CP7: 2024 – 2029

North West & Central Region

Weather Resilience & Climate Change Adaptation Plan

Document control

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P01	16/11/2022	First draft circulated for comments / additions
1.1	09/02/2023	Version 1 Third draft following Technical Authority review on 30/01/2023
1.2	10/04/2024	Version 2 following Technical Authority and Office of Rail and Road review.

Submitted as part of Network Rail Northwest and Central CP7 Delivery Plan.

This plan (contents of this document, including proposed actions) has been updated based on:

- Draft (June 2023) and Final (November 2023) Determinations from ORR
- The Network Rail Third Adaptation Report (2021)
- The Network Rail Third Adaptation Report: Appendix A Integrated Arp3 Climate Risk Assessment
- The Network Rail Environmental Sustainability Strategy 2020 – 2050 (2020)
- The North West and Central (NW&C) Strategic Business Plan (2023)

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Purpose of this document
This document defines the NW&C Region Weather Resilience and Climate Change Adaptation (WRCCA) plan for control period 7 (CP7 2024 – 2029). This comes against the backdrop of the CP6 (2019 – 2024) WRCCA plan. This assessment is supported by an evaluation of the resilience of rail infrastructure to historical weather events and an awareness of potential impacts from regional climate change projections. The resilience of the train and freight operating companies, rolling stock and passengers within the region is not specifically assessed.

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1. Foreword

Climate change and extreme weather have presented real challenges in control period 6 (CP, 2019 – 2024). The floods of 2019 – 2020 and heat of 2019 and 2022 were most notable. At times, services have been delayed or cancelled, adversely impacting passenger and freight trains.

The consequent compensation to those rail companies is presenting an increasing cost-burden to the region. The long-term average increase in delay costs is £0.61m p.a. and 3,750 delay minutes. Since 2016, the total cost of schedule 8 weather delays is £143m. These payments are costs paid by Network Rail to train and freight operating companies for reduced track access because of weather events such as track flooding.

Projections show that climate challenges are going to continue to mount. Along with our challenges in managing floods, heat, and cold weather, impacts from wildfire and large hailstones are now not improbable. The climate is changing, and this is why this plan is a critical part to the sustainable growth of the North West & Central Railway (NW&C).

In CP6 we have continued to manage extreme weather, and in places, adapted to climate change. Where assets have been impacted, they have been rebuilt or repaired in a way to make them more resilient in the future. We must continue to learn from events, evolving our engineering mindset through adopting latest practices and standards, as we move in to CP7 (2024 – 2029). The Weather Risk Task Force (WRTF) has also supported the business in improving our resilience plans and activities in CP6, with the delivery of our regional action plans resulting in improvements in weather forecasting, earthwork and drainage cross-working resilience, and heat resilience approaches – particularly for track and overhead line equipment (OLE).

The significant £7.8b NW&C CP7 funding settlement will enable us to renew priority assets. Little of this investment will, however, be on direct climate change adaptation or weather resilience projects. But we estimate that £523.67m will give primary resilience benefits – such as scour protection or drainage. Maintenance and renewals activity are key contributors to improving the network's resilience to extreme weather and continuing our drive for delivering sustainable growth. Replacing like-for-better will be key. For every extra yard of switching jointed track with continuous welded rail we can deliver, we'll generate incremental improvements to our resilience to extreme heat.

Our renewals plan can only deliver so much, especially in a constrained funding environment. We know some assets are at risk to the changing climate, but outside of a renewals programme. In these cases, we will continue to increase the use of technology to enable better risk forecasting and management. Digital Lineside Inspection (DLI), which scans vegetation in the lineside environment, extreme weather management tools such as PRIMA[1] , and slope monitoring equipment are examples of vital environmental surveillance that we will use to prevent a climate hazard from becoming an incident in CP7. We are investing to support this and implement the WRTF actions.

A core facet of this plan will be investing in the competence of our people. Our people require insight and knowledge on future climate change impacts. A fundamental part of our CP7 plan is the development of longer-term climate change adaptation pathways that will identify risk and key decision points in the future for the highest risk locations. We know some key risk locations already, such as Carlisle for inland flood risk, sections of the West Coast Mainline and Cumbrian coastal line for coastal flood and erosion risk, and sections of the line in central route are more susceptible to heat. We will now develop these into clear strategies and plans that will integrate into our Value of Service (VoS) modelling for future investment decisions.

We know the railway is facing multiple challenges from a changing climate. We also know these events are predicted to get more impactful and will be harder to manage. Delivering this plan is a priority for us in NW&C so that weather resilience and climate change adaptation (WRCCA) becomes an integral part of our asset management and operational delivery of the railway.

Kamini Edgley
Director of Safety and Engineering

[1]Proportionate Risk Response to Implementing Mitigating Speeds to Assets.

2. Executive summary

NW&C historically had to manage the vagaries of wind, rain and heat when controlling its infrastructure and train signalling operations. But the region has seen an increase in the number of delays caused by more extreme weather during CP6. This WRCCA plan for CP7 is our commitment to further investment and activity to improve the resilience of our railway. It covers both the weather management and longer-term climate change adaptation of assets.

Climate change projections suggest that extreme weather impacts are only going to grow. In the future, we are likely to see more prolonged periods of dry weather and extreme heat; increased intensity of storms leading to flooding and damage to infrastructure; and sea level rise and erosion.

