 years.	21 – 50 % Medium likelihood the risk will occur. Risk would occur between once in 5 years to just less than once a year.	51 – 75 % High likelihood the risk will occur. Risk would occur between 1 and 5 times a year.	>75 % Very High likelihood the risk will occur. Risk would occur 5 times a year or more.

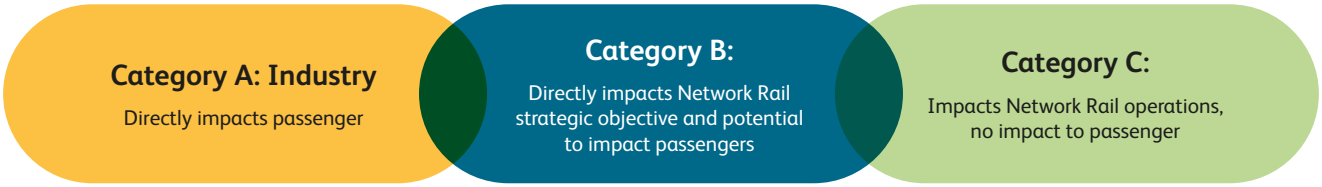
5.1.2. Enterprise risk records

The CRAM is used to assess the impact and likelihood of enterprise wide risks with the results being graded as Level 0, 1 and 2. **Table 5.1** shows the three different categories of risk impact, with the decision being aided by using 'enterprise risk categories' as shown in **Figure 5-2**.

Table 5-2 – Criteria for assessing level of enterprise risks

Level	Definition
0	• Risk requires cross-directorate intervention to be appropriately controlled i.e. via our TA and route management businesses • Requires board of director involvement, support and sign-off on the management approach to a risk and its potential impacts and effects
1	• Risks can be appropriately managed and controlled through the operational heads of a single directorate i.e. route services • Requires awareness from the executive of a directorate, and involvement, support and sign-off on the management approach to a risk and its potential impacts and effects
3	• Risk is directly concerned with the achievement of a business operations' strategic objective • Risk has the potential to impact the achievement of our corporate strategic objectives

Figure 5-3 – Enterprise risk categories



Network Rail's business assurance committees provide the risk governance, determine where new ERRs need to be created and set the levels at which risks are reported. For each risk assessed an ERR is created and the risk grading is used to define the level within our management structure at which the risk is managed. Level 0 is the most serious risk to achieving our strategic objectives, typically with cross-industry impacts and management needs. These high-profile risks are visible at level 0 (Executive Leadership team) and are subject to audit and risk committee (ARC) and safety, health and environmental compliance (SHEC) review, subsidiary committees on behalf of the Board.

Each ERR considers the causes and consequences of the risk and records controls to manage these. This is used to generate an overall current risk rating which is compared to the desired risk rating (driven by our stated risk appetite). Where the risk ratings deviate actions, with owners, are specified for each relevant risk to move the current risk to the desired level on an appropriate trajectory (based on agreed target dates). Leading indicators are established to flag if the possibility of the risk exposure or the likelihood of the risk occurring are changing and whether preventative actions may be necessary. Examples include adding or amending controls. ERR's are reviewed regularly with the appropriate stakeholders and progress is tracked by quarterly business assurance committees, which operate at different levels throughout our business.

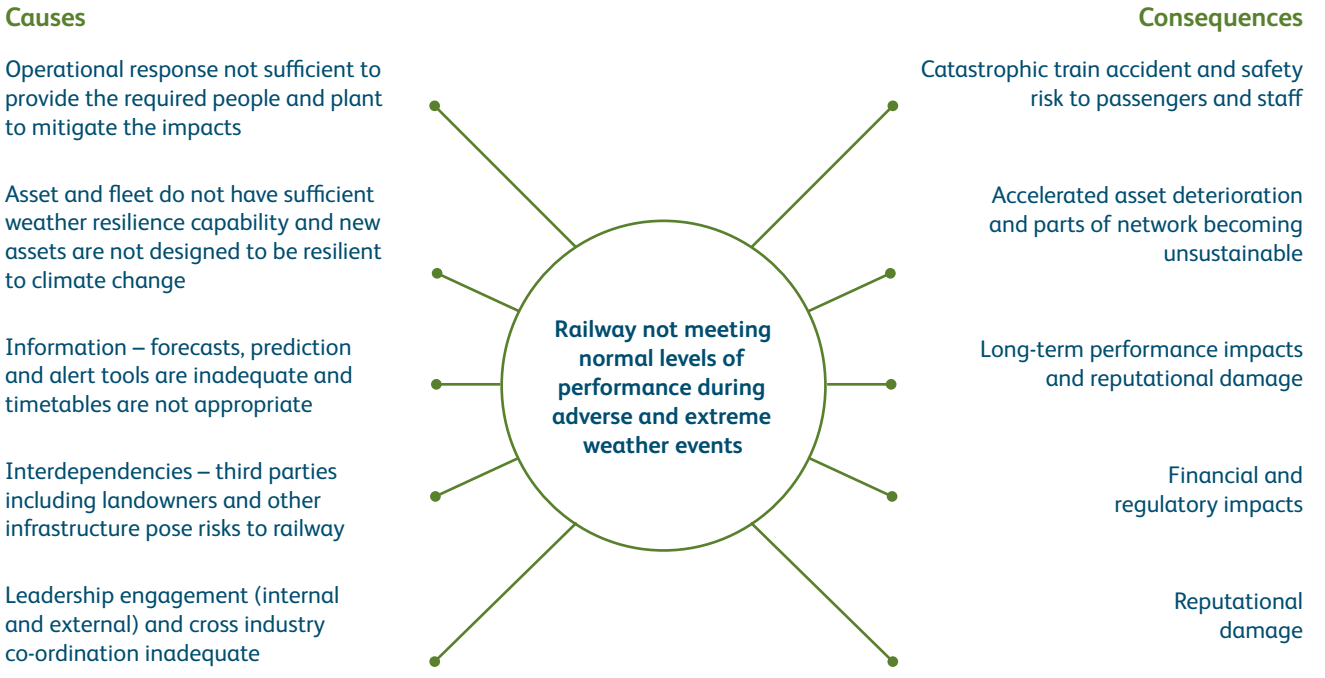
5.2 Our climate risk assessment process

To create a railway that is safe and resilient to the impacts of weather we have developed a weather and climate change risk ERR which is used to control the threat of 'the railway not meeting normal levels of performance during adverse and extreme weather events, today and in the future as a result of climate change'. The risk is given Level 0, Category A' status meaning that is reviewed by the Level 0 business assurance committee as well as by the ARC as part of the overall Network Rail risk profile update every quarter. It is also reviewed annually as part of a deep dive audit at Board level through the ARC.

Our ERR works hard for us being used to assess the implications of weather and climate change, for the safety and performance of our system (network and disruption), the welfare of our workforce and passengers and the environmental, financial, political and reputational implications of these. It also identifies and tracks the effectiveness of controls that are, or should be, in place to manage these risks. The actions and deadlines to implement, improve or create controls form a core part of our strategies and policies detailed throughout this report.

Some of the main causes of climate risk in the ERR relate to our ability to prepare for change, the level of asset and fleet resilience, and the extent to which our information (e.g. weather warnings) is available. Key consequences of severe weather and climate change include the acceleration of asset deterioration and changes in failure rates with the workforce and passenger safety, performance and financial risks that these bring. Other important consequences are the potential for catastrophic incidents on the network and challenges to our financial security. As summarised in **Figure 5-3**.

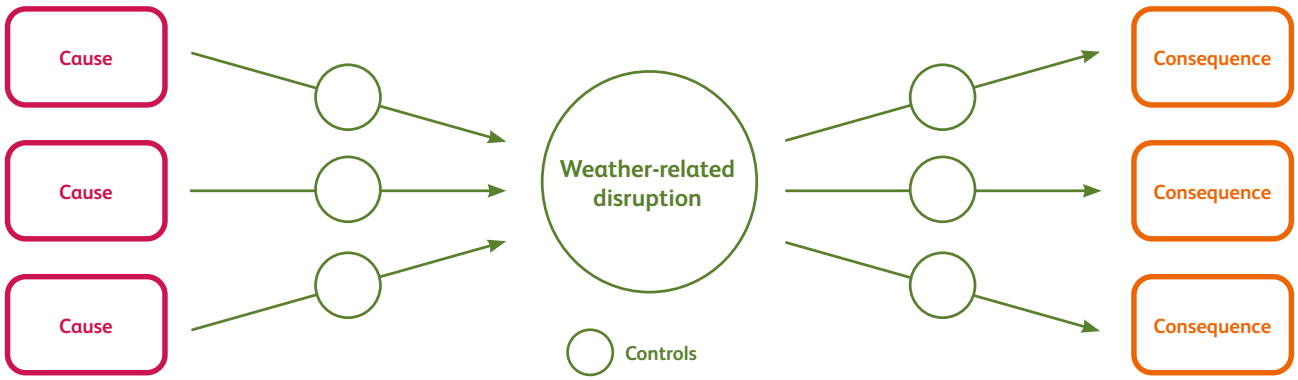
Figure 5-3 – Key causes and consequences of climate change impacts on Network Rail



The strategic risks identified in the ERR represent issues that cross various business units and are made up of a variety of other risks managed at L1 and L2 based on the criteria in **Table 5.1**. An example would be a drainage system not having the capacity to deal with an extreme rainfall event leading to various consequences such as increased asset deterioration, service disruptions and safety implications.

Management of risk at these levels within business units uses 'bow-tie' assessments (**Figure 5-4**) as mentioned in our ARP2 report and **Section 2** above. They allow us to establish a detailed understanding the adequacy of the controls that are in place to manage the causes and consequences of a severe event and enable us to identify areas which need new/additional controls or where there are things that need improving.

Figure 5-4 – Bow-tie risk assessment



5.3 The national climate change risk assessment influence on our ARP

The CCC recently published its Advice to Government for the UK's third Climate Change Risk Assessment. This includes two key data sources for us to use in the ongoing development of our risk assessments and action plans.

- A technical report summarising the latest climate change understanding, the climate change risk assessment method and the level of climate risk or opportunity across the natural environment, infrastructure, people, human health, built environment, business and international dimensions
- Summaries for each sector of the UK economy detailing how their risks have been assessed in the technical report, highlighting the key climate change risks that they face and indicating what types of action would be beneficial over the next 5 years

Network Rail engaged with the CCC in the creation of their reports by providing information and data and participating in cross sector workshops and projects such as the one on 'interacting risks'. We have used the findings from both the technical report and a combination of the Transport Sector Briefing and other relevant sector briefings such as the Flooding and Coastal Change Briefing to inform our approach to climate change risk assessment and adaptation.

We have sought to align the risks that we have identified in this report with the key infrastructure risks listed in the technical report. This will enable us to better align our work with national activity on adaptation and track our contribution to reducing the country's climate risks. We have chosen to use this wider range of risks rather than just those in the Transport Sector Briefing to reflect our wide range of assets and their interdependencies with the other sectors of the economy (See **Table 5-2**). Further detail on our interdependencies work is in **Section 6**.

Table 5-2 – Infrastructure sector risks and relevance to this report

Infrastructure risk	Relevance to ARP3
I1. Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures	Interdependencies are in **Section 6**, direct impacts on us are throughout **Section 7**. For example, flooding is in **Section 7.2**
I2. Risks to infrastructure services from river, surface water and groundwater flooding	Interdependencies are in **Section 6**, risk to our operations are in **Section 7.2**
I3. Risks to infrastructure services from coastal flooding and erosion	
I4. Risks to bridges and pipelines from flooding and erosion	Interdependencies are in **Section 6**, risks to our operations are in **Sections 7.2** and **7.3**
I5. Risks to transport networks from slope and embankment failure	
I6. Risks to hydroelectric generation from low or high river flows	Interdependencies are in **Section 6**
I7. Risks to subterranean and surface infrastructure from subsidence	Interdependencies are in **Section 6**, risks to our operations are in **Sections 7.2** and **7.3**
I8. Risks to public water supplies from reduced water availability	Interdependencies are in **Section 6**
I9. Risks to energy generation from reduced water availability	
I10. Risks to energy from high and low temperatures, high winds and lightning	
I11. Risks to offshore infrastructure from storms and high waves	
I12. Risks to transport from high and low temperatures, high winds, lightning	Interdependencies are in **Section 6**, risks to our operations are in **Sections 7.4** and **7.5**
I13. Risks to digital from high and low temperatures, high winds and lightning	Interdependencies are in **Section 6**

5.4 How have we assessed climate risk for ARP3?

Over the last five years we have worked hard to improve our understanding of the range, frequency and severity of the risks that the current weather and the projected climate changes pose across our business.

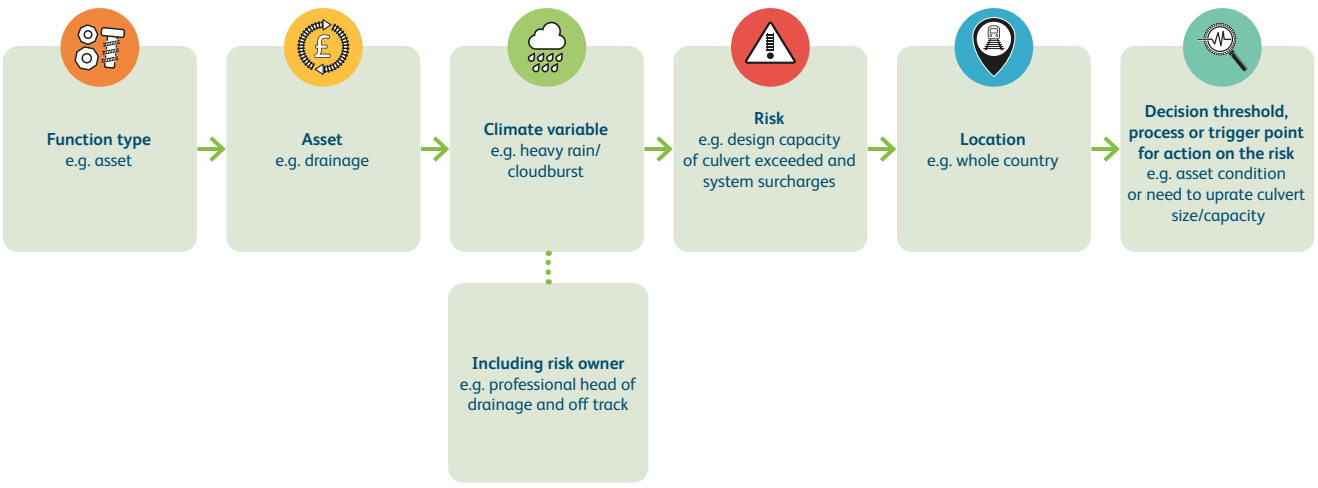
Central to this have been the risk assessments carried out by the routes in 2018/19 and the chief engineer's asset function teams in 2019/20 for their WRCCA plans. These were carried out by the appropriate individuals from across the teams and levels of the business reflecting the extent to which they have taken on responsibility for this subject. The outcomes and the WRCCA plans that they informed have provided us with robust information and data for use in our management of our climate risks and opportunities across the many facets of our organisation.

As the two risk assessments and action plans were generated over a year apart, with our learning from creating the Route WRCCA Plans informing the work on the Asset Management WRCCA Plan, the level of detail and knowledge used in them differs. Also, whilst the more recent assessment for the Asset Management WRCCA Plan was aligned with the Defra Transport Sector ARP3 risk assessment template for this report, those done for the Route WRCCA Plans were not.

Creating this ARP3 report has been an opportunity to harmonise the risk assessment methods and results bringing them together in an integrated asset risk assessment based on the Defra template. The paragraphs below outline how we created the **Asset Management WRCCA Plan** assessment and the steps taken to convert and integrate the Route WRCCA Plan risk assessment results.

For the Asset Management WRCCA Plan assessment each asset function used the categories and process in **Figure 5-5** to characterise the asset being assessed, the nature and level of its vulnerability and risk in the context of its location and, evidence of past events. They were also asked to indicate what thresholds or triggers would need to be exceeded for adaptation action to be required. Each risk was assigned a code based on its asset type (e.g., TRA1 for track risk one), an owner based on its asset function (e.g., professional head of geotechnical) and attributed to the appropriate infrastructure risk from the CCC's technical report (**Table 5.2**).

Figure 5-5 – Defining the assets within the risk assessment



The scoring of the risks used the CRAM shown in **Figure 5-1**, **Section 5.1.1** and assumed that there would be no changes in the current asset management practices. Scores for each risk were calculated for all of the time periods in the risk assessment and were graded using our standard business wide method and matrix (**Figure 5-6**). This has allowed us to identify those risks that we should prioritise for adaptation action. The highest priority has been given to those risks with a current grading of 'moderate' and those with a future grading in 2050 of 'major' or 'severe'. These risks will be discussed further in **Section 7**.

Table 5-6 – Risk scoring matrix used for ARP3

Horizons: now, 2050, 2080		Impact				
		Minimal	Minor	Moderate	Major	Catastrophic
Likelihood	Almost certain	5/moderate	10/major	15/major	20/severe	25/severe
	Likely	4/moderate	8/moderate	12/major	16/major	20/severe
	Possible	3/minor	6/moderate	9/moderate	12/major	15/major
	Unlikely	2/minor	4/moderate	6/moderate	8/moderate	10/major
	Highly unlikely	1/minor	2/minor	3/minor	4/moderate	5/moderate

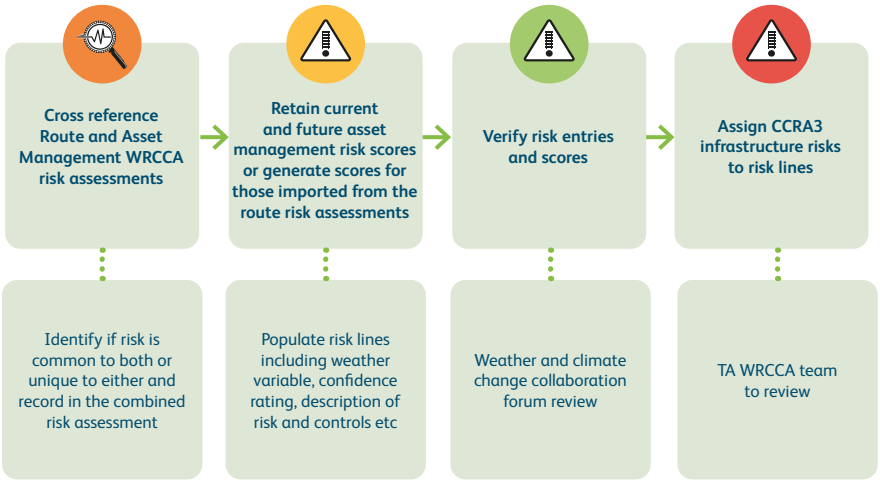
The next step was the conversion of the Route WRCCA Plan risk assessments from the narratively described risks in the text of their reports into scored risk lines. This used the same process as outlined for the Asset Management WRCCA Plan in combination with a tailored version of the standard CRAM (see **Figure 5-7**) to ensure that the outputs of both risk assessments were aligned in a common format.