During CP6, we have intervened in numerous route sections to make our railway more resilient and manage the impacts of extreme weather with less impact on the safe running of trains. Examples include:

- Raising of signalling cabinets at Caldew Junction near Carlisle to prevent flooding and damage to critical infrastructure.
- Using nature-based solutions (NbS), in partnership with the Environment Agency at Thrimby Grange (Cumbria) to reinstate river meanders that reduce flood and scour risk to the railway.
- Installation of slope movement monitoring equipment, with a trial site underway between Watford and Cleverley.
- Installation of active water control measures in the Mersey Tunnel.
- Using technology to target areas of track at risk from buckle to heat so that preventative stressing can be instigated.
- Re-tensioning of OLE contact wires most at risk from sagging during extreme heat.
- Trialling the proportionate risk response to implementing mitigating speeds to assets (PRIMA) tool, to reduce the need to use blanket speed restrictions during extreme rainfall, whilst maintaining safe operation of travel.

These are just a snapshot of the activities that NW&C plan to continue to deliver to enable the railway to become more resilient and adapt to the impact of climate change.

Looking ahead in to CP7, our approach to improving asset resilience must be viewed in light of the available funding. Our investment approach is to ensure that, when we are renewing assets, they will be designed to be more resilient than they currently are. Adherence to standards is crucial to this.

We will continue to explore opportunities to undertake more renewals from efficiencies or different ways of working as we seek sustainable growth within our railway. Where we are not renewing assets, but the asset is at risk from extreme weather, we will use technology to monitor and keep trains running safely. We shall be using CP7 to plan for the future and implement climate change adaptation pathways to support our people to make the right investment decisions. We will also support our people with training and competence development.

Our plan covers investment in asset resilience that delivers both primary climate resilience benefits; continued support and development of tools to better manage extreme weather as well as focusing on longer term asset planning that takes cognisance of climate change. The plan shall be monitored regionally, and progress reported every six months to our regulator, the Office of Rail and Road (ORR).

The plan will enable an improvement in asset resilience in certain high service value route sections where interventions occur. Works will occur in a way that is mindful of the broader funding context which will involve trade-offs. Climate resilience is a multi-control period activity, and this plan will inform future control periods just like the CP6 plan has informed the creation of this one.

How climate can affect a safe and reliable railway

Power enclosures and other equipment housings can become submerged in cases of flooding or damaged by debris in high winds and cease their operation, leading to a loss of power supply or railway signalling.

Fencing and barriers can become dislodged/damaged during high winds and storms.

Miles of rail can absorb heat from the suns rays, making rail temperature sometimes much hotter than the air temperature. High traffic route sections can compound rail heat impacts. This can cause the track to deform, or buckle. Dynamic management and train speed restrictions are sometimes required to manage risk.

De-wirements can occur due to high winds and heat causing soil shrinkage and storms/floods carry debris onto the track, damaging catenary infrastructure.

A build up of ice can effect the operation of overhead line equipment.

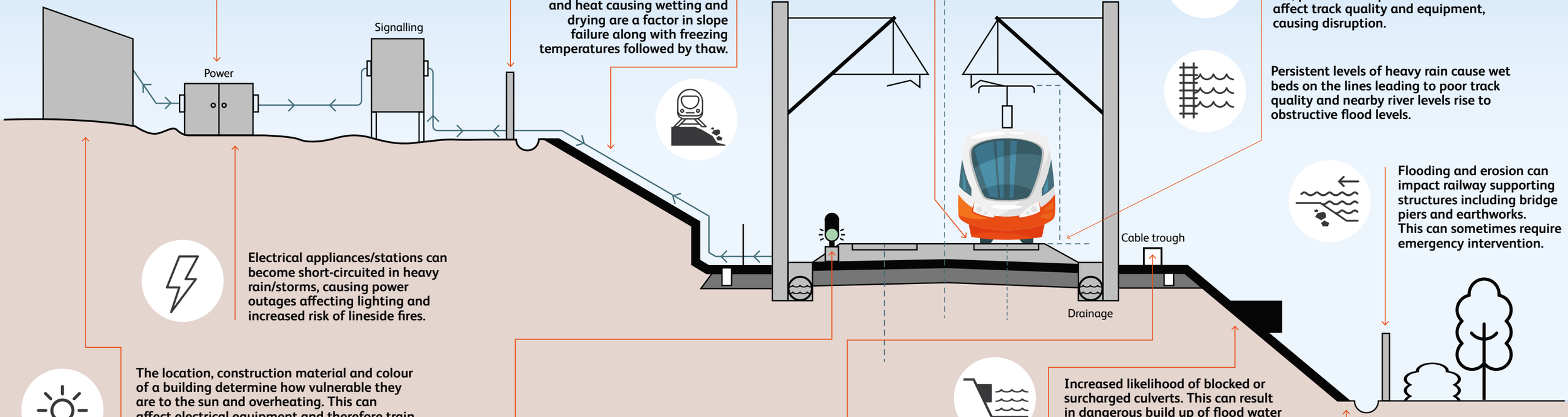
Station buildings and canopies are vulnerable to high winds.

Earthworks can fail resulting in landslides onto the railway causing obstruction and loss of track support. Intense rainfall and heat causing wetting and drying are a factor in slope failure along with freezing temperatures followed by thaw.