Table 5-7 – Modified CRAM used in the chief engineer's risk assessment

		1 - Minimal	2 - Minor	3 - Moderate	4 - Major	5 - Catastrophic
Impact	**Safety/ Environment**	Minor Safety event with the potential to cause up to 20 minor injuries or a single major injury and with environmental incidents that can be addressed using existing control measures	Significant Safety event with the potential of a single major injury to five major injuries with adverse environmental impact within a Control Period that can be mitigated using existing control measures	Significant safety event with the potential of between five major injuries and two fatalities, with significant environmental impact that results in Regulatory intervention and it exceeds existing control measures	Catastrophic Safety event with the potential of between two and 10 fatalities, with major environmental impact resulting in Regulatory fines and current control measures are not suitable	Catastrophic Safety event with the potential of over 10 fatalities, with catastrophic long term environmental damage
	Performance	Planned disruption for up to a day on any one route	Unplanned disruption for up to a day on any one route	Unplanned disruption (for up to a week) on any one route or multiple routes	Unplanned disruption for over a week on multiple routes	Prolonged and unplanned severe disruption to key routes resulting in adverse media attention and protests/lobbying resulting in a review of Network licence condition
	Finance	Costs to resolve issue - up to £2m per annum	Costs to resolve issue - £2m to £25m per annum	Costs to resolve issue - £25m - £75m per annum	Costs to resolve issue - £75m to £250m per annum	Costs to resolve issue in excess of £250m per annum
		1 - Highly Unlikely	**2 - Unlikely**	**3 - Possible**	**4 - Likely**	**5 - Almost certain**
Likelihood	**Criteria**	No known event or if known extremely rare	Low likelihood the risk will occur and current mitigations provide effective risk control	Medium likelihood with risks resolved using current controls. Further control improvements underway or actively being developed to mitigate	High likelihood the risk will occur with current controls ineffective leaving problem unresolved for a long period. No effective mitigations currently identified and control weakness known and unmanaged	Very High likelihood the risk will occur and there are no effective controls or mitigations to prevent the event

The work was co-ordinated by the TA WRCCA team in consultation with the chief engineer's asset function heads and the region WRCCA leads (the authors of the Route WRCCA Plans). The consultation was managed through the weather and climate change collaboration forum using the process in **Figure 5-8**. Further detail on the results can be found in **Section 7** and **Appendix A**.

Figure 5-8 – Modified CRAM used in the chief engineer's risk assessment



The benefits of completing this work have been:

- The creation of a single risk assessment for all our asset-based risks across our business harmonised for this report
- Cross referencing of the two assessments to identify discrepancies and duplications
- Enabling the two business units to 'sense check' and approve the results and the process
- Driving more detail into the route risk assessments

6

We cannot create a resilient railway in isolation from the wider world. Managing our risks and opportunities will need the engagement of, support from, and collaboration with, a considerable range of organisations that operate in and influence numerous UK sectors. Without this we will not be able to implement many aspects of our climate strategies and adaptation actions in the most efficient, appropriate or effective way.

There are multiple organisations who rely on us, who we rely on, and some with whom there is a 'co-dependency' in relation to our daily operations and our maintenance and asset management. These are our weather and climate interdependencies and as such they have a key role in helping us deal with cross-cutting risks and opportunities that we cannot manage as effectively alone.

As work with our interdependencies will cross sectors, the benefits will be felt beyond addressing our own risks through contributing towards addressing the range of infrastructure risks identified in the CCC's **Technical Report**, particularly cascading failures (Risk I1 – see **Table 5-2**). Case studies 1, 2 and 3 show examples of the critical importance of managing interdependent risks.

Case Study 1 – Water management

On the 12th of August 2020 large areas of Scotland saw severe thunderstorms with one near Lithgow dropping 80mm of rain over night[8], 40mm of which was in one hour[9].

This caused 30m of embankment on the Union Canal in Scotland to collapse. The escaping water flowed across fields downhill to our Edinburgh to Glasgow line and washed a significant section away, damaging the track, embankment and OLE.

The line, one of the busiest stretches of Scotland's Railway was closed for five and a half weeks causing serious disruption to our service and the lives of the customers depending on it. The final cost for the repairs necessary to get the line up and running again was £6.25 million.

This demonstrates that maintaining the resilience of our services is not just a case of us investing in our assets and incident responses. To adapt efficiently and effectively will require co-operation across sectors and a willingness from all parties to look beyond their boundaries for potential impacts and solutions.

Image source: Network Rail

[8] BBC (2020) Torrential rain and thunderstorms bring flooding and disruption [online] Available at: **https://www.bbc.co.uk/news/uk-scotland-53748192** Last accessed: 13/10/2021

[9] BBC (2020) Storm leaves 30m hole in Union Canal [online] Available at: **https://www.bbc.co.uk/news/uk-scotland-edinburgh-east-fife-53768273** Last accessed: 23/08/2021

Case Study 2 – Power dependency

A lightning-induced power cut on the 9th August 2019 impacted the grid electricity supply across large parts of England causing electric trains to stall and cutting power to stations.

While full power was restored relatively quickly a significant number of trains couldn't be automatically restarted, requiring engineers to travel to and manually restart them[10]. This left large numbers of passengers stranded on trains and at stations and disrupted the timetable for the rest of the day and into the weekend due to the back log of train movements.

This is a good demonstration of how our resilience is dependent on other systems, in this case the power supply dependency causing a cascade failure in the rolling stock exposing a second dependency on the designs used by the train and freight operating companies.

Case Study 3 – Interdependent systems

In December 2015 Storm Desmond brought between 150 and 200mm of rain onto already saturated ground in Lancashire and Cumbria[11]. The River Lune in Lancaster set a new record flow rate for an English river at the time and flooded the main city substation on Saturday the 5th.

Our OLE draws power from sources outside the flooding, so we could still run trains, but the station was closed at 4pm for safety due to a lack of lighting and there were impacts on our signalling systems and operational controls. Our ability to respond to these issues was reduced by the loss of power to the Vodafone centre which provides emergency mobile signal coverage. This shows how interdependent our own systems are in addition to external dependencies and how these interrelate.

Whilst we were able to operate a degree of service this was reduced by the signalling issues and closing the station early. Such reductions in service have wide economic and social impacts due to the impact on people's ability to travel, in this case magnified when there were also flooded roads, closed bridges and cancelled bus services.

[10] BBC (2019) Lightening strike 'partly to blame' for power cut [online] Available at: **https://www.bbc.co.uk/news/business-49402296** Last accessed: 23/08/2021

[11] Kemp, R. J. (2016). Living without electricity: one city's experience of coping with loss of power [online] Available at: **https://www.raeng.org.uk/publications/reports/living-without-electricity** Last accessed: 23/08/2021

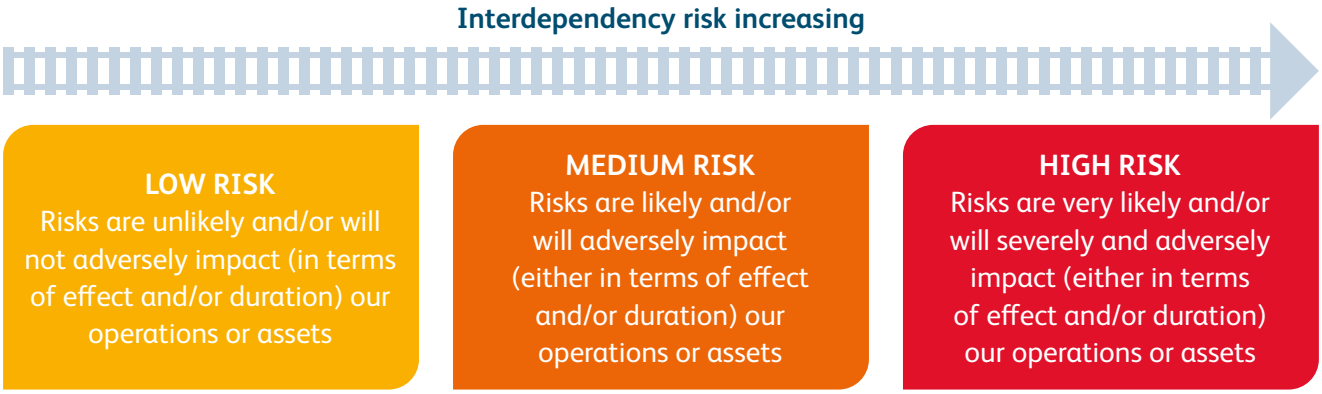
The IOAF regularly discusses the importance of interdependencies but we have yet to do a detailed assessment of what this means for the railway or draw up action plans to address the risks. In developing ARP3, we have done some high-level work to understand our interdependencies in more detail and the findings are presented below.

We consulted various business units, including the regions, TA and supply chain management and used our experiences from current and past engagement with infrastructure operators across the various sectors to:

- Draw up a list of our potential dependencies
- Identify the risks that we could pose to each other if our services were reduced or failed

We then developed an understanding of how these activities and processes relate to ours, enabling us to categorise these dependencies as: those who rely on us, those we rely on, and those with whom there is a 'co-dependency'. We also had a first pass at sorting each category into relative priorities based on the degree of impact that a service reduction or failure due to a weather event would have on either of us. This was done using the criteria shown in **Figure 6-1**.

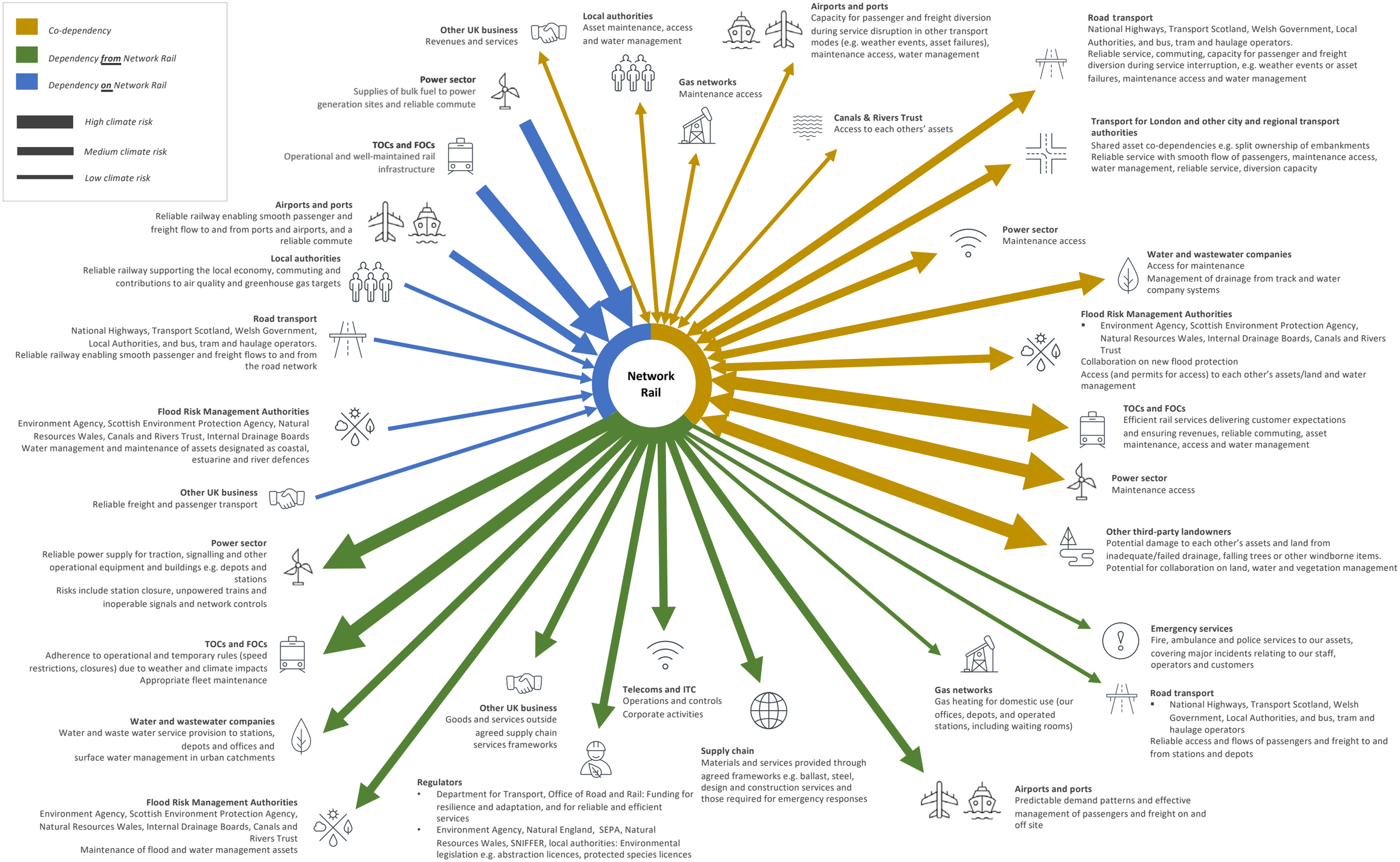
Figure 6-1 – Interdependencies screening assessment criteria



The results of our work are presented in simplified graphical form in **Figure 6-2**.

This represents the start of our interdependencies work and we recognise that we have a lot more to do to improve our understanding of the scale and nature of the interdependencies, to identify our priorities and what we need to do to address the risks. Our planned actions for achieving this are included in **Section 8.3**.

Figure 6-2 – Network Rail's climate interdependencies: the risks and opportunities



7

7.1 Choosing our key risks

The work on our integrated risk assessment has demonstrated that all of our assets, operations and services carry some degree of weather and future climate related risk. Whilst our full integrated risk assessment can be seen in Appendix A its scale means that it would not be practical or proportionate for this section to discuss the full range of risks it contains.

To help the users of this report understand which of our risks we will be addressing as our priorities we have chosen to discuss our 'key' risks based on their current and 2050s risk ratings. The following sections will address those with a current risk rating of 'moderate' and/or a future risk rating for the 2050s of 'major' or 'severe' (as scored using the matrix in **Figure 5-6**).

To help simplify the communication of the wide range of risks and to encourage the use consistent language and terms when discussing and acting on them we have categorised the risks into four key groupings as described in **Figure 7-1**.

Figure 7-1 – Key climate variable groups in our Integrated ARP3 Climate Risk Assessment

Precipitation

Precipitation is any liquid or frozen water that forms in the atmosphere and falls to the earth in the form of rain, freezing rain, sleet, snow, and hail.

Fluvial flooding occurs when the water level in a river, lake or stream rises and overflows onto the surrounding banks, shores, and neighbouring land. This can be as a result of excessive rain or snow melt. Precipitation, river levels and soil conditions can be used to determine the likelihood of river flooding.

Pluvial flooding occurs when surface water accumulates as result of intense rainfall that cannot be removed quickly enough by the drainage system or infiltrated by the ground. This type of flooding is associated with surface water floods and flash floods.

Climate variables assessed: • Snow Ice/Hail • Snow/ice • Heavy snow • Long wet winter/spring • Heavy rain/cloudburst • Light rain/drizzle • Intense rainfall • Low average rainfall • High soil moisture • Low soil moisture • Fluvial (river) flooding • Pluvial (surface water) flooding

Sea level rise and coastal erosion and flooding

Coastal erosion and **flooding** are hazards that, when combined with vulnerable coasts and assets, represent sources of coastal risk.

Changes in the coast (such as erosion) modify the flood hazard: future flood risk depends on changing shoreline position, and the simultaneous occurrence of erosion-flooding events.

Common causes of coastal flooding are intense wind storm events occurring at the same time as high tide (**storm surge**).

Climate variables assessed: • Sea level rise • Coastal erosion • Coastal flooding (storm surge)

Temperature

Extreme cold is temperatures that are lower than normal, with near freezing temperatures that are often associated with ice and frost.

Extreme heat is defined as temperatures that are much hotter and/or more humid than average.

A **heatwave** is an extended period of hot weather relative to the expected conditions of the area at that time of year, which may be accompanied by high humidity. A UK heatwave threshold is met when a location records a period of at least three consecutive days with daily maximum temperatures meeting or exceeding the heatwave temperature threshold. This threshold varies by UK county ranging from 25 to 28°C. Heat can exacerbate **drought** and **hot dry** conditions which can in turn result in wildfires and urban heat islands, posing a threat to people, ecosystems and the economy.

Diurnal temperature range is defined by the difference between the maximum and minimum temperatures within one day, this is modified by the season and geographical location.

Sun glare occurs throughout the year, during winter months it can be particularly noticeable because the sun is low in the sky, meaning the chances of being dazzled by direct sunlight is more likely.

Climate variables assessed: • Extreme cold temperatures • Extreme hot days • Heat wave • Higher average temperature • Large diurnal temperature range • Long hot dry summer • Sunglare

Storm and wind events

Although **high winds** and **storms** can relate to coastal risks, these variables can also take place in areas not situated along the coastline.

Thunderstorms form when warm moist air rises into colder air, creating an unstable atmosphere.

All thunderstorms produce **lightning** – which is a giant spark of electricity in the atmosphere between clouds, the air, or the ground.

Wind storms that are strong enough to cause damage to trees, buildings and infrastructure are not necessarily accompanied by precipitation. They can last anywhere between a few minutes to hours or days when they result from large scale weather systems.

Climate variables assessed: • Lightning • High winds • Storms • Storms/high winds

7.2 Precipitation

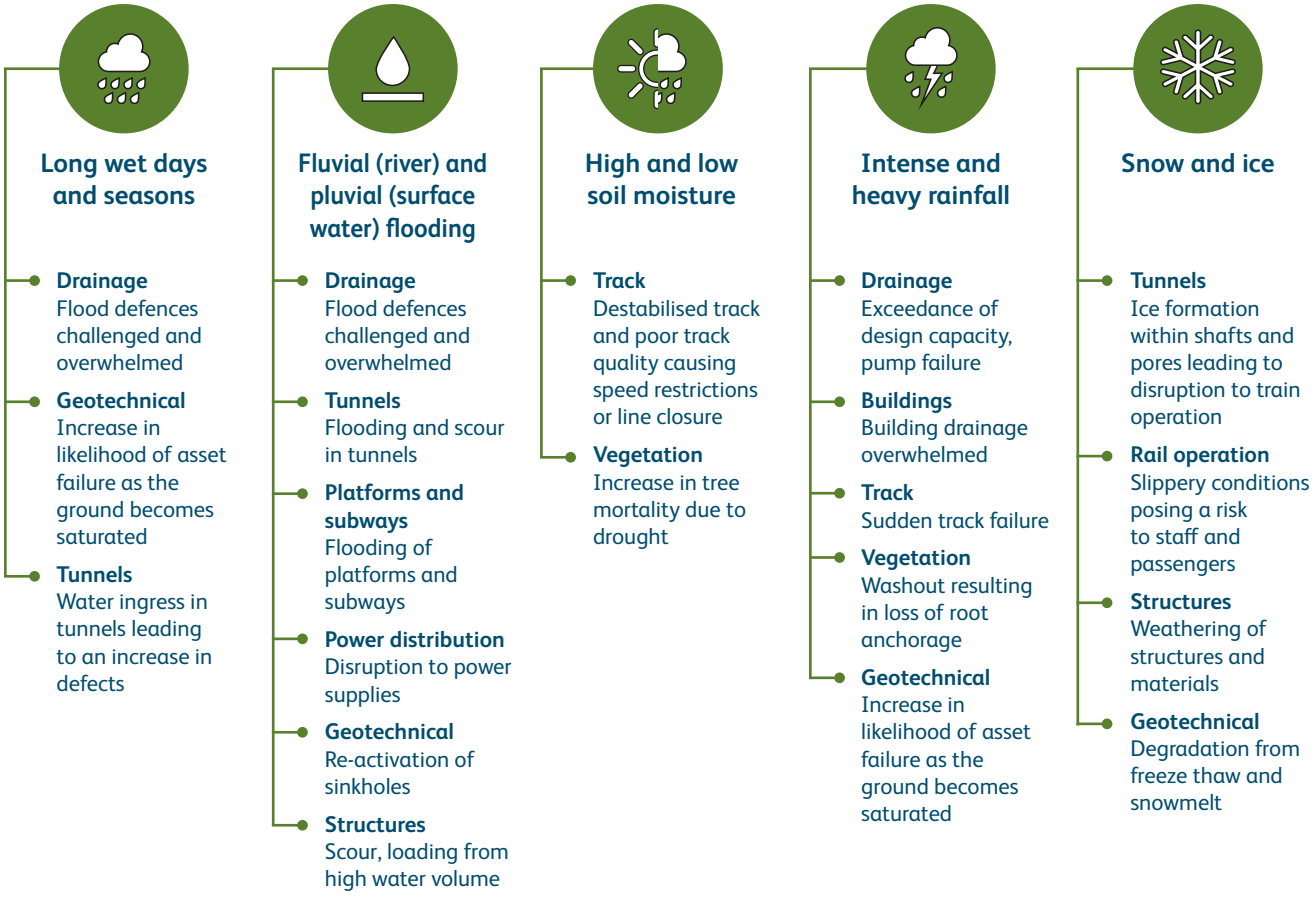
As demonstrated by Figure 1-4 the impacts associated with too much or too little precipitation are already three of the most costly weather-related impacts on our services. From 2016 to 2021 flooding, snow and subsidence events caused just under 3.7 million minutes of delay costing us £209 million in Schedule 8 compensation payments. Flooding alone accounted for over a third of all-weather related Schedule 8 costs in 2020/21[12]. Additional costs are accumulated from the operational responses necessary to cope with and recover from the events along with investing in any repairs that are necessary.

Such incidents also pose safety and wellbeing risk to the people using and running the railway. Rain and snow can increase the risk of slips and falls, earthworks failures have the potential to damage other railway assets and derail trains and disruptions to services can increase stress of passengers and staff alike.

With the exception of snowfall, which is expected to decrease in frequency, potentially reducing our winter risk (although current winters may still be possible) we are planning for increased impacts from winter rainfall and summer storm and drought risk as their frequency and intensity rise.

Figure 7-2 illustrates our key precipitation risks and **Table 7-1** shows the expected risk trajectories and the linked CCC infrastructure sector risks from **Section 5.3**. The sections below explore the current and future impacts of these risks on the relevant assets.

Figure 7-2 – Key precipitation risks to our network



[12] It should be noted that whilst the flooding impacts of sea level rise are dealt with in **Section 7.3** the data above is for all flooding as this cannot be separated out at this time

Table 7-1 – Key precipitation risks and scores

Climate variable	Risk	Score			Infrastructure sector risk
		Current	2050s	2080s	
Long wet days and seasons	Flood defences challenged and overwhelmed	12/major	12/major	16/major	I2
	Increase in likelihood of asset failure as the ground becomes saturated	12/major	25/severe	25/severe	I2, I3, I5, I7
	Water ingress in tunnels leading to an increase in defects	12/major	16/major	20/severe	I2
Fluvial (river) and pluvial (surface water) flooding	Flood defences challenged and overwhelmed	12/major	12/major	16/major	I2
	Scour, loading from high water volume	9/moderate	9/moderate	12/major	I2, I4
	Flooding and scour in tunnels	9/moderate	12/major	16/major	I2
	Re-activation of sinkholes	8/moderate	12/major	12/major	I5
	Flooding of platforms and subways	9/moderate	12/major	12/major	I2
	Disruption to power supplies	9/moderate	9/moderate	12/major	I1
High and low soil moisture	Destabilised track and poor track quality causing speed restrictions or line closure	9/moderate	9/moderate	12/major	I2, I5, I7
	Increase in tree mortality due to drought	9/moderate	9/moderate	9/moderate	I12
Intense and heavy rainfall	Exceedance of design capacity, pump failure	12/major	12/major	12/major	I2, I4
	Increase in likelihood of asset (rock cuttings, soil cuttings and embankments) failure as the ground becomes saturated	12/major	25/severe	25/severe	I2, I3, I5, I7
	Washout resulting in loss of root anchorage	9/moderate	10/major	12/major	I5, I7
	Building drainage overwhelmed	9/moderate	12/major	12/major	I2
	Sudden track failure	8/moderate	8/moderate	12/major	I2, I5, I7
Snow and ice	Degradation from freeze thaw and snowmelt	12/major	25/severe	25/severe	I5, I7, I12
	Weathering of structures and materials	9/moderate	9/moderate	6/moderate	I12
	Slippery conditions posing a risk to staff and passengers	8/moderate	9/moderate	10/major	I2
	Ice formation within shafts and bores leading to disruption to train operations	12/major	12/major	10/major	I12

7.2.1. Precipitation impacts on our drainage assets

The most significant impacts of intense and prolonged rainfall events on our drainage assets are on the safety of our passengers and staff, and the performance of our services.

Many of our drainage systems were built during the Victorian era (some 150 years ago) without the design standards and modelling tools that we have today. However, even now, modern systems built using these tools and standards do not usually consider climate change appropriately.

The combined effects of inherited legacy infrastructure and the low level of climate change consideration in design processes means that the effects of climate change will continue to be a challenge. Climate change impacts will put increased pressure on our track and building drainage systems, increasing the likelihood that they become overwhelmed and have an adverse knock-on effect for specific assets such as pumps and flooded assets.

Floodwater can dislodge the ballast supporting our railway track and damage earthworks and other equipment adjacent to the railway such as lineside electrical equipment. Tunnels may also experience water ingress (and related scour) and platforms and subways can be flooded by intense rainfall (leading to slippery conditions) and the inability of drainage assets to cope.

Recovery work is needed to remove any debris that has washed onto the railway or into the drainage systems and assets associated with watercourse such as culverts as well as to repair any damage. Responses to all these events must be organised and delivered before train services and other operational activities can be safely restored.

Case study 4 – Watford collision

On September 16th 2016, heavy rains caused flash flooding across southern parts of England with significant impacts on our network and services including our West Coast South route.

At the northern entrance to the Watford slow lines tunnel surface water flooding washed soil and rock onto the track. This was hit by a passenger train which derailed[13] and was subsequently struck a glancing blow by a second passenger train travelling in the opposite direction.

Thankfully no passengers or crew were seriously injured, however both trains were damaged, and the line had to be closed for recovery and repair. This led to over 22 thousand minutes of delay for our passengers and delay compensation costs of more than £4 million.

Whilst the site had not been identified as 'at risk' from flooding induced landslips, an evaluation of the incident found that the crest drainage at the top of the embankment was not sufficient and that there had been a landslip in this location in the 1940s. The drainage was improved as was access for emergency services.

This incident highlights the importance of weather event attribution in incident investigations and the necessity of recording the data for use in the assessment of the current weather risks to our assets. Gaining a comprehensive knowledge of our current risks is the baseline for developing our understanding of how they will alter under climate change.

[13] RAIB (2017) Rail Accident Report: Derailment due to a landslip, and subsequent collision, Watford 16 September 2016. Available at: **https://www.railwaysarchive.co.uk/documents/RAIB_Watford2016.pdf** Last accessed: 23/08/2021

The resilience of the railway drainage to flooding will continue to be heavily dependent on the use, condition and capacity of systems that are outside of our immediate control. As such, drainage is one of our key interdependencies with extensive interconnectedness with Local Authorities, third-party landowners and other organisations (see **Section 6**). This means that changes to our systems to improve their resilience to climate change may also affect flood risk potential for others, with increased flood risk for downstream land, properties or infrastructure a particular concern.

As our vulnerability to flooding rises we will have an increasing dependency on the adaption actions taken by (or in collaboration with) other parties. This must be a key consideration in the future funding and design of water management strategies and systems with collaboration at the core of the process.

Case study 5 – Flash flooding at London Euston

On the 12th July 2021, the Met Office issued a yellow weather warning for rain for a large part of southern England stretching from Devon to Cambridgeshire. That evening, parts of London saw 76mm of rain in 90 minutes[14] causing severe flash flooding.

At Euston surface water flooded the track as well as an electricity substation which then caught fire, causing a loss of power to the London overground services to Watford[15]. All services were cancelled until the water could be pumped away and power restored.

Image source: Network Rail[16]

The lines were then closed for a further seven hours between 11pm on Wednesday 14th July and 6am on Thursday 15th July to allow for repairs to the substation and cables damaged in the electrical fire.

This case study highlights how our assets are interconnected and operate as a system, and how one weather incident can cause multiple impacts. It highlights how our responses to weather need to consider all possible impacts from an event and how we can gain multiple benefits from appropriate actions. It also emphasises the need for our asset designs to enable swift recovery from incidents.

7.2.2. Precipitation impacts on our geotechnical assets

Most of the earthworks (embankments) our tracks lie on and the cuttings they pass through were constructed during Victorian times. By modern standards, these are considered poorly engineered and are often not sufficiently resilient to the intense or prolonged rainfall events we are increasingly experiencing.

As a result, our geotechnical assets are sensitive to all precipitation climate variables[17] and the following can cause our cuttings and embankments to become unstable:

[15] Network Rail (2021) West Coast main line flood repairs to impact London Euston trains [online] Available at: https://www.networkrailmediacentre.co.uk/news/london-euston-flood-repairs-means-changes-to-trains-tomorrow Last accessed: 23/08/2021

[15] Network Rail (2021) West Coast main line flood repairs to impact London Euston trains [online] Available at: https://www.networkrailmediacentre.co.uk/news/london-euston-flood-repairs-means-changes-to-trains-tomorrow Last accessed: 23/08/2021

[16] London Euston Twitter: https://twitter.com/networkraileus/status/1414643409185394691?lang=en

[17] Vardon, P.J. (2014) Climatic influence on geotechnical infrastructure: a review. Journal of Environmental Geotechnics, V2 Issue EG3, p 166-174.

- Intense precipitation leading to significant soil erosion, rapid soil wetting, flooding, and ground pressure changes leading to slope instability and subsidence. This can cause track destabilisation, sudden track failure or washout removing tree and vegetation root support
- Freeze-thaw of snow and ice accelerating soil erosion and weathering (particularly within shafts and pores), causing soil to lose its structure
- Drought events causing soil desiccation and destabilisation of ground materials, which can increase the potential for landslip during subsequent rainfall. The incidence of tree mortality could increase as a result of drought
- Increased average precipitation resulting in; soil erosion and loss of soil quality and higher water table levels leading to further instability

Changes in groundwater are a key cause of subsidence. Common mechanisms include; the sinking of the ground due to loose water saturated sediment swelling and shrinking causing damage to overlying infrastructure (regarded as the most damaging geological hazard in Britain today[18]), or washouts and landslips caused by heavy or persistent rainfall.

Landslips are mass movements of soils and rocks that can undermine or cover the track. They often occur after long periods of heavy rain when the ground is saturated with water, forcing apart grains of soil so that they no longer lock together causing the structure to become loose and unstable. These events can result in delays, a need to re-route of services, and potential health and safety impacts such as derailments.

Case study 6 – Carmont/Stonehaven derailment 2020

Following a month of more than average rainfall, the morning of the 12th August 2020 saw heavy rain and thunderstorms across north eastern Scotland causing transport disruption over a wide area. Around Carmont in Aberdeenshire, over 50mm of rain fell onto already saturated ground in just 4 hours with tragic consequences.

Image source: Network Rail[20]

At half past nine that morning, a passenger train from Aberdeen to Glasgow Queen Street derailed just northeast of Carmont and three people, the driver, the conductor, and a passenger lost their lives.

Although formal investigations into the derailment continue a Rail Accident Investigation Branch (RAIB) interim report[19] found that the train collided with gravel, stones and eroded soil that the morning's heavy rain had washed onto the track from the drains and surrounding land. The RAIB report makes it evident that more needs to be done to manage the impacts of weather events, and the loss of life reminds us of the critical importance of protecting our passengers. We owe it to those involved to learn the lessons.

Key responses were the setting up of two independent expert reviews to assess the appropriateness of our earthworks management and operational weather response, the Weather Advisory Task Force led by Dame Julia Slingo and the Review of Earthworks Management led by Lord Robert Mair. These have delivered their findings and we have created the Weather Risk Task Force to ensure that they are implemented appropriately across our operations and network.

[18] UK Climate Risk (2021) Transport Sector Briefing. Available at: h**ttps://www.ukclimaterisk.org/wp-content/uploads/2021/06/CCRA3-Briefing-Transport.pdf** Last accessed: 23/08/2021

[19] Rail Accident Investigation Interim Report, RAIB, April 2021, accessed here: **IR012021_210419_Carmont.pdf (publishing.service.gov.uk)**. Last accessed 09/11/21

[20] Network Rail (2020) Resilience of rail infrastructure. Available at: **https://www.networkrail.co.uk/wp-content/uploads/2020/09/Resilience-report-28-08-20.pdf** Last accessed: 03/11/2021

Case study 7 – Harrington Sinkhole

In January 2018, a 0.6m wide, 1.2m deep sinkhole opened up on the Cumbrian coast railway at Harrington. Investigations found that a likely cause was a rising water table, high-speed winds, rough seas and increased surface run-off from Storm Eleanor causing water movement through loose porous material in mine workings below the railway[21].

As engineers were concerned that the hole may expand and damage the railway, the line was closed for emergency repairs. Although the hole itself was small, stabilisation work required the building of a bridge and replacement of a significant length of the railway bed and a section of the sea wall. This caused cancelled services and cost just under £2 million in repairs.

This illustrates how, what may appear to be relatively minor weather induced damage, can have very significant and expensive impacts on our assets and their service to our customers. It also demonstrates that our ability to maintain our service has an interdependency with the activities of past 'neighbours', not just our current ones.

7.2.3. Precipitation impacts on track, power and signalling

Heavy rain can short-circuit power for trains and trackside points and signalling equipment rely on intricate electrical wiring and supplies that can easily fail during flooding. In these circumstances, electrical equipment generally needs to be fully replaced before the network can be safely operated again. Like the other rainfall risks in this section we expect this risk to rise as climate change progresses.

In cold weather, snow and ice can build up on the track blocking points and, in severe cases, the route itself. This is because trains are unable to run safely in snow deeper than 30cm. Ice can coat the electrified third rail and overhead power cables, preventing trains from drawing the power they need to run leaving them stranded. Icicles on tunnels, bridges and other structures can also damage trains and overhead power cables. Points can also become frozen.

Case study 8 - Ice and snow

Between the 22nd February and the 3rd March 2018, the UK experienced extreme cold and snow fall. Starting on the 22nd, the 'Beast from the East' hit the east coast of the country. This brought Siberian temperatures and snow to regions from the South East up to Scotland and as far west as Wessex and the West Midlands. On the 2nd March, Storm Emma blew in from the Atlantic, bringing heavy snow to the South West and southern Wales.

While we have invested in mitigation measures like points heaters at vulnerable locations, snow ploughs and other snow clearing methods, the intensity of the events meant that even their successful deployment was overwhelmed. For example, the vast majority of our points heaters operated as designed, but were unable to keep the points clear.

Image source: Network Rail

[21] Terrafirma (10th January 2018) Analysis of the Harrington Sinkhole, Cumbria. Available at: **https://www.terrafirmaidc.co.uk/blog/blog_01_harrington_sinkhole_analyse** Last accessed: 29/10/21

This caused widespread disruption to the majority of our network, with 20 of the 23 train operators reducing services. Our PPM performance dropped 5.1 percentage points to our worst February performance since the harsh winter of 2009. Across the network, we experienced just under 700 thousand delay minutes and it cost us nearly £35 million in delay compensation costs.

Lewisham de-training

A knock-on impact of the disruption to the services was an increase in the risk to the welfare of our passengers. There were some well documented reports of passengers being stranded on trains, including South Western Railway services being stranded overnight because of ice on the third rail.

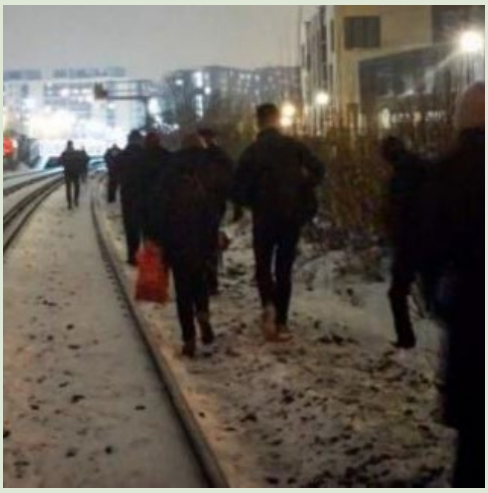


Image source: Network Rail

On the 2nd March, a busy South Eastern service leaving Lewisham station became stranded due to ice accumulating on the conductor rail. This caused the train behind it to block a critical junction and a total of 9 trains became stranded losing heating and lighting. As the delay grew, this and the lack of toilets meant that conditions became very difficult for passengers and staff. Eventually more than 30 passengers began to leave the trains. This posed grave risks to them as the evacuation was not planned and the tracks were still open to traffic, with the electrical conductor rail still live.

Thankfully no one was injured, but this does highlight the need for us to ensure that our network is appropriately resilient to such weather events. However, as we cannot design for every possibility, it does expose interdependencies with the train operating companies around the design of rolling stock in the area of passenger welfare resilience and better evacuation contingency planning.

7.3 Sea level rise and coastal erosion and flooding

As the results of sea level rise often manifest themselves in the form of overtopping high tides, asset erosion/damage and speed restrictions/closures during storms their delay minutes and Schedule 8 compensation costs are captured under the flooding, subsidence and wind categories. We are not currently able to disaggregate these figures so we cannot provide estimates or relative rankings for this impact in those terms.

Sea wall failures at Dawlish on the Great Western Railway in 2014 and between Folkstone and Dover at the end of 2015 however give us an insight into the high capital costs of such events. Repairing and upgrading the Folkstone Dover line cost £41 million and reinstatement at Dawlish cost £35 million with a further £28 million in disruption costs. In CP6 £286.2 million will be spent improving the resilience of the Exeter to Newton Abbot part of the Great Western Railway. Catastrophic failures like these are currently rare, but disruptions due to wave spray and overtopping are not.