Intense prolonged rain can result in drainage systems being overwhelmed and water sitting on the ballast, rail, points or sleepers. This can affect track quality and equipment, causing disruption.

Persistent levels of heavy rain cause wet beds on the lines leading to poor track quality and nearby river levels rise to obstructive flood levels.

Flooding and erosion can impact railway supporting structures including bridge piers and earthworks. This can sometimes require emergency intervention.



Electrical appliances/stations can become short-circuited in heavy rain/storms, causing power outages affecting lighting and increased risk of lineside fires.

The location, construction material and colour of a building determine how vulnerable they are to the sun and overheating. This can affect electrical equipment and therefore train performance. Air conditioning can be expensive and power intensive measure.

Flooding can move contaminants, including from oils.

Signalling systems can be disrupted by extreme heat, electrical storms and flooding, with the loss of the ability to safely signal trains.

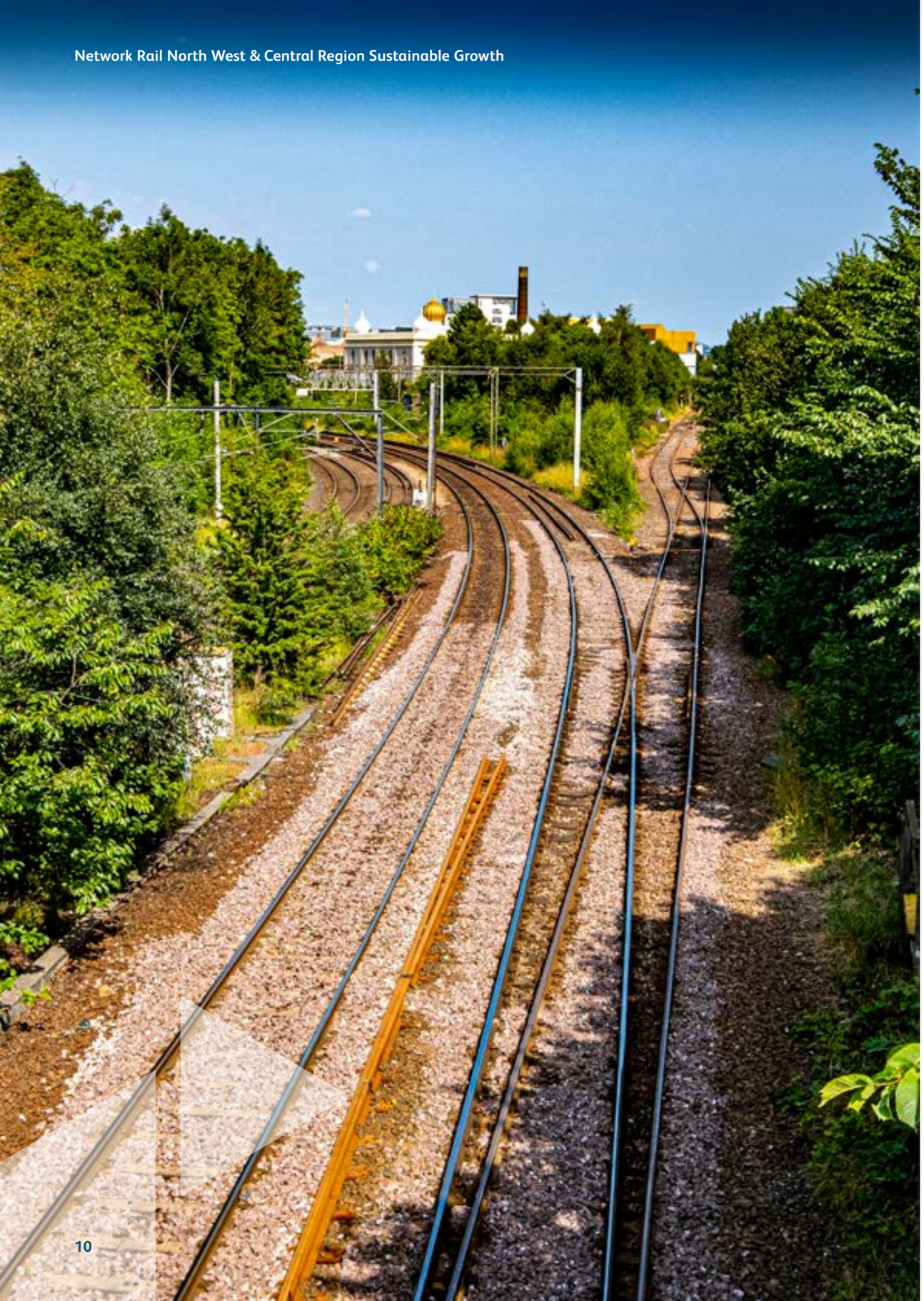
Water can enter cable routes and cause cables to be submerged, over time this causes cable failure leading to electrical failures and equipment failure to operate.

Increased likelihood of blocked or surcharged culverts. This can result in dangerous build up of flood water on one side of an embankment.

In rare instances water and soil can descend down railway verges affecting line-side neighbours.

Excessive vegetation growth can block signals and access to safety critical assets and in high winds trees fall on the line.