Sea level rise will be greater in the south than the north as the terrain continues to adjust after the ice age, but all UK regions will see significant changes. This is likely to increase incidences of asset damage and service disruption, leading to greater costs and it is the most significant climate risk to our coastal operations. It should be noted though that the staff and passenger safety risks are relatively low, because sea level rise is incremental not sudden, and most incidents coincide with planned line closures due to high storm winds.

Figure 7-3 illustrates the key erosion and flooding risks (wave spray is covered in **Section 7.5**) and **Table 7-2** shows expected risk trajectories and the linked CCC infrastructure sector risks from **Section 5.3**. The sections below explore the current and future impacts of these risks on the relevant assets.

Figure 7-3 – Key sea level rise, coastal erosion and flooding risks to our network

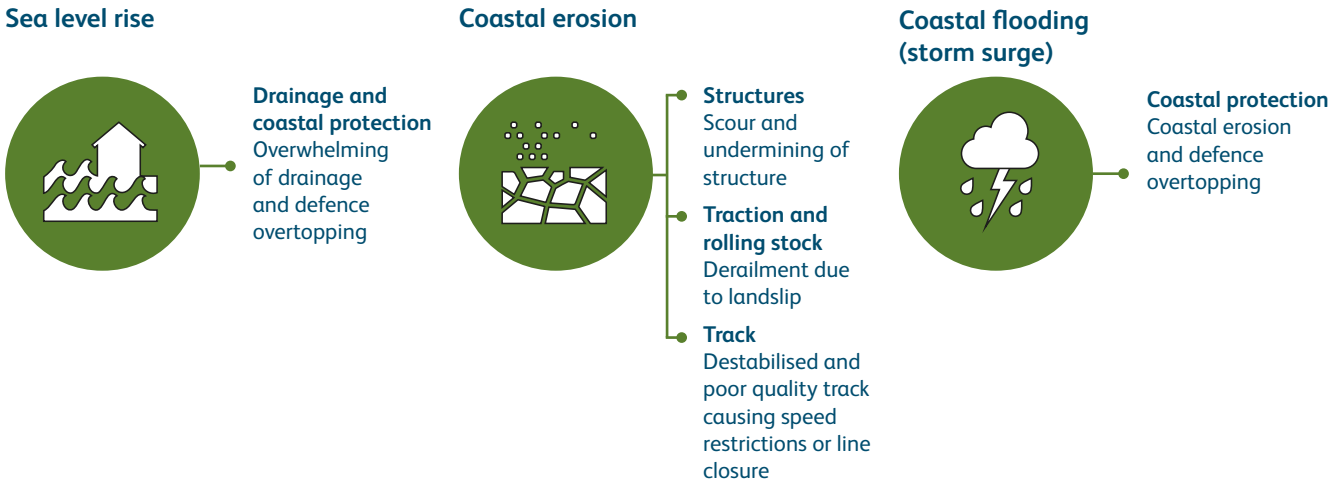


Table 7-2 – Key sea level rise risks and scores

Climate variable	Risk	Score			Infrastructure sector risk
		Current	2050s	2080s	
Sea level rise	Overwhelming of drainage and defence topping	9/moderate	9/moderate	12/major	I4
Coastal erosion	Scour and undermining of structure	9/moderate	9/moderate	12/major	I2
	Destabilised and poor track quality causing speed restrictions or line closure	6/moderate	9/moderate	12/major	I3, I12
	Derailment due to landslip	12/major	12/major	16/major	I3, I5, I7
Coastal flooding (storm surge)	Coastal erosion and defence overtopping	10/major	12/major	16/major	I3

The current coastal and estuarine threats from the sea are:

- Overtopping of defences leading to flooding and ingress into sea defences, track beds, lineside equipment and rolling stock
- Erosion/scour damage to earthworks and defences
- Disruption to track causing speed restrictions or line closure to avoid a train derailment risk

As the sea level rises, the frequency and severity of these events is expected to increase due to higher baseline tides and in particular spring tides and storm surges. These changes are expected to mean that even minor storms will impact our operations.

New risks that we will face include changes in the ability of our coastal drainage systems (particularly gravity systems) to operate effectively:

- In the short-term drainage outfalls will experience periods of tide locking either when the incoming high tide pressure directly stops flows from discharging or indirectly by causing river to back up achieving the same effect
- In the longer-term, without appropriate prevention (e.g. flap valves on outfalls) tidal flows and/or river water could surcharge drainage systems leaving them unable to accommodate storm flows and in extreme cases limiting the capacity for normal discharge flows
- A potential outcome of this is an increase in flooding at our assets due to an inability to drain them. In combination with the projected changes in winter and summer storm precipitation this is a serious risk that needs to be considered in scheme designs

Erosion rates of the coastline and the pressures this will put on our defences and assets are expected to increase.

Case study 9 – Coastal impacts

Parton sea wall

Storm Jonas hit the Cumbrian coast on the 26th January 2016, causing 3 breaches in the sea wall of the Whitehaven to Workington line at Parton. The heavy stone wall which provides the foundations for the line and approximately 640m of ballast and track bed were damaged[22].

The railway was closed for 11 weeks for repairs including pumping concrete into the failed sections to prevent the damage spreading along the sea wall. In addition to the inconvenience to our customers and the communities that depend on our service this cost us £600,000

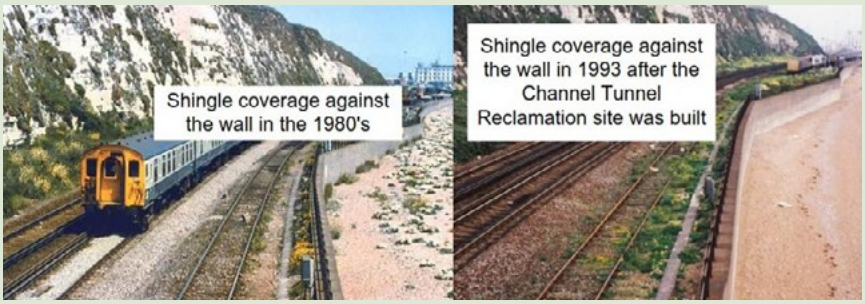
Image sources: Network Rail

[22] Network Rail (2016) Network Rail assessing track and sea wall damage on the Cumbrian coast line. Available at: **https://www.networkrailmediacentre.co.uk/news/network-rail-assessing-track-and-sea-wall-damage-on-the-cumbrian-coast-line** Last accessed: 23/08/2021

Case study 9 – Coastal impacts (continued)

Dover to Folkstone

Over the week up to Christmas 2015 the UK saw a run of increasingly stormy weather. This impacted our Dover to Folkstone line with powerful waves damaging the foundations of our sea wall. This caused more than 100m of the wall to settle by over a metre severely compromising its ability to protect our line and leading to a closure that lasted for 9 months. A subsequent investigation found that the channel tunnel construction had changed sediment flows in the area increasing the exposure of the sea wall to increase.



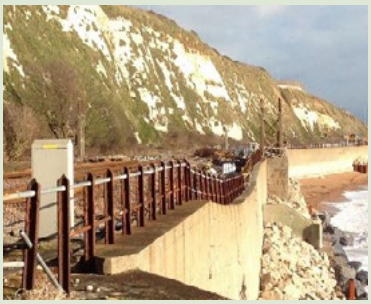


Image sources: Network Rail

Significant repairs were needed with the railway being rebuilt on a 235m piled viaduct and 375m of rock armour placed along the beach to protect it and the cliff face behind it from the power of the sea. A new footbridge was also installed across the railway to the beach[23]. The total cost of this was around £35 million with a further £1 million spent in 2018 to extend the life of the Folkstone Warren protective apron.

These works caused considerable disruption to our passengers and the local community through the service loss and the closure of the beach during construction.

Both of these examples show that our coastal assets are already vulnerable to the power of the sea and that this can result in high social and financial costs. The Dover to Folkstone example also serves as a reminder that our railway system does not exist in isolation from other sectors of the economy and systems. It reinforces the need for a robust collaboration strategy so that we can learn from and input into the plans and activities of other organisations – in this case the coastal groups set up to develop Shoreline Management Plans.

7.4 Temperature

The analysis of our Schedule 8 data has revealed that the annual average performance costs attributable to both cold and hot temperatures are relatively low in comparison to other weather categories (see Figure 1-4).

Between 2016 and 2021 low and high temperatures have accounted for £71 million in Schedule 8 costs (£4.7 million per year) and just over 1.1 million delay minutes. High temperatures were responsible for £57 million (£3.8 million per year) and just under 850,000 delay minutes.

[23] Network Rail (2017) Once more unto the beach, dear friends!' Channel swimmers join Network Rail to celebrate reopening of Shakespeare Beach [online] Available at: **https://www.networkrailmediacentre.co.uk/news/once-more-unto-the-beach-dear-friends-channel-swimmers-join-network-rail-to-celebrate-reopening-of-shakespeare-beach** Last Accessed 06/09/2021

However, the impacts of both extremes are highly variable. In 2016/17 cold impacts cost £1 million and £7 million in 2017/18. High temperatures have varied from less than £1 million in 2007/08 to being our highest cost in 2018/19 at £20 million. It should also be noted that extreme temperatures tend to affect much wider areas than other more localised impact types such as flooding.

As with all of the weather impact categories any work necessary to repair and maintain the railway as a result of incidents would add to the costs tracked by our Schedule 8 data analysis.

The recent run of hot summers has put a spotlight on our vulnerabilities to high temperatures particularly around our track and OLE assets and the welfare of passengers on stranded trains. Additional safety and wellbeing risks come from the potential for derailments from track buckles in high temperatures, increased need for incident response work, reduced workforce capacity to undertake tasks and service disruptions increasing the stress of passengers and staff.

As climate change progresses, we expect the impacts associated with cold temperatures to reduce and the effects of high temperatures to increase. Risks associated with the diurnal range are also likely to rise and these can have a considerable impact on our infrastructure.

Figure 7-4 illustrates our key temperature risks and **Table 7-3** shows how the degree of risk is expected to change and the linked CCC infrastructure sector risks from **Section 5.3**. The sections below explore the current and future impacts of these risks on the relevant assets.

Figure 7-4 – Key temperature risks to our network

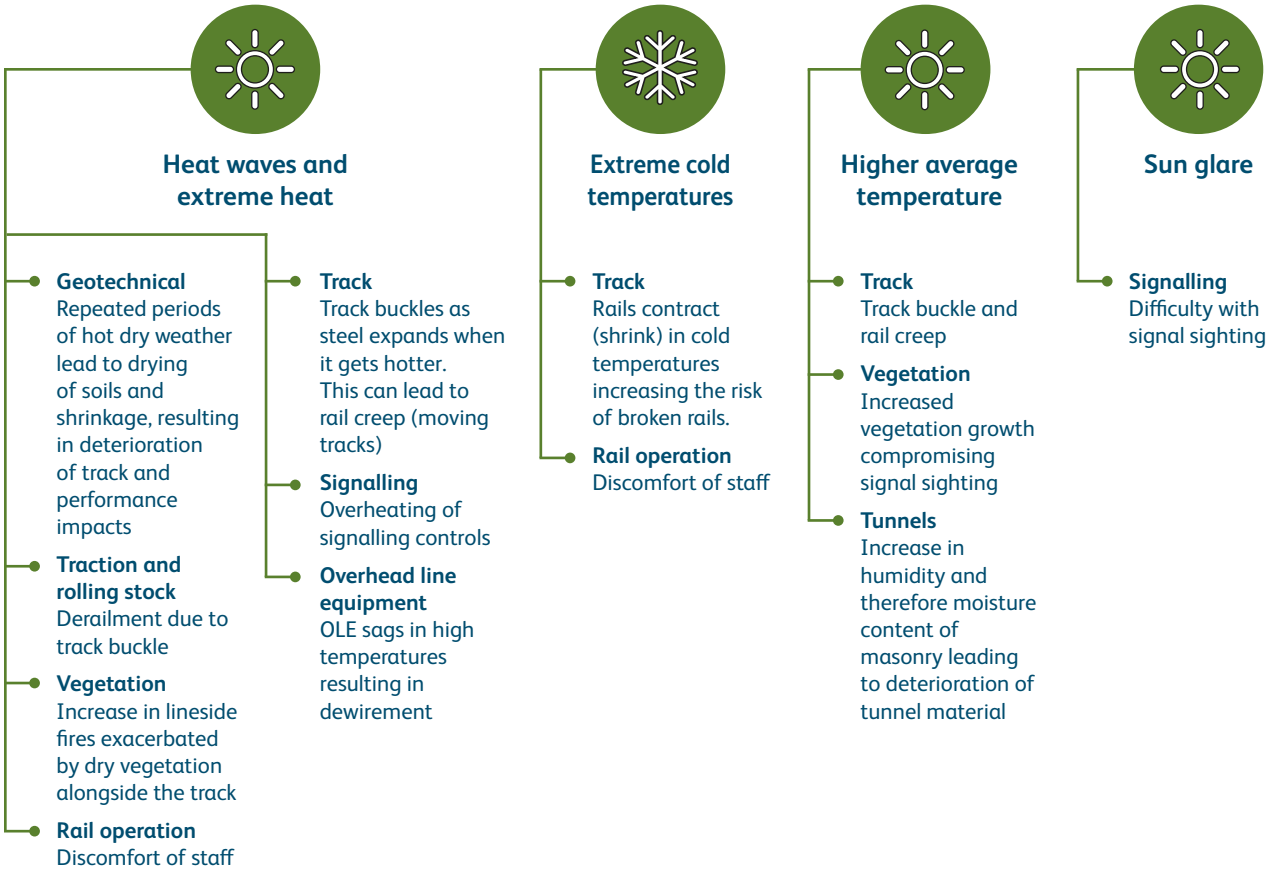


Table 7-3 – Key temperature risks and scores

Climate variable	Risk	Score			Infrastructure sector risk
		Current	2050s	2080s	
Heat waves and extreme heat	Derailment due to track buckle	10/major	12/major	15/major	I12
	Increase in lineside fires exacerbated by dry vegetation alongside the track	8/moderate	10/major	10/major	I12
	Staff welfare	8/moderate	9/moderate	10/major	I12
	Track buckles as steel expands when it gets hotter. This can lead to rail creep (moving of tracks)	9/moderate	10/major	12/major	I12
	Overheating of signalling controls	9/moderate	12/major	12/major	I12
	OLE sags in high temperatures resulting in de-wiring	9/moderate	9/moderate	12/major	I12
	Repeated periods of hot dry weather lead to drying of soils and shrinkage, resulting in deterioration of track and performance impacts	12/major	25/severe	25/severe	I5, I7, I12
Extreme cold temperatures	Rails contract in cold temperatures increasing the risk of broken rails	10/major	9/moderate	8/moderate	I12
	Staff welfare	9/moderate	8/moderate	6/moderate	I12
Sun glare	Difficulty with signal sighting	9/moderate	4/moderate	N/A	
Higher average temperature	Increase in humidity and therefore moisture content of masonry loading deterioration of tunnel material	12/major	16/major	20/severe	
	Increased vegetation growth comprising signal sighting	8/moderate	9/moderate	10/major	I12
	Track buckle	9/moderate	9/moderate	12/major	I12
	Rail creep	8/moderate	10/major	12/major	I12

7.4.1. Temperature impacts on our track assets

Our network contains two types of track, rail welded together in one continuous length and jointed rail made of short sections linked together. Steel rails expand or contract depending on their temperature and in direct sunshine can be up to 20˚C hotter than air temperature. Continuously welded rail has many advantages over jointed rail which is why it makes up the majority of our network. However, as it does not have joints that allow for expansion it has a greater risk of buckling under higher temperatures. Examples of a buckle and the consequences can be seen in **Figure 7-5**.

Figure 7-5 – Track buckles - **Image sources**: Network Rail

The risk can be increased by existing deficiencies in track condition and track support infrastructure and the work undertaken to fix these. Other engineering work on or around the track bed can also introduce new instabilities whilst the assets settle. Another risk factor is rail creep where the rail moves towards a fixed asset. Certain rail fastenings increase this risk as well as locations with significant track gradients and repeated braking of trains.

A risk mitigation measure for track buckles is to slow trains travelling on hot rails through temporary speed restrictions. The hot summers experienced over the past few years have resulted in a high number of speed restrictions in place when track temperatures reach up to 46˚C (roughly 30˚C air temperature). While this allows most of the network to operate under a reduced capacity it can cause major disruption particularly if restrictions are widespread with cancellations and severe train delays to passengers and freight as was the case experienced in 2018 (see case study 10).

Case study 10 – Heatwaves

Asset impacts

Extreme and high average temperatures, as experienced in the recent run of hot years, can have significant impacts on the railway. An example is 2018 which was the joint hottest year on record with prolonged periods of very high temperatures from spring through to the heatwave declared between June 22nd and August 7th.

Train performance suffered significantly with PPM dropping 16 %, a quarter of which was due to asset failures and speed restrictions. Spring saw failure rates increase by up to 80 % due to the unseasonal high temperatures and a very wide day/night temperature variation, while the rest of the period saw rates around 40-50 % higher than normal.

Service affecting failures were 9 % higher than the year before with track and signalling assets accounting for two thirds of the related delay minutes. Switches and crossings, OLE and power supply equipment and external causes such as lineside fires were also significant contributors.

Extreme weather action teleconferences were set up to assess incidents and agree appropriate mitigation, monitoring and contingency plans such as asset monitoring and speed restrictions. Even so our customers and passengers suffered serious inconvenience in the form of delays and the event cost us between £35-40 million in delay compensation costs up to the September of that year. This compares to £13 million over whole of the previous year.

Passenger and Staff Welfare

Failures in our network can also have big impacts on the welfare of passengers and staff who are having to work and travel in potentially extreme conditions. The 2019 heatwave demonstrated this when damage to the OLE on the 25th July cased a passenger service to become stranded near Peterborough.

Without power the air conditioning failed making it hard to control the carriage temperatures. Staff did their best to help in the sweltering conditions handing out water to passengers and attending to their concerns[24], but conditions became very difficult until the train could be recovered.

This shows the scale of impacts that nationwide events such as heatwaves can have and the potential for serious health risks associated with them. It highlights an increasing need to understand and manage the vulnerability of our assets to heat.

Given that rail temperatures of 51˚C have already been recorded and that average and extreme temperatures are projected to rise under climate change these risks are expected to increase.

On the other end of the spectrum the key cold weather risks are interrelated with the precipitation occurring at the time. As discussed in **Section 7.2.4** these include the impacts of icicles in tunnels and on bridges, ice formation on OLE and third rail contact systems and frozen points. As climate projections show a fall in frost days, we expect the risks to reduce in frequency, but remain possible.

[24] BBC (2019) UK heatwave: Sweltering commuters face heatwave woes [online] Available at: **https://www.bbc.co.uk/news/uk-england-london-49112939** Last accessed: 23/08/2021

7.4.2. Temperature impacts on our electrification assets

During extreme hot weather, overhead wires can sag as they expand beyond the capacity of the built-in systems which maintain their tension. Sagging lines can catch on train pantographs, which transfer the power to the train, and be torn down causing delays which can take a significant amount of time to repair. There are a number of designs of OLE in operation each with a different range of temperature tolerances.

Summer 2019 was one of the warmest on record with a UK record temperature of 38.7˚C in Cambridge. This coincided with 34 failures and incidents related to our OLE systems. The ORR report into the summer temperature effects[25], found that the failures were mainly due to heat induced sagging of fixed termination conductors, balance weight defects, excessive differential along track movement of conductors and other secondary causes.

Fixed termination equipment is designed to operate between -18˚C to +38˚C, only slightly lower than the temperature recorded suggesting that the systems were less resilient than thought. More modern systems on other parts of our network are designed to higher operating temperature limits of +40˚C and use a more resilient tensioning system (Tensorex) instead of balance weights. As average and extreme temperatures are expected to rise, we expect this risk to increase.

We are not currently funded to replace all of the old systems but have improved our maintenance regimes and are identifying sort term enhancement activities based on lessons from the events. We will review our asset resilience and renewal schedule as we develop future asset management policies.

In very cold weather, ice can coat the electrified third rail and overhead power cables, preventing trains from drawing the power they need to run and leaving them stranded. Icicles that form on tunnels, bridges and other structures can also damage overhead power cables.

We currently run ‘proving’ trains down lines before services start to remove the ice, but as with the other cold weather impacts the climate change projections suggest that we may be able to reduce this activity as the risk will reduce.

[25] Office of Rail and Road (2021) Overhead Line Equipment (OLE) Hot Weather Resilience: Targeted Assurance Review **www.orr.gov.uk/media/22720**

7.4.3. Temperature impacts on vegetation

A recent study by the Tree Council (see **Section 8.1**) has given us the following insights into how climate change may affect the vegetation on our land.

Shorter periods of temperature close to freezing will increase the active growing season for many plant species. This combined with wetter winters will lead to more vigorous growth in the spring, although it is possible that the drier summers will act as a growth limiter. For some species there may also be a later period of growth in the late summer/early autumn. This suggests that current patterns of vegetation management will need to change, potentially starting earlier and continuing longer leading to greater costs and workforce safety issues.

Existing vegetation, particularly trees, may not be ideally suited to the future climate, experiencing periods of stress which may result in damage, requiring additional intervention. It is possible that these species may need to be gradually removed from the network where they would pose an increasing risk. Again, this could cost more and add to workforce risk exposure.

During prolonged periods of dry weather, the risk of fires near the railway increases with fires normally occurring on warm days in areas that are fully exposed to the sun. Grassy areas with dry or dead vegetation are particularly at risk.

New species may colonise our land and these may grow more vigorously than those they displace. If this occurs it will again require a review of our management practices. These findings will need to be included in our sustainable land use strategy as detailed in **Section 8.1**.

While these risks may increase under future climate projections there is still a lot of uncertainty in this area and further research will be necessary.

7.4.4. Temperature and solar impacts on health and safety

For Network Rail staff, there is an increased risk of fatigue, heatstroke and being struck by trains whilst undertaking patrolling duties in hot weather. Sunburn and dehydration may also occur.

Passengers may also suffer negative health and safety impacts such as heat exhaustion and dehydration, particularly if cooling systems within trains fail and/or trains are stranded due to other service or asset issues.

Wintery weather has the potential to cause danger to passenger journeys. As well as the health and wellbeing of staff. According to our winter safety campaign, the number of major injuries suffered by railway employees peaks every winter period. Dark nights and difficult conditions bring their own hazards, which can lead to some nasty slips, trips and falls[26].

Whilst the effects of darkness will not change, the projected reductions in frost days and snow days and snow volume should lead to a reduction in cold related risks.

As well as temperature effects solar glare from the sun reflecting off surfaces like glass or water can cause a dazzling effect. In winter this can be due to the low angle of the sun and in the summer it can be due to the intensity and brightness of the sun. As a result, the position of the sun can result in railway accidents, impacting the health and safety of passengers, staff and the general public.

With the projection of increased winter rainfall, it is possible that a higher degree of cloud cover may reduce the effect, although more water around may raise the risk. In summer the lower rainfall suggests less cloud cover which, could potentially raise the risk. In short, the picture for this risk is unclear.

[26] Network Rail – Winter Safety Campaign [online] Available at: **https://safety.networkrail.co.uk/safety/winter-safety-campaign/** Last accessed: 08/09/2021

7.5 Storm and wind events

Although storms generally bring significant volumes of precipitation with them this section covers their wind and lightning risks, with precipitation being covered in Section 7.2. Adhesion is also discussed here because of the influence that storms can have on leaf fall.

As **Figure 1-4** reveals wind is currently our single biggest weather-related cost with adhesion and lightning occupying the 4th and 7th slots respectively. Between 2016 and 2021, their combined impacts were £190 million Schedule 8 costs and just over 3.3 million delay minutes. Wind alone represented two thirds of the costs and more than half of the delay minutes.

As with all of the risks discussed throughout **Section 7** these events cause additional costs by way of repairs and can pose significant safety risks to staff and passengers. Injury risk can come from significant asset failures damaging trains, staff working to prevent or respond to events in poor weather or flying debris. And again, wellbeing can be affected by disruption related stress and fatigue.

Whilst the UKCP18 data does not contain probabilistic projections for these weather types the evidence suggests that they are likely to show increases as the climate changes, so we need to plan accordingly.

Figure 7-6 illustrates our key storm and wind risks, and **Table 7-4** shows how the risk is expected to change and the linked infrastructure sector risks from **Section 5.3**. The sections below explore the current and future impacts of these risks on the relevant assets.

Figure 7-6 – Key storm and wind risks to our network

Lightning

- **Power distribution** A direct lightning strike will damage electrical equipment
- **Vegetation** Trees struck by lightning may fall onto the track or onto vulnerable lineside plant and equipment

High winds and storms

- **Drainage** Coastal erosion and sea defence overtopping
- **Traction and rolling stock** Damage of rolling stock and containers being blown off freight trains
- **Track** Destabilised track and poor track quality causing speed restrictions or line closure
- **Vegetation** Vegetation obstruction on the line from trees blown over. The risk will increase further due to longer growing seasons
- **Structures** Inundation, erosion, scour, loss of stability and structural damage from overtopping
- **Signalling** Disruption to signalling from leaf fall
- **Level crossing** Failure of barriers

Table 7-4 – Key storm and wind risks and scores

Climate variable	Risk	Score			Infrastructure sector risk
		Current	2050s	2080s	
Lightning	Trees struck by lightning may fall onto the track or onto vulnerable lineside plant and equipment	9/moderate	9/moderate	9/moderate	I12
	A direct lightning strike will damage electrical equipment	8/moderate	8/moderate	8/moderate	I12
High winds and storms	Failure of barriers	9/moderate	9/moderate	12/major	I2, I12
	Disruption to signalling from leaf fall	12/major	9/moderate	N/A	I2, I12
	Inundation, erosion, scour, loss of stability and structural damage from overtopping	9/moderate	16/major	20/severe	I3
	Vegetation obstruction on the line from trees blown over. The risk will increase further due to longer growing seasons	9/moderate	10/major	12/major	I12
	Destabilised track and poor track quality causing speed restrictions or line closure	9/moderate	9/moderate	12/major	I2, I5, I7, I12
	Damage of rolling stock and containers being blown off freight trains	8/moderate	8/moderate	9/moderate	I12
	Coastal erosion and sea defence topping	9/moderate	10/major	12/major	I3

7.5.1. Storm and wind impacts (vegetation)

Storms and high winds damage lineside trees and can increase the number of trees and branches blown onto the line, OLE and trains. This is a risk which will increase further as the number of storms increase and the extended growing season results in more trees remaining in leaf as the stormy period in autumn begins.

Leaf fall onto the track is compressed by passing trains into a layer on the rails that reduces adhesion (the grip of train wheels) making it necessary for drivers to take extra precautions such as lower speeds and longer stopping distances to avoid wheel-slip or overshooting stations and signals. During leaf fall events (storms and autumn) we use a fleet of more than 60 rail cleaning trains to remove the leaves and clean the rails in a targeted programme.

Leaf fall can also cause issues for our drainage systems which can become clogged requiring enhanced or reactive maintenance.

Case study 11 - Storm impacts

Storms can bring a whole variety of impacts with them depending on the time of year and the nature of the storm with high winds, lightning, intense rainfall, hail and snow being the most obvious characteristics. Each of these brings their own problems but they can also have combined effects for example rain-soaked ground making it easier for trees to be blown down. Beyond precipitation, which is dealt in Section 7.2, wind is our biggest impact.

Storm Doris, February 2017

Over the night of 22nd February into the morning of the 23rd, Storm Doris crossed the UK bringing gusts of up to 94mph across the country. This brought widespread disruption to our services as a result of numerous trees, branches and other debris blown on to our tracks and OLE[27].

Although Doris affected most of UK the biggest impacts on our network were seen across the North West and Central, Eastern and Southern regions. In addition to the safety risks posed by flying debris, the possibility of trains being struck by obstacles and to our staff involved in the clean-up the event was costly and a cause of much disruption to our passengers. We saw a combined total of over 308 thousand delay minutes and paid more than £21.2 million in delay compensation costs.

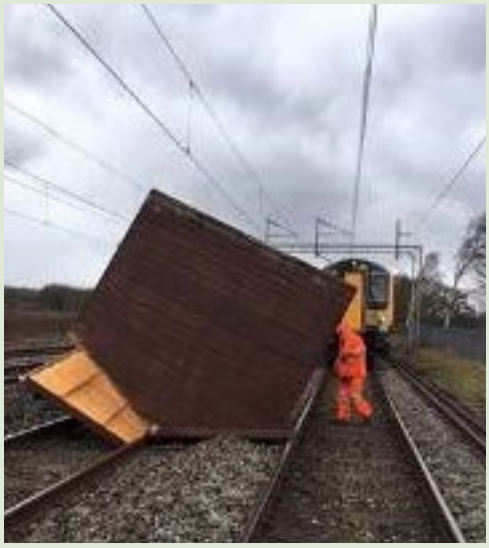


Image source: Network Rail

Given the scale of impact that storms can have on us we put a lot of time and effort into managing our lineside risks, however our experiences show that there is still much work to be done. We are taking steps to improve our resilience through improvements in our vegetation management under our sustainable land use programme and we are looking to improve our collaboration with our neighbours and other stakeholders to manage risk from outside of our boundaries.

The combination of increased storm frequencies and severities with the potential for changes to a later or more lengthy leaf fall period means that our current vegetation and leaf control regimes may need to be reviewed.

7.5.2. Storm and wind impacts (other debris and spray)

Wind affects performance directly in that blanket speed restrictions are imposed when thresholds of wind speed are reached. This is mainly due to the danger of various debris being blown onto the line from our lineside environment and from neighbouring sites – as shown in the case studies for Storms Barney and Doris. Other impacts can include:

- Containers blown off freight trains
- Damage to track protection assets such as fences
- Station roofs, platform canopies and lineside equipment such as signs and lights getting damaged
- Level crossing barriers failing and blocking the crossing

[27] Network Rail (2017) Speed limits imposed to keep people safe as Storm Doris rolls in [online] Available at: **https://www.networkrailmediacentre.co.uk/news/speed-limits-imposed-to-keep-people-safe-as-storm-doris-rolls-in** Last Accessed: 23/08/2021

The high winds in storms drive wave formation in both the sea and other significant waterbodies such as estuaries. Large volumes of spray from breaking waves can lead to speed restrictions and even service cancellation in extreme conditions. It can also wash away ballast destabilising tracks, damage earthworks, overwhelm drainage systems and salt water can accelerate asset corrosion.

With storms expected to increase in both severity and frequency this risk is expected to grow.

7.5.3. Lightning impact on our electronic assets

When lightning strikes our equipment or the surrounding area the high voltage can damage the sensitive electronic equipment (such as signalling). As the signalling system fails-safe, when a component is damaged all signals in the area turn red and trains must stop. Direct strikes can also lead to damage to buildings and structures if adequate protection is not fitted. Additionally, lightning strikes may result in tree fall which can lead to delays due to track obstruction, damage to lineside plant and/or equipment.

Case study 12 – York lightning strike

On the 27th of July 2018, one of the busiest days of the summer holidays, lightning struck our signalling equipment near York causing substantial damage[28].

Beyond the physical damage, it caused the total loss of the Leeds East and Leeds West signal centres and multiple failures of sets of points around York due to interrupted communications. This meant that multiple trains became gridlocked and unable to move. The line was closed for several hours while work was undertaken to repair the damage and rectify the situation leading to dozens of cancelled trains.

Delays to our services totalled nearly 19 thousand minutes causing serious inconvenience to thousands of our passengers and costing us over £3.2 million in delay compensation payments.

Whilst it can be tempting to become focussed on the biggest of our weather impacts such as wind and flooding this event reminds us that even a very localised lightning strike in the wrong place has the potential to have much wider impacts. The cascade of failures from the original strike reinforces the need for us to better understand and mitigate the impacts of dependencies between our assets.

The projections for lightning are still uncertain, but assuming that an increased frequency of storms (particularly summer storms) it is sensible to assume that we may see an increase in risk.

[28] BBC (2018) Lightning strikes cause rail chaos across East Coast [online] Available at: **https://www.bbc.com/news/uk-england-44978970** Last Accessed: 23/08/2021

8.1 Progress on ARP2 actions

The development of our WRCCA and environmental sustainability strategies (Section 4) has elevated climate change adaptation up the agenda within Network Rail. As a result, we have made significantly more progress than was anticipated when we developed the actions in ARP2. In addition, the Weather Risk Task Force, set up to implement the recommendations following the Carmont incident last year is aiming to fundamentally change the way we use data and systems to manage our operational weather response and assets.

8.1.1. Strategic actions in ARP2

ARP2 identified three overarching strategic actions to be taken forward across the whole network in that 5-year report period. Progress on these actions has been detailed in **Table 8.1**.

Table 8-1 – Progress against ARP2 planned actions

Action	Risk addressed	When	Progress
Develop and publish long term route studies	All	2015/16	Work is ongoing on the development of long-term climate change strategies for our regions. CP6 WRCCA plans provided an update to the 2014 vulnerability assessments and strategic business planning is underway for CP7 and the WISP aimed at developing an overarching strategy for the network We will be developing detailed adaptation pathway strategies and investment plans over the coming years with detailed modelling in those areas at highest risk. Long-term studies have been completed for some parts of the network e.g. Exeter to Newton Abbot in Western route and the Cambrian Coastline in Wales and some other areas are under investigation at the moment e.g. the Cumbrian coastline in North West and Central region. This action remains for ARP3 albeit in an amended form
Develop CP6 asset policies	All	2016	**Complete.** Asset policies were updated in advance of CP6 (2019-2020) to reference climate change. Some examples include: **Asset Management Policy:** We will align all asset management interventions to the principles defined in our asset policies. These will be continuously improved to: Define resilience requirements as a specified range of weather conditions, taking account of emerging knowledge of climate change **Structures Asset Policy:** We will design renewals and new works to allow for climate change predictions We continue to work on further integrating adaptation into our asset management processes
Publish CP6 strategic business plan	All	2018	**Complete.** Network Rail's CP6 strategic business plan was published in 2018 and the Route WRCCA Plans outlining the associated investment in weather and climate change resilience in CP6 were published in 2019/2020[29]

[29] Our Delivery Plan for 2019-2024 - Network Rail

8.1.2. Route actions in ARP2

The CP5 Route WRCCA Plans signposted in our ARP2 report (see **Section 4**) provided detailed plans of the actions proposed by the routes across our network, for their 'on the ground' work to manage the resilience of their assets.

The plans contained a total of 214 actions across all regions. 41 % of these have been completed, 39 % are ongoing and the remainder have either been deferred to CP6 or abandoned because an alternative solution or approach has been identified.

A key driver behind why some of these activities have not been completed is that the plans were not fully funded at the outset and financial constraints in the final years of CP5 (2014 – 2019) meant that routes have needed to re-prioritise some of their activity into other areas. Detailed assessments of the progress on these actions by each route, including narrative on their status can be seen in the route actions sections of their new **CP6 Route WRCCA plans**.

We have learnt from this and ensured that the actions contained in the new CP6 Route WRCCA Plans are based on funded workbanks from our approved CP6 strategic business plans.

Section 8.2 contains details of the key CP6 Route WRCCA Plan actions that have been delivered between the end of the CP5 plans and the writing of this report. Detail regarding the delivery of CP6 Route WRCCA Plan actions beyond this report can be found in **Section 8.3**.

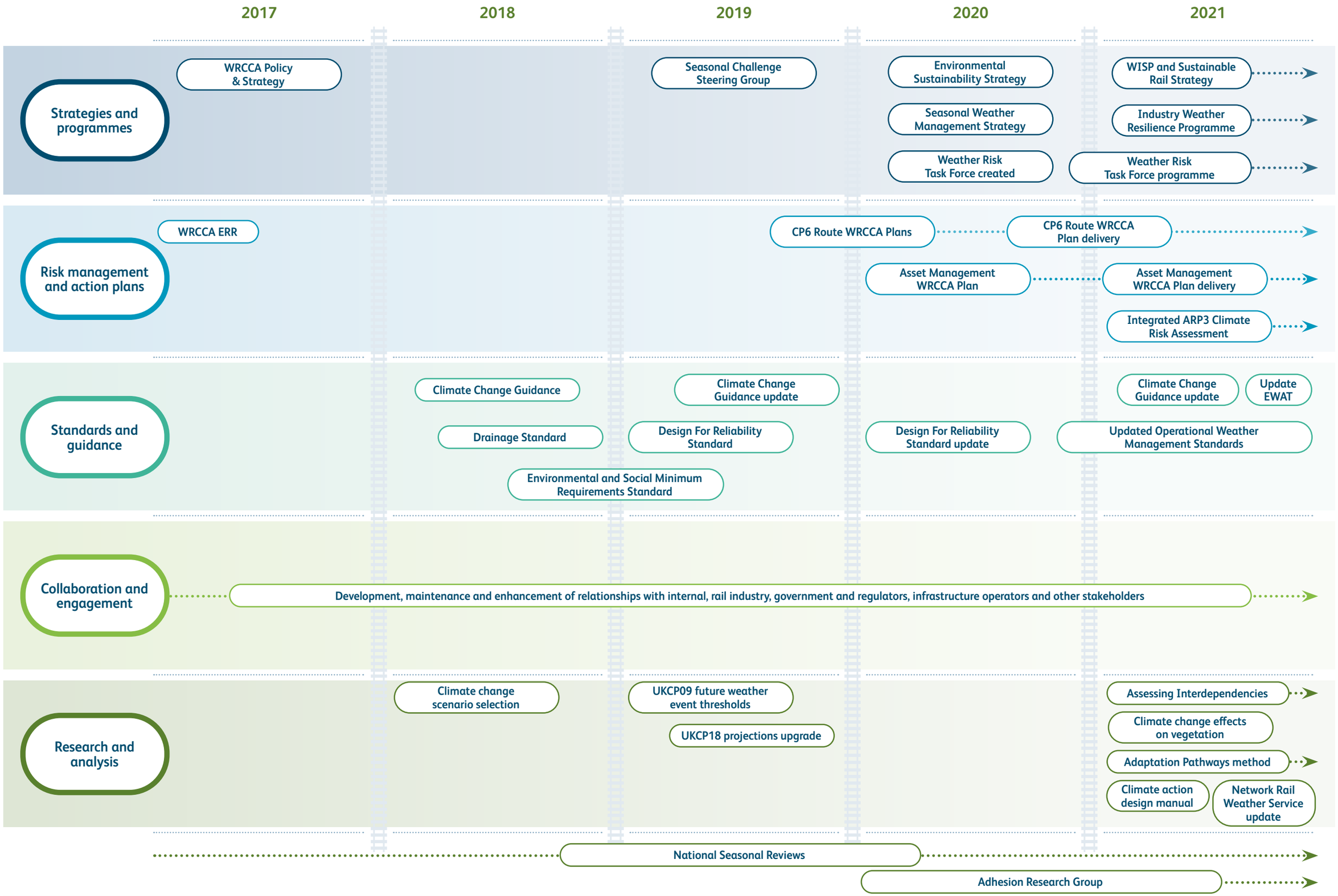
8.2 Progress on actions beyond ARP2

We have made significantly more progress than was anticipated over the past five years. Our ARP2 report was good practice when it was written and contained actions to set us on the correct path for increasing our current and future resilience. However, the understanding of climate change, its impacts on us and how best to deal with them is continually evolving meaning that the work needed is ever changing. We have risen to this challenge adapting our approach to improve our understanding and management of weather and climate change risk.