Figure 1) Weather and climate impacts on the railway Credit: Network Rail (NW&C) and Matrix Communication Consultants



3. Introduction

3.1. Purpose

The railway has always managed the impact of weather on its safe operation throughout the seasons (Figure 1). We know that the passenger and freight services that use our infrastructure can be impacted by:

- **Heavy rain** – leading to flooded infrastructure, track washouts, damage to structures such as bridges from scour and earthworks failures leading to landslips. Storm Desmond (2015 – 2016), and subsequent storms have resulted in disruption for passengers and freight (Figure 2).
- **Excessive heat** – that can lead to a range of failures including sagging of overhead lines (and subsequent fouling of pantographs), track buckles, lineside fires, subsidence from soil desiccation and equipment failure from overheating (Figure 4).
- **Lightning strikes** – which can damage electrical and signal equipment.
- **High winds** – resulting in objects striking OLE, track obstruction, resulting in objects striking OLE, track obstruction and windspeeds that make it unsafe to operate at full speed or – in extreme cases – not at all.
- **Autumn leaf-fall** – resulting in objects striking OLE, track obstruction and windspeeds that make it unsafe to operate at full speed or – in extreme cases – not at all.
- **Snow, hail and ice** – leading to the blocking of the line, flooding through thaw, points freezing-up and damage to trains from the impact of ice formations in tunnels.
- **Fog** – causing issues with signal sighting and safe operation of services.

We also know that our climate is changing. It is projected to continue to evolve and place further challenges to the safe running of our railway. This plan sets out how NW&C region will prioritise work to adapt to the changing climate in CP7 – building on our WRCCA plans for CP5 and CP6. The geography of the regions is in some ways a determinant of the climate impacts, the NW&C region is discussed in the next section.

3.2. The NW&C region

The NW&C region is the economic spine that links many major cities – from Euston in the South all the way to the Scottish border. The West Coast Mainline (WCML) is its most prominent asset. The region is split in to three independently managed routes, covering 24% of the National Rail network:

- **West Coast South** – operating the WCML South from the principal station of Euston to Crewe, and branch lines such as the Abbey Line and Bletchley to Bedford.
- **Central** – encompassing the West Midlands with busy cross-country routes via Birmingham New Street, as well as the Chiltern Mainline to London Marylebone.
- **North West** – operating the WCML North, running from Crewe to the Scottish border, major stations include Manchester Piccadilly and Liverpool Lime Street. There is also the Cumbrian coastal line and Hope valley line – low revenue but important strategic route sections for the wider economy.

Our routes are enabled by regional support functions, as well as capital delivery who undertake renewal and enhancement projects for the routes. The geography of NW&C affects the regional climate with marked differences from the coastal uplands of the North West generating higher rainfalls compared to the lowlands of the West Coast South that can be more prone to higher temperatures. This means that the North West route is more susceptible at times to autumnal and winter storms – leading to flooding, landslips and track obstruction issues. Although, as a whole region, these issues are also seen in the Southern half. This infrastructure exists to serve key train and freight customers in the region, which is discussed in the next section.

Figure 2) Flooding on the West Coast Main Line north of Carlisle – storm Desmond (2015 - 2016). **Source:** West Coast Main Line to reopen today (networkrailmediacentre.co.uk) **Credit:** Network Rail.

3.3. Key customers

The region is home to 6,700 passenger and freight services per day[2], moved by a range of Train and Freight Operating Companies (TOCs & FOCs). Customers in the region are: Avanti West Coast, Cross Country, Transpennine Express, Northern, Mersey Rail, Great Western Railways, Chiltern Railways, London Northwestern Railway, West Midland Railway, West Coast Railways[3], Transport for Wales, Rail Operations Group[4], Arriva Rail London, Caledonian Sleeper, GB Railfreight, Freightliner, Direct Rail Services, Colas Rail and DB. These companies offer services which span routes with differing usage, investment and climatic challenges.