Since ARP2, we have put a lot of effort into pushing forward our understanding of climate change risks, the impact on the railway, the responses necessary and investing in our assets to improve our resilience. Whilst a wide range of stakeholders are involved in this work across our company, most of the strategic actions since ARP2 have been carried out by or led by the WRCCA team in the TA or the National Weather team in the System Operator. The delivery of work on our assets to improve the resilience has primarily been carried out by our routes and regions.

We have made significant progress in building adaptive capacity and enabling adaptation action on the ground by our regions over the past five years. An overview of these actions, which go beyond those set out in ARP2, can be seen in **Figure 8.1** as aligned with Network Rail's five pillars of resilience shown in **Figure 4-4**.

Figure 8-1 - Key strategy, risk assessment and planning achievements since ARP2



8.2.1. Strategies and programmes

Our overarching WRCCA strategy and policy were published in 2017 covering operational weather management as well as longer term climate change resilience (see **Section 4**). These set out the principles and commitments that have guided our work to understand and act on the threat from extreme weather and climate change for our business. The strategy is due for renewal following organisational changes over the past few years and to include a number of other strategies and plans which fall under its umbrella including:

- **Environmental Sustainability Strategy** – published in 2020, this sets our vision: 'To serve the nation with the cleanest, greenest mass transport'. This strategy has updated our ambition with climate change adaptation forming one of the 4 key priority areas
- **Seasonal Weather Management Strategy** – published in 2020, this sets our 10-year weather resilience strategy to improve seasonal and operational weather management
- **WISP and sustainable rail strategy** – climate change resilience is a core element of these strategies and we work closely with the teams leading them to ensure that weather resilience and climate change adaptation requirements and thinking are include in line with our Environmental Sustainability Strategy and our adaptation activity

In addition to the strategies listed above, the Weather Advisory Task Force led by Dame Julia Slingo and the Review of Earthworks Management led by Lord Robert Mair commissioned after the Carmont derailment in 2020 have led to the creation of the Weather Risk Task Force. This is a cross function programme established to implement the recommendations from two previous task forces and drive change in the way we operate and manage the railway in extreme weather.

Following the hot summers of 2018 and 2019, the wider rail industry recognised the need to work together to improve our understanding and management of our operational response to extreme weather and seasonal impacts. The SCSG was formed following evolution of various seasonal preparation groups into one cross industry group with the aim of collaboratively achieving a railway that has the same high-level of performance across all seasons. The Industry Weather Resilience Programme has been created to drive improvement into our operational weather management (planning and response).

8.2.2. Risk management and action plans

A **Weather and Climate Change ERR** was developed in 2016 to manage the risk at a corporate level. This was raised to Level 0 in 2020 and is now reviewed at Board level and manages the organisational issues required to control the consequences of weather impacts on the railway as discussed in **Section 5**. The improvement actions linked to ineffective controls in the ERR provide an action plan for improving our management of weather and climate change risk.

We updated our route level climate change risk assessment in line with the latest climate change projections (UKCP18) and including additional weather parameters to inform the CP6 Route WRCCA Plans. Further detail is in **Section 4**.

In October 2021, we published our Asset Management WRCCA Plan which details the results of our assessment of the climate change risks posed to our assets in 2020, 2050 and 2080. The aim of the plan is to enable our asset functions to plan and deliver the effective management of the risks identified. Further detail can be seen in **Sections 4** and **8.3.2**.

During the production of this report, we have taken the opportunity to combine the above risk assessments to produce an Integrated ARP3 Climate Risk Assessment. This has improved the quality and level of detail of the route risks and allowed us to fill gaps in both individual risk assessments (see **Section 5**).

8.2.3. Standards and guidance

Our approach to adaptation over the past five years has focussed on the development of the framework, tools and evidence base for managing climate change, and to take action using progressively improving local plans. Integration of weather and climate change resilience within business as usual in Network Rail relies on it being embedded within our suite of standards and specifications across our design, construction, operation and maintenance functions.

Over the last five years we have developed guidance and updated standards that drive positive change in project planning and delivery activities. All capital delivery projects going through our project acceleration in a controlled environment (PACE) project management process are required to undertake a climate change impact assessment using our climate change guidance. Our approach to 'design for reliability' requires consideration of climate change and our Drainage Standard makes specific provision for future rainfall levels. Our operational weather management standards have been updated in light of the increasingly more severe weather events we are experiencing to improve our preparation, response and recovery activities. The remainder of this section outlines some of the activities we have been working on.

- **Climate change guidance** – we have developed two related climate change guidance notes which are primarily designed to be used in our asset planning, renewal, and creation activities. However, they can be applied to any project or process where the activity or asset may be vulnerable to current and future weather impacts in their lifespan. These were first published in 2018 and are periodically updated as required such as to reflect the new UKCP18 projections
    - Weather Resilience and Climate Change Impact Assessment Guidance Note – this provides users with a simple step by step method for identifying if a project has any vulnerabilities to current or future weather events, assessing how climate change may alter these and a process for incorporating the conclusions into the development and delivery of the end product. The climate data used in this method is sourced from the Climate Change Projections Guidance Note
    - Climate Change Projections Guidance Note – this provides a suite of climate change related data for use with the weather resilience and climate change impact assessment guidance note including UKCP18 and (where appropriate) UKCP 09 weather parameter projections, regulator generated flooding guidance and derived future weather event frequencies

This ensures that a consistent approach is used across our business to evaluate the weather and climate risks to our assets and the development of actions to respond to them.

- **Environment and Social Minimum Requirements** – design and construction – this 'ESR' standard (NR/L2/ENV/015) sets out Network Rail's minimum requirements for the management of environment and social risks and opportunities during design and/or construction activities. It is mandatory for all construction and design works carried out by Network Rail and its contractors as part of our formal PACE project management process

  In 2019 the ESR was updated to require all projects subject to it to, after December 2019, to carry out a weather resilience and climate change risk assessment. The weather resilience and climate change impact assessment guidance note and the Climate Projections Guidance Note detailed above were provided as a method for undertaking this work

- **Drainage Standard** – Network Rail's standard for drainage design (NR/L2/CIV/005/09 Module 9 - Drainage design) was updated in 2018 to require designs to include climate change uplifts in their design life and vulnerability of the assets. The uplifts used were in line with the Defra recommendations at the time and they will be revised as part of the ongoing revision of the drainage and water management strategies

- **Design For Reliability Standard** – our Design For Reliability Standard (NR/L2/RSE/0005) ensures that the products we use on the railway meet our required performance and design tolerances and are reliable in the range of environments that they are expected to operate in

  In March 2019 it was updated to include a reference to consider future climate changes in product development and design. In March 2020 this was changed to: 'For products vulnerable to weather (e.g. temperature, humidity or water ingress) the environmental requirements shall set specifications which account for expected climate changes during the product's operational lifespan.' The Climate Change Projections Guidance Note is referenced as the source for the climate change data to ensure consistency with our other work

- **Extreme weather action teleconference** – the 'EWAT' is a process which is triggered when extreme weather is forecast. It is used to assess the impact of extreme weather on our infrastructure, establish the priorities and timescales for recovery of the network, agree appropriate mitigation, set monitoring and contingency plans as detailed in the established integrated weather management plan, communicate actions and decisions, and identify, capture and create improvement plans. This standard has recently been updated to include structures and earthworks asset teams in the preparation for events

- **Updated operations weather management standards and processes** – our existing weather standards are reviewed on a rolling basis and in response to serious events. Following the significant impacts to the network in summer 2019 and the Carmont derailment in 2020, the weather related national operating procedures have been reviewed and incorporated into standard processes and updated for all asset functions. This has enabled best practice to be included in seasonal assurance activities and to make sure that we learn lessons from past experiences and build that into the way we operate in the future. Key performance indicators (KPIs) have been developed for managing seasonality and this work continues in line with the 10-year Seasonal Weather Management Strategy

8.2.4. Collaboration and engagement

Operating a large diverse nationally strategically important infrastructure network across Great Britain means that we interact with wide range of organisations as demonstrated by our interdependencies in **Section 6**. This combined with the range of significant current and future challenges associated with weather and climate change make cooperation and coordinated actions with our stakeholders critical to achieving successful adaptation.

Since our ARP2 report we have put a large amount of effort into expanding and improving our engagement activities to increase our ability to deliver our objectives. Details of our engagement activities with key stakeholders are laid out in **Section 3.5**.

In addition, we work closely with a number of specific programmes within Network Rail to enhance the overall benefit of all of our activities and to ensure we achieve our ambitions in the Environmental Sustainability Strategy. These include:

- **Sustainable land use programme** – seeks to manage the risks to the railway from lineside vegetation whilst achieving our Environmental Sustainability Strategy ambition of 'improved biodiversity of plants and wildlife'. There are strong links to the WRCCA workstreams as vegetation has a key role to play in both causing and mitigating weather-related impacts, for example tree management to reduce the impact of wind blowing trees onto overhead lines or tracks, or the role of vegetation in sustainable water management solutions that could increase biodiversity
- **Decarbonisation programme** – seeks to reduce our direct, indirect and embodied greenhouse gas emissions to meet government targets to decarbonise the railway by 2045 in Scotland and 2050 in England and Wales. The main link between this and climate change adaptation is the potential for investment in resilience solutions to embed more greenhouse gas emissions into our assets and operations. Engagement will ensure appropriate consideration of low carbon solutions such as catchment and nature-based solutions
- **Intelligent infrastructure** – is a digital asset performance management programme improving our use of technology and data so we can work safer and smarter to improve our service to passengers and freight customers. An example is improving our RCM use and condition monitoring knowledge to predict where and when faults will occur so we can plan actions to prevent them leading to fewer asset failures and safety and performance issues. This links to the development of a digital platform for geotechnical assets under the Weather Risk Task Force as well as understanding the weather and climate change implications for asset criticality, vulnerability and asset deterioration modelling

8.2.5. Research and analysis

We continue build on the analysis outlined in ARP2 through a wide range of weather, resilience and climate change related research and analysis activities across our business. To ensure that we access the best available data and research we engage a wide range of organisations from world leading universities, the RSSB, Construction Industry Research and Information Association (CIRIA), the Natural Environment Research Centre (NERC) through to other institutions and consultancies.

Our central R&D team coordinate much of this activity. This has led to a continual investment in innovative asset management activities, modern technologies and operational systems. For example, materials research, remote monitoring, intelligent infrastructure, digital signalling and low carbon solutions. A particular focus is currently on geotechnics and drainage and analysis to improve our understanding of the criticality and vulnerability of our assets in relation to weather events and climate change.

Over the last five years, the WRCCA and National Weather teams have also undertaken a number of targeted projects to support development of tools and guidance and to provide the business with the information it needs to adapt the railway. The projects are detailed below.

- **Climate change scenario selection**[30] – in 2018 we commissioned a review of the UKCP09 and (at the time) proposed UKCP18 climate projection scenarios, the national greenhouse gas emission pledges from the Paris Climate Change Agreement and other sources of information related to global trends. The purpose was to provide us with science-based guidance that would allow us to select the most appropriate climate change projection scenarios for use in our adaptation strategy. The result was the production of our Climate Change Projections Guidance Note (see **Section 8.2.3**)
- **Future weather event thresholds under UKCP09**[31] – as part of our work to understand how our assets may act under our chosen climate projection scenarios, we had work undertaken to determine the future frequency of certain weather events based on current data from our asset failures. This data was included in our Climate Change Projections Guidance Note so that it could be used in areas such as asset design, adaptation pathways and asset degradation and whole life cost modelling
- **UKCP18 projections upgrade** – as part of the process to update our Climate Change Projections Guidance Note to UKCP18 we commissioned two pieces of research:
    - In the transition from UKCP09 to UKCP18 it was noted that the UKCP09 data used to generate the future weather frequencies in our guidance had not been replicated for our chosen primary scenario. The project generated synthetic RCP6.0 90 % data to allow the updated values to be created[32]
    - Although UKCP18 did contain some additional data sets, projections were not produced for a number of parameters important to our operational and asset management activities. We commissioned a review of the latest information in order to provide narrative guidance for these (e.g. snow days/fall)[33]
- **Climate change effects on vegetation**[34] – we worked with the Tree Council to understand what the latest research could tell us about the effect that climate change may have on our lineside vegetation. Their report made suggestions for changes to current management practices, identified knowledge gaps and suggested future research avenues. This was a joint study with the sustainable land use programme as delivery of the recommendations lies with our lineside management teams

[30] Identifying a climate change planning scenario, JBA, February 2018
[31] Defining Future Weather Threshold Frequencies, WSP, June 2019
[32] Network Rail – climate data and guidance update Task 4 Weather threshold exceedance frequencies: UKCP18 multipliers Mott MacDonald, April 2020
[33] UKCP18 Extremes Lightning and Fog, WSP, April 2020 and UKCP18 Extremes Snow and Wind, WSP, May 2020
[34] Scoping Review on the Potential Impact of Climate Change and Trees and Vegetation Along the Railways, The Tree Council, August 2021

- **Interdependencies** – as part of development of this report, we have started work to understand our weather and climate resilience interdependencies with organisations across Great Britain. The findings are set out in **Section 6** and follow up work proposed in **Section 8.3**
- **Adaptation pathways** – we have been working to develop guidance for our regions that will enable them to create long-term regional adaptation pathways to guide their resilience and adaptation decision making over the next 100 years. This initial piece of work will feed into a core ARP3 action discussed further in **Section 8.3**
- **Climate action design manual** – our buildings and architecture asset function commissioned the development of guidance on sustainable building design aimed at reducing operational and embodied carbon and enhancing resilience through actions such as sustainable drainage systems and nature-based solutions. It is hoped that this is the first of a series of guides to share best practice with our asset managers and engineers to help implement innovative ideas as we build the railway of the future

- **Network Rail Weather Service** – our weather forecasting and alert system has been in use for a number of years and several upgrades were required to implement lessons learned over this time. This project involved re-specification of the weather forecasting contract to include bespoke forecasting tools for OLE icing, conductor rail forecasting, adhesion forecasts, over topping forecasts and precipitation analysis. The Weather Risk Task Force will develop and implement a new 'digital platform' with enhanced weather data as one of the Dame Julia Slingo recommendations to support the operational management of the railway
- **Adhesion Research Group** – development of trials of management techniques that are now live on the Network
- **National seasonal reviews** – a review is held at the end of each autumn, winter and summer to learn lessons from incidents and to build response measures into maintenance and preparation plans for the season the following year. A best practice library is being developed through this process

In addition to the targeted research that we commission we routinely liaise with numerous organisations, universities and consultancies though direct relationships and wider forums such as the IOAF (see **Section 3.5** for details of our collaboration). This enables us to track and access the latest research and best practice and, where appropriate, develop relationships and workstreams that allow us to use it within our weather resilience and climate change activities to improve our resilience.

8.2.6. Region and route actions since ARP2

In addition to driving forward our strategic capability on weather resilience and climate change adaptation, we have also been delivering actions to enhance the resilience of the assets out on our network through the work of our regions and routes. This section provides a detailed narrative on our progress since ARP2 using selected examples of actions completed to date from the CP5 (2014-2019) and CP6 (2019-2024) Route WRCCA Plans. These are laid out in line with the key risk climate variables discussed in **Section 7**. Full details of the actions are available in our **CP5 and CP6 Route WRCCA Plans**.

8.2.7. Precipitation

Selected examples of actions we have implemented and progressed since our ARP2 report in relation to increasing our resilience to precipitation events are identified below.

Drainage resilience:

- Wessex route has a drainage renewal and refurbishment programme on track to be delivered by 2024. They also have a programme to reduce track flooding and landslip at the highest risk drainage locations (costing £20m)
- In the North West & Central region a project is underway to collect drainage asset data to ensure targeted maintenance. It is currently 50 % complete with 100 % completion by 2023
- Scotland's Railway have completed the first seven of a CP6 programme of targeted schemes to reduce the potential impact of flooding at locations with a history of past flood incidents
- In Wales route, slope stabilisation has been undertaken route-wide to improve drainage within tunnels and cuttings
- We have partnered with Southampton University (Wessex route) and Cardiff University (Wales route) to provide PhD and MSc topics with industry placements for investigations into earthwork stability and geotechnical and drainage issues, respectively. This will allow better modelling, understanding and management of the impact of weather on assets for CP7 and beyond
- One of our major successes was the delivery of a £6M project to implement RCM controls on almost six miles of route in Kent and Sussex (South East region). This enables a robust procedure for stopping services when river levels are unsafe

In addition to the impacts on drainage assets, heavy, persistent, and extreme rainfall can result in damage to our structural assets. To reduce the risk of flooding and structural scour, actions have been taken across the regions.