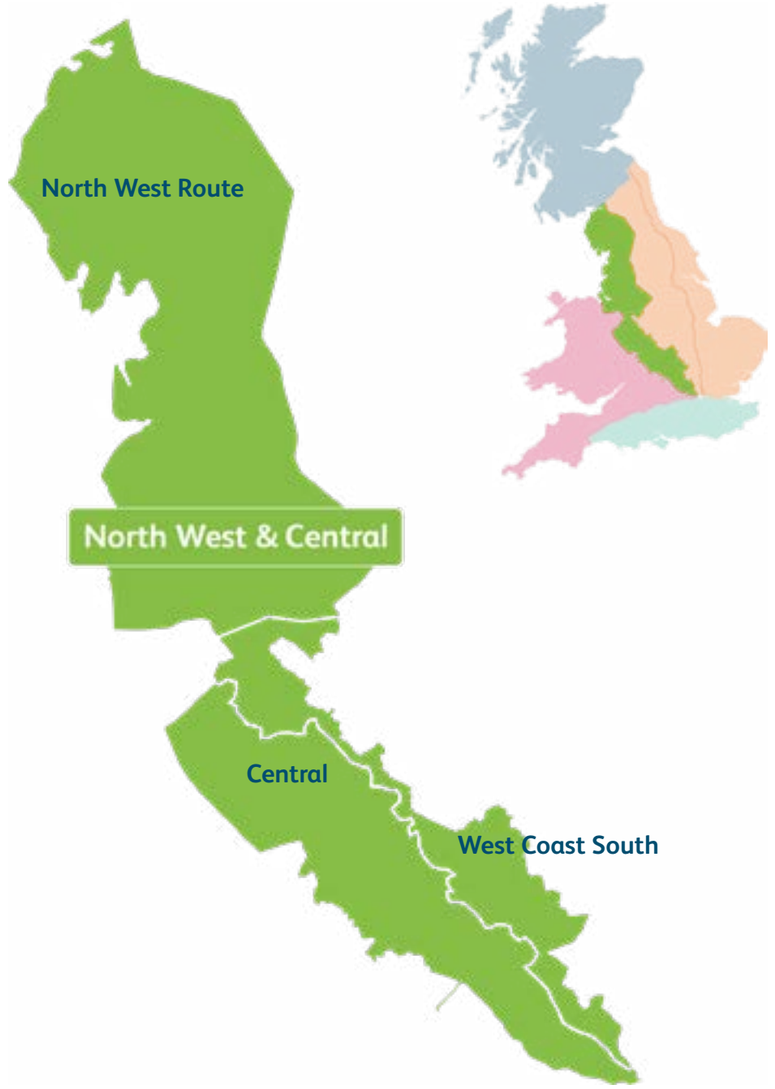


Figure 3) A map of the North West and Central region. **Source:** North West & Central region – Network Rail. **Credit:** Network Rail

[2]North West & Central region – Network Rail. [3]A specialist operator of scenic and charter trains – including steam trains.
[4]A provider of ad-hoc movement of rolling stock for train operating companies, charter trains and locomotive spot hire.

3.4. Weather impacts for the NW&C region

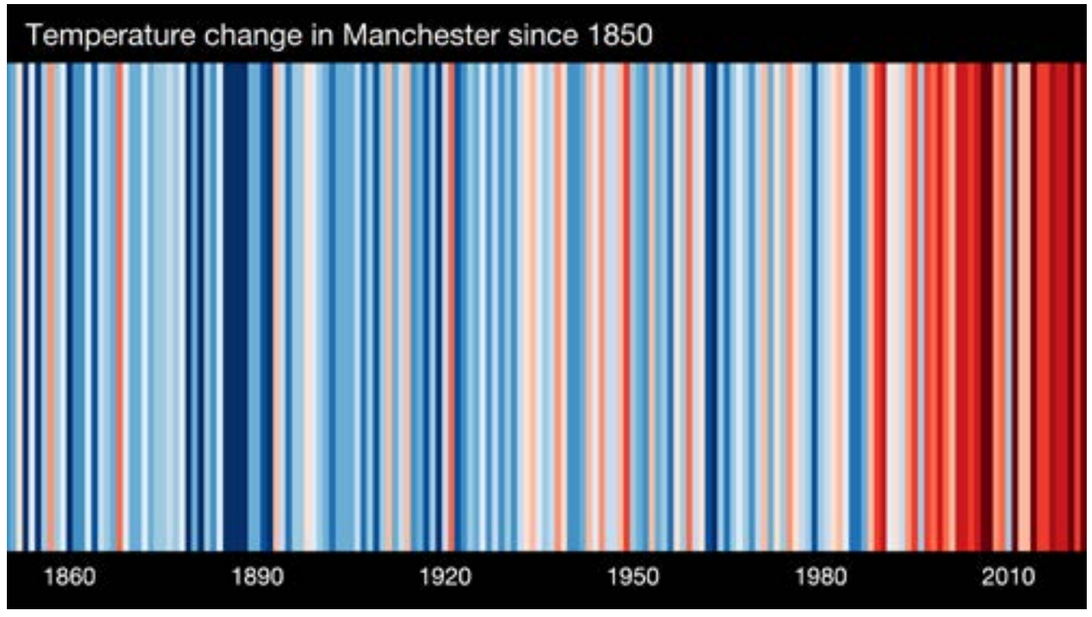
Geography and climate

The geographical make-up of the region and the current weather patterns can be clearly attributed to our operational delays on the railway. This is seen by flooding, most prominent in the North West, and periods of extreme heat in the Central and Southern part of the region. This is explored more in Section 6 (Our Climate Change Risks). In the last century observations for average temperatures demonstrate the effects of global heating (Figure 4). Consequent new challenges in CP7 will emerge for management of assets not originally designed and built to tolerate extreme heat. The onset of hotter spells observed in Figure 4 (below), would appear to correlate with hot weather delays shown in Figure 5. Figure 1 sets out some of the heat impacts to interconnected rail systems.

Understanding delay costs and minutes by weather category

Passenger and freight journeys have been delayed or cancelled because of extreme weather. The delays and their costs have increased over the long-term across several control periods. Costs incurred by Network Rail, to the TOCs and FOCs, mainly fall under schedule 4 and 8 payments. Schedule 8 would initially cover unplanned delays. Whereas schedule 4 covers reduced access for a planned Network Rail restriction of use. Figure 5 (minutes) and Figure 6 (costs) demonstrate schedule 8 flooding is still by far our largest cause of delay followed by wind, and weather-related earthwork failure. It is fair to say that wind and rain (that can also lead to subsidence) from storms cause more issues than heat, cold and the autumn leaf fall[5]. Yet heat presents an increasing recent challenge, if a close look at the graphs is undertaken. The actual cost in terms of schedule 8 compensation payments is broadly aligned, but Figure 6 does highlight that these compensation costs are disproportionately higher for flood and wind events.

Schedule 4 compensation for reduced infrastructure access, to TOC and FOCs is set out Figure 8. Heat stands out as the biggest schedule 4 impact in CP6. Schedule 4 costs are incurred when remedial works resulting from weather events are undertaken, where temporary closure occurs, or where access is reduced including through speed restrictions. Section 7 (Climate Projection Risk Assessment: Assets) and Section 8 (Control Period 6 (2019 – 2024) Delivery) provide more detail on the sorts of works undertaken. Beyond the general trend discussed, there are some particularly costly events that stand out in CP6, mostly which relate to named storms or heatwaves.



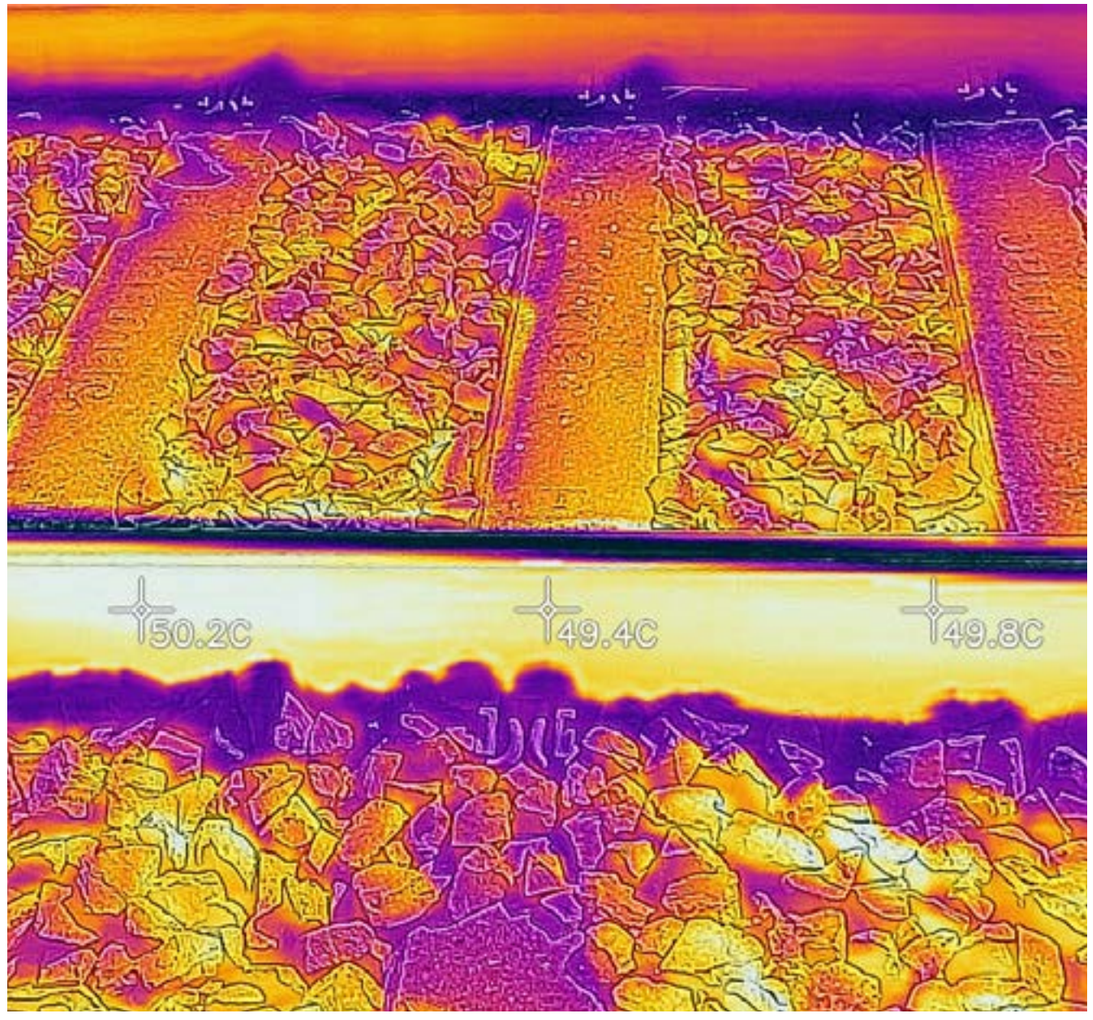


Figure 4) Average temperature increase in Manchester. **Source:** New tab (showyourstripes.info). **Credit:** Ed Hawkins, National Centre for Atmospheric Science, University of Reading. **Data:** Berkeley Earth, NOAA, UK Met Office, MeteoSwiss, DWD, SMHI, UoR & ZAMG.

[5]The way that weather related impacts are recorded for schedule 8 does inhibit analysis. Storms that cause wind damage and flooding are not categorised separately.

The costliest single events in CP6 were:

- **2019/20** – £6m of schedule 8 costs were for the Hanslope Landslip, between Watford Junction and Milton Keynes Central. Flooding costs overall were £10.9m in that operational year.
- **2022/23** – £6.2m for schedule 8 extreme heat damage, mainly occurring during the summer of 2022. A record 40˚C was passed in July, it was the UK's warmest year since 1884 and the first time the Met Office issued a heat weather warning[6]. The heat on 18 – 20th July 2022 resulted in 50,000 minutes of delay. Notable incidents included OLE failure in Cumbria at Hest Bank (£0.7m), wire sag in Plumpton (Cumbria) (£0.28m) and a third-party tree on the line (North London, £1.9m) – potentially linked to heat stress.
- **2019/20** was one of the costliest weather-delayed years. Links can be drawn with the winter flooding events and the associated named storms: Ciara, Dennis and Jorge (Figure 5). The heatwaves from 2019 show in the delay minutes and cost, and feature prominently in recent years (Figure 6 & Figure 8). Schedule 4 and 8 payment data for weather delays is showing an average yearly increase at approximately 3,750 minutes and £0.61m since 2006 – dependant on the statistical technique used to analyse the data. Multi-agency action has been taken in response to these pressures and is discussed in the next sub-section (4.5).