Flooding and scour resilience measures include:

- In Wales, Barmouth Bridge refurbishment started in 2021 and will improve resilience against future extreme climatic events as well as extending the lifespan of the bridge
- Scotland's Railway has continued to carry out works on structural assets to reduce the risk of flooding and scour, by undertaking site-specific interventions at 32 sites across the network
- In Wessex, a £1M scheme to put river level monitoring installations and review processes and procedures in place to improve the detection of flooding and flood damage to structures. This is on track for completion by spring 2022
- London North-East and the East Midlands has a £20M scheme to increase resilience to scour at 75 sites. This work is on track for completion over the course of 2019-2024
- Western route plans £7.9M of investment in a package of bridge structures assessments and intervention works at 27 locations. This is on target to be completed by April 2024
- Anglia route plans to install rock armour and toe gabion baskets or reno mattress to remediate the risk of scour in high-risk sites by 2022

Case study 13 - Conwy Valley

The Conwy Valley railway line runs through fields which are prone to flooding from the River Conwy. Over the years this route has suffered from a number of flooding related incidents including two in an 18-month period over 2019-2020. Both incidents washed away sections of the earthwork under the tracks with the second causing it to be closed all summer from June 2020[35].

Reinstatement work costing over £1m was carried out including installing 16,000 tonnes of rock armour to just over a mile of embankment between Tal-y-Cafn and Llanrwst[36]. This has been successful in protecting the line from more significant damage during this year's storms.

The repeated closures of this line and the disruption to travel, often lengthy, have led to passengers losing confidence in the reliability of the service and use of the line drop. After the completion of the repair work and the subsequent good performance in the recent storms the number of passengers using the line has seen an increase. This has continued even through the pandemic restrictions highlighting the importance of the railway in enabling social and economic travel for the communities it serves.

Image source: Network Rail

This is an important lesson. It reinforces the need for us to consider the role that our network and services play in the local, regional and national communities and economy when we look to improve the resilience of our assets.

Precipitation can have severe consequences for earthworks assets at either extreme. Heavy or persistent rainfall can lead to washouts and landslips and during prolonged dry periods reduced soil moisture can lead to subsidence from ground shrinkage, particularly in clay soils. The actions and resilience measures mentioned in the following summary of actions will reduce these risks.

Subsidence resilience measures:

- The North-West & Central region CP6 WRCCA plan includes actions to; invest £150M on remedial works at locations at risk of earthworks failure by 2024, installing £2.5M of slope movement and monitoring equipment in a rolling programme across the period - all actions are on target
- Wessex route have a geotechnical renewal and refurbishment programme which is on track to be delivered by 2024, and are spending £80M to reduce landslip risk by 25 % at the highest risk geotechnical assets
- In April 2020 South East route completed a £112M programme to reduce the number of geotechnical sites affected by adverse and extreme weather
- Scotland's Railway are delivering a geotechnical workbank to reduce the number of earthworks deemed vulnerable to adverse weather

In addition, multiple regions plan RCM rollout which will lead to early detection of earthslips, giving us the capability to a) carry out timely and efficient maintenance intervention as opposed to reactive work and b) to better manage traffic on the network to mitigate the risk of train accidents in the event of earthworks failures.

[35] Eryl Crump (2020) 'Lifeline' Conwy Valley railway washed away for second time in 18 months will stay closed all summer [online] Available at: **https://www.dailypost.co.uk/news/north-wales-news/lifeline-conwy-valley-railway-washed-18403798** Last accessed: 23/08/2021

[36] Network Rail (2020) Additional work to Conwy Valley line aims to prevent long closures due to railway wash out [online] Available at: **https://www.networkrailmediacentre.co.uk/news/additional-work-to-conwy-valley-line-aims-to-prevent-long-closures-due-to-railway-wash-out** Last accessed: 23/08/2021

8.2.8. Sea level rise, coastal erosion and coastal flooding

Since publishing our ARP2 report we have worked to improve the resilience of our coastal assets to reduce the risk that sea level rise and its impacts pose. Examples of where we are protecting our coastal assets are provided below.

Sea defence resilience activities

- Western is undertaking work to repair and reinstate sea defences at Exmouth and between Lostwithiel and Fowey by 2024
- Western is implementing the Southwest Rail programme which is significantly improving the resilience of the Exeter to Newton Abbot route (which runs through Dawlish). Work includes track realignment, sea wall strengthening, cliff face stabilisation, beach reclamation and a rock fall shelter. Climate change scenarios were used in the design of this work
- Wales will continue to use their 'Assetcoast' and 'Forecoast' tools to monitor and manage the risk to their estuarine and coastal assets respectively
- Wales undertook a strategic review of the implications of shoreline management plans which could result in an increased risk from coastal erosion and flooding to the railway

8.2.9. Temperature

The section below summarises the key actions that our routes and regions have taken and are progressing since the publication of our ARP2 report.

Hot, dry weather (heatwave) clay embankment desiccation actions

- Western plans to create a high-risk desiccation embankment register, undertake surveys and install equipment to monitor slopes known to be vulnerable and to develop a cyclic tamping strategy with ringfenced shifts to take place twice a year
- Western and Anglia both plan to carry out the ongoing removal of high-water demand trees on high-risk clay embankments
- Anglia route will also commission research into alternative stabilisation techniques
- Wessex has a new process for more effective management of desiccation sites was established for summer 2019 with annual reviews

Actions to combat extreme hot temperatures

- General actions include ongoing maintenance of track deficiencies each winter as part of our summer preparation, installation of rail temperature probes to allow better management, painting of assets (e.g. rails and roofs) white to reflect solar radiation and installation of track on reinforced concrete slabs rather than sleepers and ballast at vulnerable locations[37]
- London North East and East Midlands replaced 51km of jointed track with continuously welded rail reducing temperature related impacts, and since 2019, temperature should now be considered in the installation of signalling and telecoms and electrical plant and equipment in buildings by. They have schemes to convert OLE to more resilient modern designs by 2024
- North West and Central has actions to consider heat impacts in all signalling equipment renewals and re-tensioning of OLE to restore wire tensions to current requirements for 18˚C to 38˚C resilience, by March 2024

[37] https://www.networkrail.co.uk/running-the-railway/looking-after-the-railway/delays-explained/buckled-rail-and-summer-heat/

Actions to combat extreme cold temperatures

- General annual activities across our regions include: using our specialised winter fleet to keep lines open and safe (snow ploughs, snow blowers, equipment fitted with brushes, steam jets, scrapers, hot air blowers and the use of antifreeze where appropriate), a winter preparation maintenance programme, and close liaison with train and freight operating companies over timetables and services
- Scotland's Railway saw the implementation of management process for icicle formation on OLE and tunnels by 2019 and their CP6 Plan will see an increase in the amount internally heated points operating equipment. It also earmarked £11M to reduce frost heave impact on platform surfaces and coping stones
- Western plans £17.4M investment to reduce rock cutting slope failures from freeze-thaw at various locations, including scaling and installation of netting, and maintenance of existing netting for completion by 2024
- Wales route installed points heaters at various locations by 2019

Action is also taken on this issue by the train and freight operating companies to better equip trains to cope with cold weather conditions. More modern train designs include modifications such as anti-ice systems and wheel slip protection.

8.2.10. Storm and wind events

Resilience and adaptation action to address the rainfall element of storms is included in the precipitation actions text earlier in this section. The text below covers the actions that we are taking cover the wind, lightning and spray effects on our network caused by the risks detailed in **Section 7**.

Examples of lightning resilience actions

- Western has an ongoing buildings risk assessment with protection installation and maintenance if necessary, and commits to include lightning resilience in buildings, signalling and telecommunications equipment renewal designs
- London-North East and the East Midlands is incorporating lightning mitigation in signalling improvement schemes

To combat the impacts that we experience from the effects of the wind in storm events actions have been taken across our routes including vegetation management schemes planned or implemented and detection systems to improve our responses to failures.

Examples of wind risk management schemes:

- Wessex has a route-wide vegetation plan and tree surveys to improve planning and response to increase resilience and passenger safety
- Wales route completed a targeted removal of 20 % of high-risk vegetation in 2020 with a 2024 target of 100 %
- In Western route vegetation on their assets and neighbours land is being surveyed by Light Detection and Ranging (LiDAR) to allow better management of the falling vegetation risk. They are also using train mounted cameras to detect potential or actual overhead line failures to improve their prevention and response activities. A high wind alert process for buildings is also being developed
- The South East route has a rolling programme of vegetation inspections including the identification and removal of dying/diseased trees before they can damage assets
- In the North West and Central region, removal of high-risk vegetation is occurring on high-risk routes reducing, adhesion issues, damage to lineside infrastructure from tree falls. Opportunities are being identified to increase biodiversity at the same time

8.3 Planned actions for ARP3

All of the work done by our central teams and the regions and routes and detailed in this report has greatly improved our adaptive capacity and increased our understanding of the impacts of weather on our assets and nature and scale of the work we still need to carry out. Building on this work into the next 5 years of ARP3 we will be delivering a plan of further strategic actions and asset improvements to ensure progress is made on the delivery of our pathway to 'a reliable railway service that is resilient to climate change' laid out in our Environmental Sustainability Strategy.

This section presents the key adaptation measures planned covering the following key themes:

- Putting strategies, policies and structures in place to drive and manage adaptation action
- Developing guidance and standards to support decision making and adaptation activity
- Engaging in collaboration forums to exchange knowledge and support
- Improving ownership, competence and training
- Continue research and analysis on the weather impacts on the railway
- Region and route actions to improve their resilience including plans and strategies, research and investment in asset resilience

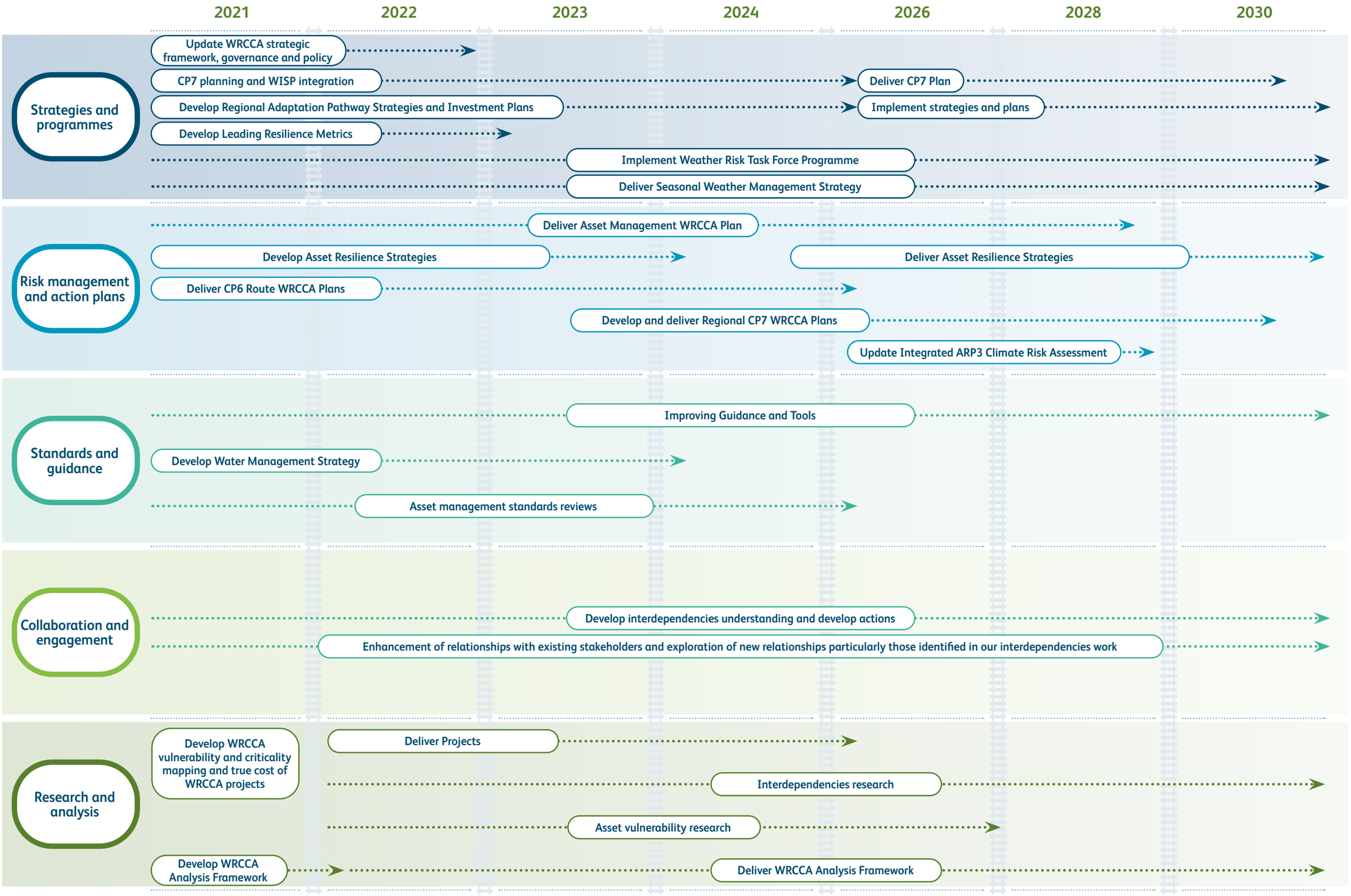
Although the last 5 years has seen good progress in this area our 2020 Environmental Sustainability Strategy has set an ambitious pathway for action, and the changes we are seeing in weather impacts on our services continues to increase the need for action. Going forward further work will be necessary to meet these challenges.

We will continue to deliver work in our core strategy areas and explore what new directions we may need to take to improve our adaptive capacity by:

- Cementing our progress in appropriate governance, policy, and strategy over the short and long-term planning horizons
- Continuing to improve our understanding of the risks through analysis and research into the financial, safety and performance impacts of weather and climate, for example asset sensitivities to climate change, the true cost of current and future weather impacts and how system interdependencies affect the vulnerability and criticality of our assets
- Exploring new methods of adaptation planning, continued collaboration on best practice and responding to reviews and recommendations

Figure 8.2 summarises the key workstreams that we will be undertaking with the aim of creating the framework for adaptation in CP7. Further detail on this work and a summary of actions is provided in the remainder of this section.

Figure 8-2 - Key actions planned for the next 5 years



8.3.1. Strategies and programmes

Strategic framework and governance – In the short-term we will review and update our overarching weather and climate change resilience strategic framework. We will identify any improvements in governance methods and structures and clarify accountabilities where necessary to enable the delivery of our Environmental Sustainability Strategy Weather Resilience and Climate Change road map and goals.

This will take into account the changes in the structure of our business since ARP2, our last strategy, the transition from Network Rail to GBR, our work with the CP7 planning process and the WISP and the lessons that we have learnt from our work on the route and Asset Function WRCCA risk assessments and plans.

Weather and climate change resilience policy – Our WRCCA team will update our Policy and re-issue it in 2022. It will be aligned with our new strategies and include the principles necessary to enable us to achieve our milestones in CP7 and beyond as laid out in our Environmental Sustainability Strategy Climate Change Adaptation roadmap. Further detail on our CP7 work is in the paragraphs below.

CP7 planning and WISP integration – Our past approach to CP planning has been to secure incremental improvements in resilience as assets require repair and renewal or by delivering targeted resilience schemes such as the Exeter to Newton Abbot (Dawlish) Line upgrades. However, the increasing severity and consequences of weather events make it evident that a step change in resilience will be required to meet the challenges of climate change. It is therefore important that our CP7 investment strategies include sufficient provision to build climate resilience into the railway from 2024 onwards.

To start this transition, we are working with the regions in developing their business plans, the Analysis and Economics team to improve the inclusion of climate change impacts in business plan costing and the CP7 planning team to set weather and climate change resilience requirements for CP7.

As the CP7 approach develops it is being used to inform our work with the GBR Transition team (representing the Rail Industry) on the development of the Sustainable Rail Strategy for the next 30 years. This is part of the WISP which is due to be presented to the Transport Secretary in 2022 with an ambition to publish a version to the wider rail industry. The purpose of the WISP is to drive longer-term, more coordinated decision making by:

- Recognising the consequences of the shorter-term business planning decisions on the delivery of longer-term strategic outcomes
- Dovetailing these with the ability to understand what the key options, choices and trade-offs are for the funder(s) to make given the constrained nature of the railway's financial envelope over the next CP

Integrating and embedding the consideration and understanding of climate change risks throughout the industry business planning process from project managers to regulators will be key to delivering a successful adaptation strategy for the railway.

Regional Adaptation Pathways Strategies and investment plans – We are currently developing a Network Rail methodology and guidance for our regions to use over CP7 to develop and put in place their own full Regional Adaptation Pathway Strategies for delivery in CP8 and beyond. These will allow a much more granular understanding of the priority and cost of weather and climate change resilience investment for CP8 and the longer term.

Weather Risk Task Force – The recommendations from the Weather Advisory and Earthworks Review Task Forces are being implemented through the Weather Risk Task Force. Our climate is changing and keeping our railway running safely and reliably in the face of extreme weather is a challenge. Both task force reports will help us improve current practices, the 50 plus recommendations will help to improve safety and performance. The recommendations are far-reaching and complex, involving every region of our business, capitalising on cutting-edge weather science, and transforming our drainage and asset management.

Over the past six months we've been turning those recommendations into realistic and achievable action plans. Our focus now is to keep up this momentum, to keep delivering at pace against these plans and continue to make real, tangible changes. We're working with partners in the wider rail industry, as well as with Lord Robert Mair and Dame Julia Slingo, and together we will tackle the ever-increasing demands of a changing climate, and significantly improve the railway for passengers whatever the weather. For further information on this wide-ranging programme of work, see the November 2021 Weather Risk Task Force Update report.

Competence and capability – As our understanding of how the climate change will affect our business continues to grow and we seek to achieve greater integration of the tools and process necessary to deal with it across our operations we will become more aware of the degree of training, knowledge and resources that will be needed and where. This will allow us to identify what types and levels of competencies we will require our staff to develop and to design competency frameworks and training.

We will learn from and build on the work we have done as part the Environment and Sustainable Development Competence Framework. A key resource in this area will be the Weather Academy which is being developed under the Dame Julia Slingo Weather Advisory Task Force.

Seasonal management – The National Weather team will continue to drive improvement into our operational response to weather events and resilience and deliver the SCSG's 10-year Seasonal Weather Management Strategy (**Section 4.2.3**). This will be through their ongoing programmes of research, assurance reviews of weather preparedness, review and development of their operational weather standards, the production and delivery of the 1-5 year Operational Weather Strategies with the regions and the implementation of the core workstreams in the 10-year Industry Weather Resilience Programme.

The WRCCA team will continue to work closely with them and the SCSG to ensure the alignment with the longer-term climate change strategy and actions.

Measuring resilience – We have significantly advanced our understanding of the current and future weather-related risk to our operations in the form of safety risks, service interruptions and, to a degree, costs. However, with the exception of the climate change data used in our assessments all of this work has been done using current and past data and trends, and to date we have not identified a leading method of tracking our risk trajectory or adaptation progress. Work to develop a methodology and a leading resilience metric will support development and delivery of strategic plans and enable us to measure the benefits of investment and progress in building a resilient railway.

8.3.2. Risk management and action plans

Asset Management WRCCA Plan – The creation of this plan has significantly advanced our Asset Function's knowledge of the climate risks to the asset portfolios managed by our regions and identified actions necessary to embed weather and climate change risk management and adaptation into our existing asset management framework.

As detailed in **Section 4.3.2** the work generated a plan of actions that the Asset Functions have identified as necessary to address their risks. The next phase of the work will be the implementation of these over the remainder of CP6 through the following workstreams:

- Update the risk assessment and action plan to include the Telecoms team that has now moved into the chief engineer's team
- Agree implementation plans with the individual Asset Functions within the chief engineer's team
- Set up a progress monitoring and reporting process that mirrors the one already used for the Route WRCCA Plans
- Commission any research or analysis identified as necessary to enable actions and/or close knowledge gaps

This work will be carried out by the chief engineer's team with technical support from the WRCCA team throughout and it will ensure that the appropriate asset management framework is in place to support our regions asset management strategies from CP7 and beyond.

As the current actions are implemented and new actions are identified by the periodic review cycle baked into the management of the plan the net result will be the integration of climate change adaptation into our asset management process as the default at design level. This will accelerate our incremental adaptation by integrating it across our investment and project delivery activities in the regions.
Detail on the specific actions to be taken can be found in our Asset Management WRCCA Plan.

Asset Function Resilience Strategies – The integration of the risk assessments from the Route and Asset Management WRCCA Plans has given us insight into the scale and nature of the risks that our assets face and the ability to identify the actions that need to be taken to address them.

The Asset Management WRCCA Plan contains actions for our TA chief engineer's team to ensure that the framework for asset management enables and promotes adaptation as the default when asset interventions are planned, and the Route WRCCA Plans have identified specific resilience actions for their assets.

Using the outputs of the risk assessment and building on the implementation of their action plan the chief engineer's team will work with the ALTs to explore the development of resilience strategies for the asset groups. These will take a systems approach to the management of the risks, taking into account our asset interdependencies and where appropriate our interdependencies identified in **Section 6**.

Route WRCCA Plans – Regions will work to deliver actions in their CP6 Route WRCCA Plans and will develop plans for CP7 (2024 – 2029) based on the funding settlement linked to their strategic business plans. Further details of the CP6 Plans can be found in **Section 4.3.1**, key actions completed to date are in **Section 8.2** and the full plans and actions can be found **here**.

Case Study 14 - Vineyards Farm

Our track at Vineyards Farm in Wales is highly vulnerable to the consequences of heavy rain and has seen increasingly frequent washouts of its embankment and track bed. This causes around two weeks of track closure every time and each event has cost us roughly £1 million.

After consecutive years of failures, we are investing £3.3 million in work to improve the resilience of the line to future heavy rainfall events by installing approximately 800 metres of rock armour on the downside of the embankment. Whilst this will not stop floods from occurring, it will reduce the scour impact of flowing water which would weaken the structure and improve embankment stability. This will reduce the likelihood of washouts and lessen their severity when they occur leading to reduced recovery times and improving train performance.

Completely removing the flood risk at this location would have been far more intrusive and costly. This scheme is a good example of how we can use targeted proactive measures to increase the resilience and deliver safety and service improvements while balancing the need to invest our resources efficiently.

As climate change increases the likelihood and severity of weather-related impacts eliminating risks will become harder, more costly and potentially unsustainable or impractical. To meet this challenge, we will need to agree service levels for extreme weather conditions with Government and regulators and explore more sustainable solutions such as catchment-based water management.

Image sources: Network Rail

Integrated ARP3 Climate Risk Assessment – We will continually review and update our integrated risk assessment to expand its scope beyond asset risks to encompass the wider risks to our business and to account for changes in our understanding of the weather and climate change adaptation challenge.

Key areas of risk already earmarked for exploration are:

- How the climate changes that we are planning for will affect the wellbeing and safety of our workforce both on the front line and in our buildings
- Integrating our interdependency risks as we build our understanding of them
- Long-term strategic planning issues such as the need to move or abandon sections of track

8.3.3. Standards and Guidance

Improving guidance and tools – We periodically review and update our current climate change guidance to incorporate new data such as updated climate projections and in response to user feedback on ease of use/ relevance and scope. We are currently converting the extensive data tables in our Climate Change Projections Guidance Note into a simple Power BI based query building tool making it easier and quicker for users to access the data. It will also reduce the possibility of users accidentally selecting incorrect data.

We will continue to work with our stakeholders to understand what further information and tools would facilitate the adoption of adaptation practices and the embedding of them into our business as usual operations and how best to provide it.

One action we have already identified in this area is the conversion of our two current guidance documents into standards. Not only will this mandate their use in our asset management processes, it will also make it easier for them and their requirements to be incorporated into other existing standards.

Other actions are likely to be the incorporation of climate data into asset management tools such as asset deterioration and costing models, the identification of new data sets like failure asset thresholds and the development of training and briefing tools as part of the work to develop competencies.

Asset management standards reviews – The Asset Management WRCCA Plan contains 55 actions relating to the review and update, as appropriate, of standards and specifications. The chief engineer's teams will carry this out across the remainder of CP6 as part of the work to ensure that the asset management governance framework is fit for CP7.

Water Management Strategy – Whilst investment in our drainage management has been a priority over recent years and our current Drainage Standards do include climate change uplifts for system designs, we recognise that there are areas of significant improvement that could be made.

Our current strategy is based very much on a predict and provided basis reliant on pipes and ditches to remove water from our assets. Also the UKCP09 climate change projections used have been superseded by newer UKCP18 based uplifts specified by the EA, SEPA and NRW.

We are currently developing a new strategy focussed on the sustainable management of water using a catchment-based approach. This will include the consideration of the future effects of climate change on precipitation and water flows in line with our Climate Change Projections Guidance Note which incorporates the current regulatory guidance on flooding.

The benefits of this more holistic approach to water management involving wider stakeholders will be solutions that are more environmentally and operationally sustainable whilst continuing to reduce safety and performance risks and impacts.

8.3.4. Collaboration and engagement

As we have said in this report and in many of our interactions with our stakeholders the scale and nature of the weather and climate change challenges that we face mean that we will only be able to adapt successfully with the help of others.

Section 5.3 has clearly laid out the current broad reach of our work with many of our stakeholders, particularly through key interactions internally and with government, the rail industry and the wider infrastructure sector across the UK and abroad. We will continue to maintain and strengthen these relationships going forward to ensure that we can clearly communicate our plans and needs, understand those of our stakeholders and so that we can identify opportunities to work together to achieve the best and most efficient adaptation outcomes.

Key areas of collaboration over the short-term will be with:

- DfT to build understanding of the scale of the issue for the rail industry, the expectations that will be placed on us in terms of service and efficiency
- The GBR Transition team to develop the WISP and the Sustainable Rail Strategy
- The Flood and Coastal Erosion Risk Management and wider water management community to, particularly in the implementation of our Water Management Strategy and over the increasing activity in the areas of third party involvement in flood management
- Our Relationships with the IOAF and the Transport Adaptation Steering Group
- Extending our understanding of our interdependencies so that we can start to identify management actions

8.3.5. Research and analysis

Our R&D team will continue to co-ordinate our core innovation and research activities with their wide range of partners including asset specific projects dealing with aspects of the weather, for example to better understand the relationship between rainfall, soil moisture and slope failures. It is likely that for the foreseeable future the focus will remain on remote monitoring technologies, intelligent infrastructure, digital signalling, low carbon solutions, geotechnics and drainage.

In addition, the WRCCA, National Weather and chief engineer's teams will need to continue their analysis to improve our understanding of the criticality and vulnerability of our assets in relation to weather events and climate change. Key pieces of work in this area will be:

WRCCA vulnerability and criticality mapping – This will develop a methodology and tool to support the identification and prioritisation of WRCCA resilience interventions based on the vulnerability to current and future weather conditions, and asset risk and criticality. It will draw on a repository of existing and, where appropriate, new asset, operational, cost, geospatial and climate change information through a common and simple to access interface.

The goal is to provide a 'single source of the truth' for use in making informed investment and engineering decisions that are resilient to our current weather conditions and the likely climate change effects over their lifespan.

The real cost of WRCCA – This is designed to fill the gaps in our understanding of the full costs of current incidents, to identify how the projected future climate trends will change the frequency and scale of these and to provide tools and methods of integrating this data into business as usual cost benefit analysis, and other investment decision making tools. The outcomes of this project will be a key input of the WRCCA vulnerability and criticality mapping tool.

Interdependencies – Although there is no specific work stream for interdependencies related research at this time it is anticipated that the work to improve our understanding in this area is likely to identify research and analysis needs. For example, modelling the effect on passenger flows of weather event impacts on the road network, catchment modelling to understand the impacts of land use changes or the effect of fluctuations in our power supply.

Asset vulnerability – The Asset Management WRCCA Plan has already identified 20 research and analysis actions such as:

- OLE designs and conversion of legacy systems to provide more robust components against projected Network Rail climate change guidance
- Non-destructive testing of stress in rails to provide a more accurate and efficient means of measuring rail stress in track
- To understand the role of weather (e.g. heatwaves and precipitation) and climate change on soil moisture and the subsequent impacts on drainage assets
- On aerial surveys to determine vegetation growth rates and development of decision support tools to integrate improved controls in standards

It is anticipated that the review of standards and specifications and the development of the national and regional resilience strategies will identify further needs for research.

WRCCA Analysis Framework – With such a large amount of research being undertaken across our business by a wide variety of teams in such a fast-moving field it is very hard to keep a handle on what we know, what someone knows that hasn't been widely shared and what we still don't know. We are reviewing our internal research and relevant external research with the aim of developing a targeted analysis framework to guide our work going forward.

8.3.6. Summary of ARP3 actions

Table 8-2 below summarises the actions discussed above indicating ownership and a timeframe for delivery.

Table 8-2 – ARP3 actions

Action	Owner	Completion date
Strategies and programmes		
Update WRCCA Strategic Framework	TA WRCCA strategy manager	2022
Update WRCCA Policy	TA chief environment & sustainability officer	2022
Publish CP7 Business Plans	Chief executive	2024
Develop Regional Adaptation Pathway Strategies and investment plans	Regional directors for Engineering and Asset Management	2024 (develop) Delivery ongoing
Implement Weather Risk Task Force programme	Weather Risk Task Force programme manager	2024 and beyond
Deliver Seasonal Weather Management Strategy	Seasonal Challenge Steering Group	2030
Develop leading resilience metric	TA WRCCA strategy manager	2022 and beyond
Risk management and action plans		
Deliver Asset Management WRCCA Plan	Chief engineer	2024 and beyond
Develop and deliver Asset Function Resilience Strategies	Chief engineer through Asset Leadership teams	2024 (develop) Delivery ongoing
Deliver Route CP6 WRCCA Plans	Regional directors for Engineering and Asset Management	2024
Develop and deliver Regional CP7 WRCCA Plans	Regional directors for Engineering and Asset Management	2024 (develop) 2029 (deliver)
Review and update Integrated ARP3 Climate Risk Assessment	TA WRCCA strategy manager	2026 and beyond
Standards and Guidance		
Improving guidance and tools	TA WRCCA strategy manager	Ongoing
Asset management standards review and update	TA network technical heads of assets	2024
Water Management Strategy	TA network technical head of drainage	March 2023
Collaboration and Engagement		
Continued collaboration with internal and external stakeholders	TA WRCCA strategy manager	Ongoing
Research and analysis		
WRCCA vulnerability and criticality mapping R&D project	TA WRCCA strategy manager	2024
Real Cost of WRCCA R&D project	TA WRCCA strategy manager	2024
Interdependencies research and risk assessment	TA WRCCA strategy manager	Ongoing
Asset vulnerability research	TA network technical heads of assets	Ongoing
Development and delivery of WRCCA Analysis Framework	TA WRCCA strategy manager	2022 (develop) Ongoing delivery

9 Conclusions

Current weather patterns already pose a significant challenge to the resilience of the railway and our services. Weather impacts can pose serious risks to the safety of the railway and our passengers, cause costly damage to our assets and disrupt our service affecting the wider economy and the lives of our passengers and neighbours.

We have long recognised that the successful forecast and management of weather risks is key to running a safe, reliable and efficient railway. As the effects of climate change become more pronounced delivering our vision of 'a reliable railway that is resilient to climate change' will become more challenging.

Our climate change adaptation policy and strategy framework and the systems that enable its delivery are supported by our Executive Leadership team and are improving through collaboration with our partners in adaptation, particularly our National Weather team, the asset management community and our regions. Key to driving action has been the commitment of key individuals across these business units which have become our network of WRCCA leads.

Since our ARP2 submission we have made good progress in improving our understanding of the risk, the governance structure that enables our activities and in the development of our knowledge base through research and analysis. We have transformed this knowledge into action by providing guidance and tools for our regions and routes to deliver climate change adaptation action 'on the ground'.

We have integrated climate resilience into our asset policies and strategic business plan and published our Environmental Sustainability Strategy. Our asset management process has been made more resilient with an integrated risk assessment and action plan in place across our asset functions and through greater integration of weather resilience and climate change assessments into asset creation. Improving the resilience of our assets and processes will continue to remain one of our planning and investment priorities to ensure that we can build on our ARP2 progress.

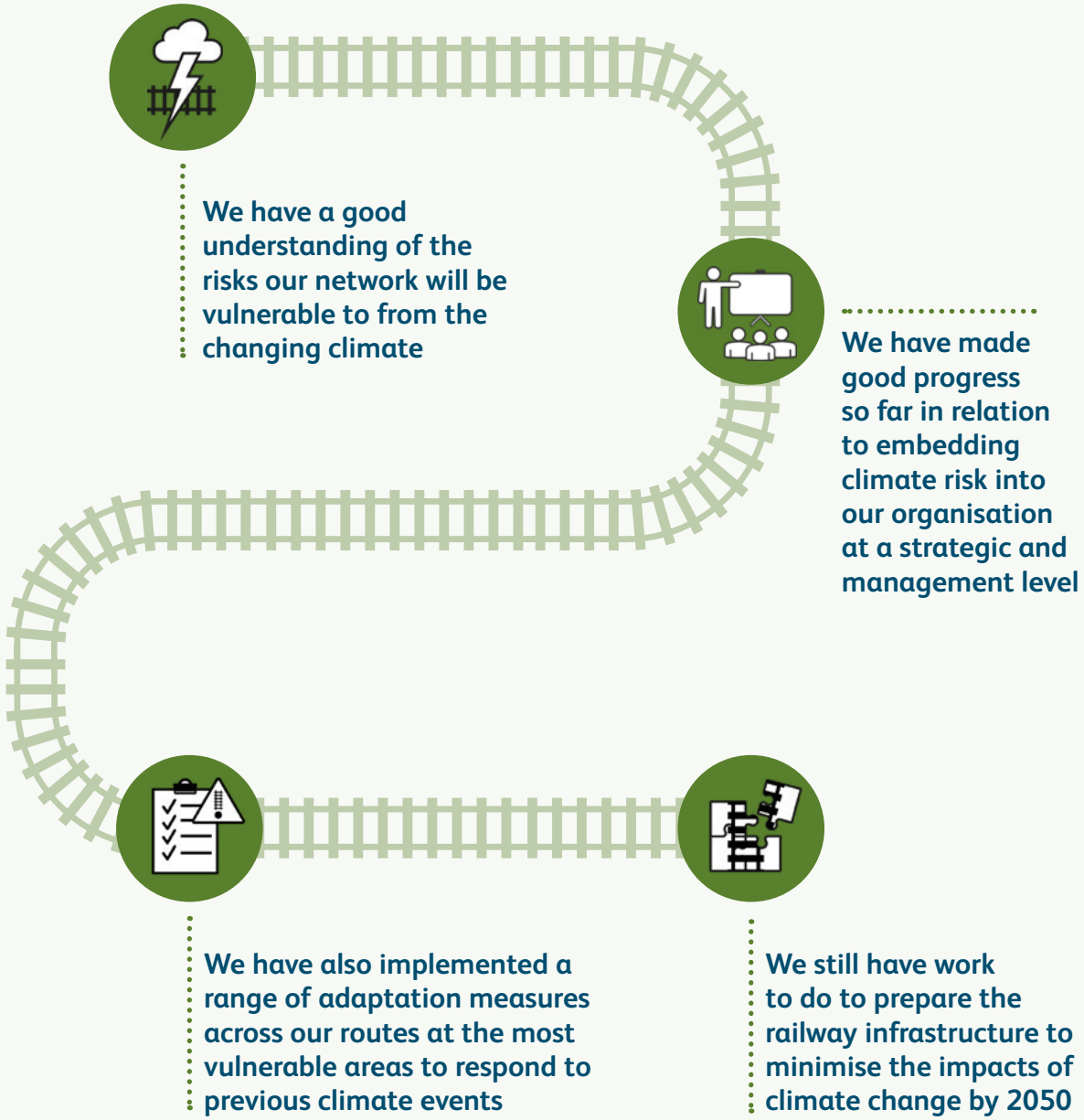
Compared with previous investment periods, we have seen a greater number of resilience actions in CP6 and are making good progress towards improving the embedding of climate change into CP7. However, we understand there is still much to do and we require continued action on understanding our risks, building our adaptative capacity and investing in current and future levels of resilience.

Particular focus will continue to be through the delivery of strategies and investment in our asset management processes at both national and Regional levels, enhancement of our standards and climate guidance, and continued knowledge generation through research and collaboration. Through the development of long-term regional strategies and adaptation pathways we will support the regions in developing and delivering their own actions, in alignment with our core national strategy.

While improving the resilience of our own systems and processes will remain a core business priority the scale of our company's activities and the climate challenges make it obvious that we cannot adapt successfully on our own, a conclusion reinforced by our recent interdependencies work. We will continue to be an active partner in transport and cross-sector collaboration groups and seek to grow our understanding of our interdependencies and our relationships with them. We will also actively seek out opportunities for partnership working on research and adaptation actions.

Delivering our planned actions will enable us to increase our resilience to meet the current and future needs of our customers and the UK economy in the face of the climate change challenge. This will require increased collaboration across organisations and sectors and the prioritisation of and commitment of resources within our business, across the transport sector and the wider economy. Achieving this will enable us to deliver our vision of: 'Serving the nation with the cleanest, greenest mass transport'.

Figure 9-1 represents the key conclusions from this round of adaptation reporting.



Appendix A – Integrated ARP3 Climate Risk Assessment

A full copy of our Integrated ARP3 Climate Risk Assessment can be found here.

Appendix B – Linked documents

You can find links to all of the core documents that feature in the Third Adaptation Report (ARP3) below.

Network Rail Asset Management WRCCA Plan

Climate Change Projections Guidance Note

CP5 and CP6 Route WRCCA Plans

Environmental Sustainability Strategy

The Great British Railways: William-Shapps Plan for Rail

Social Value Framework

Weather Resilience and Climate Change Impact Assessment Guidance Note

Weather Resilience and Climate Change Adaptation Strategy (WRCCA)

Weather Risk Task Force

Network Rail Limited
1 Eversholt Street
London NW1 2DN

Tel 020 7557 8000
Email ClimateAdaptation@networkrail.co.uk

networkrail.co.uk

Company number: 4402220
Registered in England and Wales
Company number SC229780
Registered in Scotland