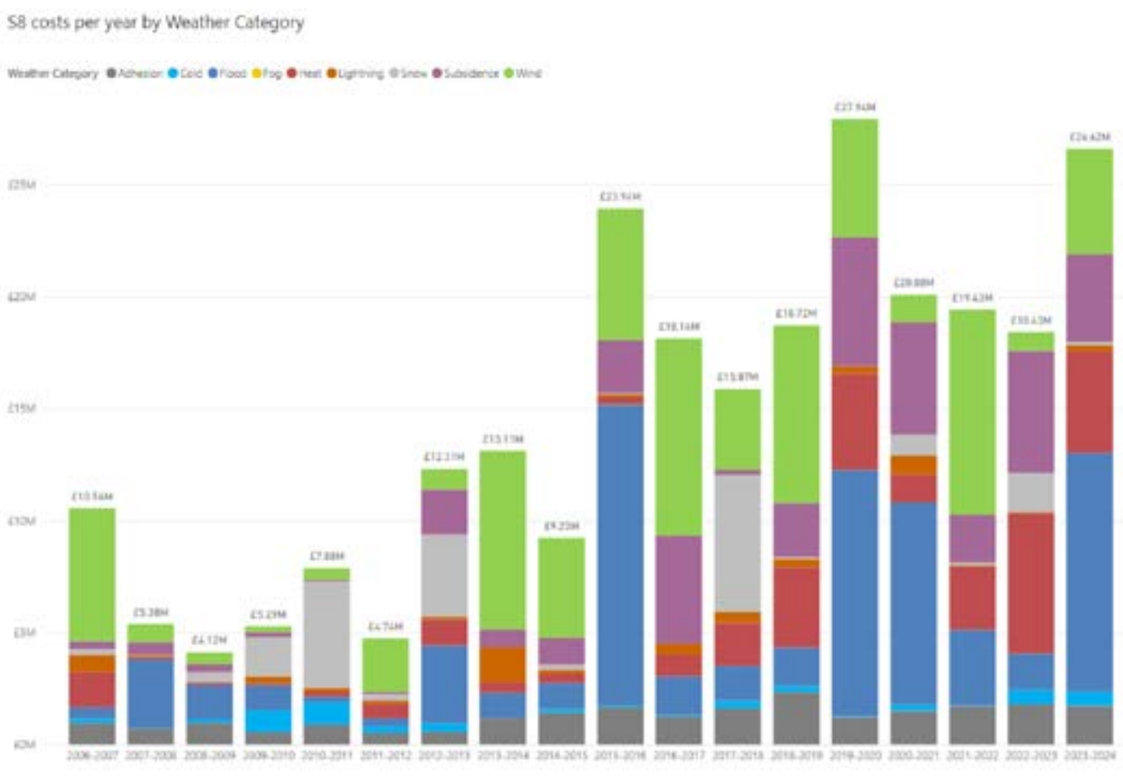


Figure 5) NW&C Schedule 8 costs by year and weather category. **Source and credit:** Network Rail analysis of trust data.

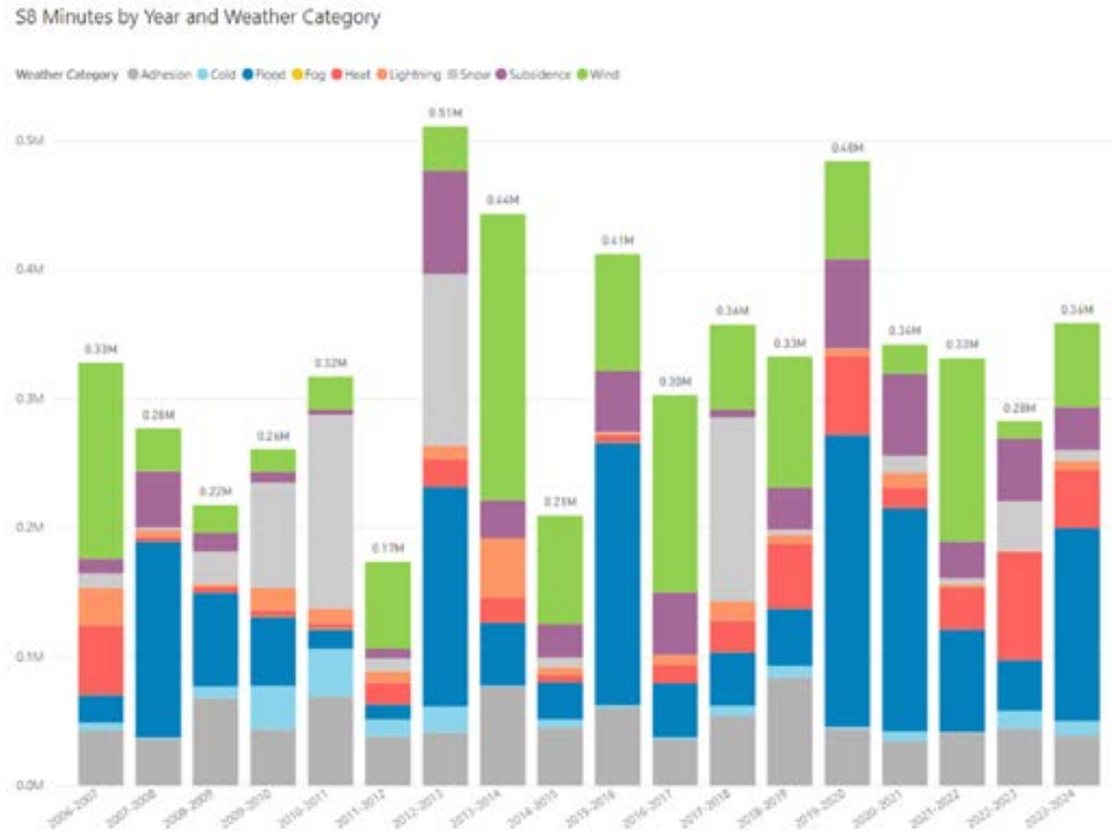


Figure 6) NW&C Schedule 8 minutes by year and weather category. **Source and credit:** Network Rail analysis of trust data.

[6]2022 provisionally warmest year on record for UK – Met Office.

Underestimation of weather and climate impacts

Costs for emergency response and repair to damage are not included here. So, the actual costs to NW&C are considerably higher than the £15m to £30m paid out in compensation each year.

At present, maintenance, capital or associated enabling works costs are not reported in a way which would allow weather impacts to be assessed.

Failure of asset services due to weather, which support the running of trains, are also not presented here.

These represent key fundamental point of weather impact underestimation, and work is currently underway to understand more about the real costs of WRCCA. Section 7 discusses service affecting failures (SAFs), and further work with the Network Rail's Technical Authority (TA) will be sought in CP7 to address underestimation of weather impacts. The WRTF are also working on refining incident recording related to weather and climate. There is a need to embed these techniques as part of business as usual (BaU) approach to ensure climate change impacts are accurately recorded and presented.

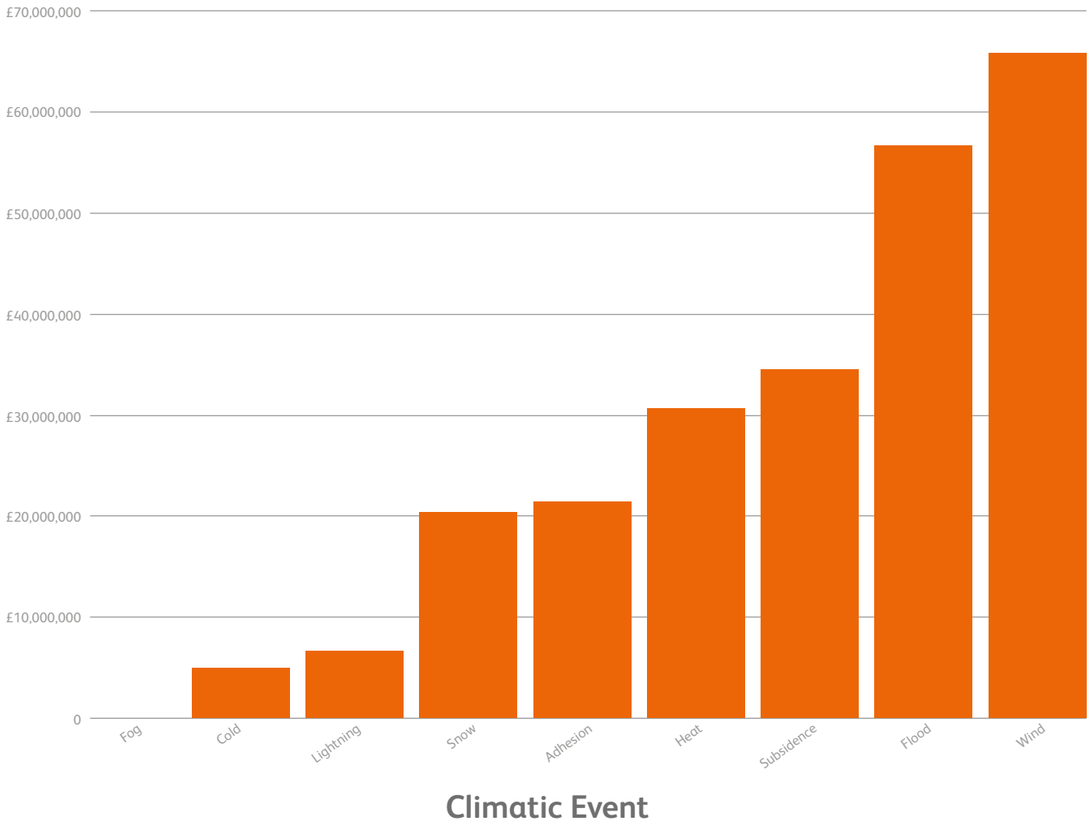


Figure 7) Schedule 8 weather costs by category (2006 - 2023). **Source and credit:** Network Rail analysis of trust data.

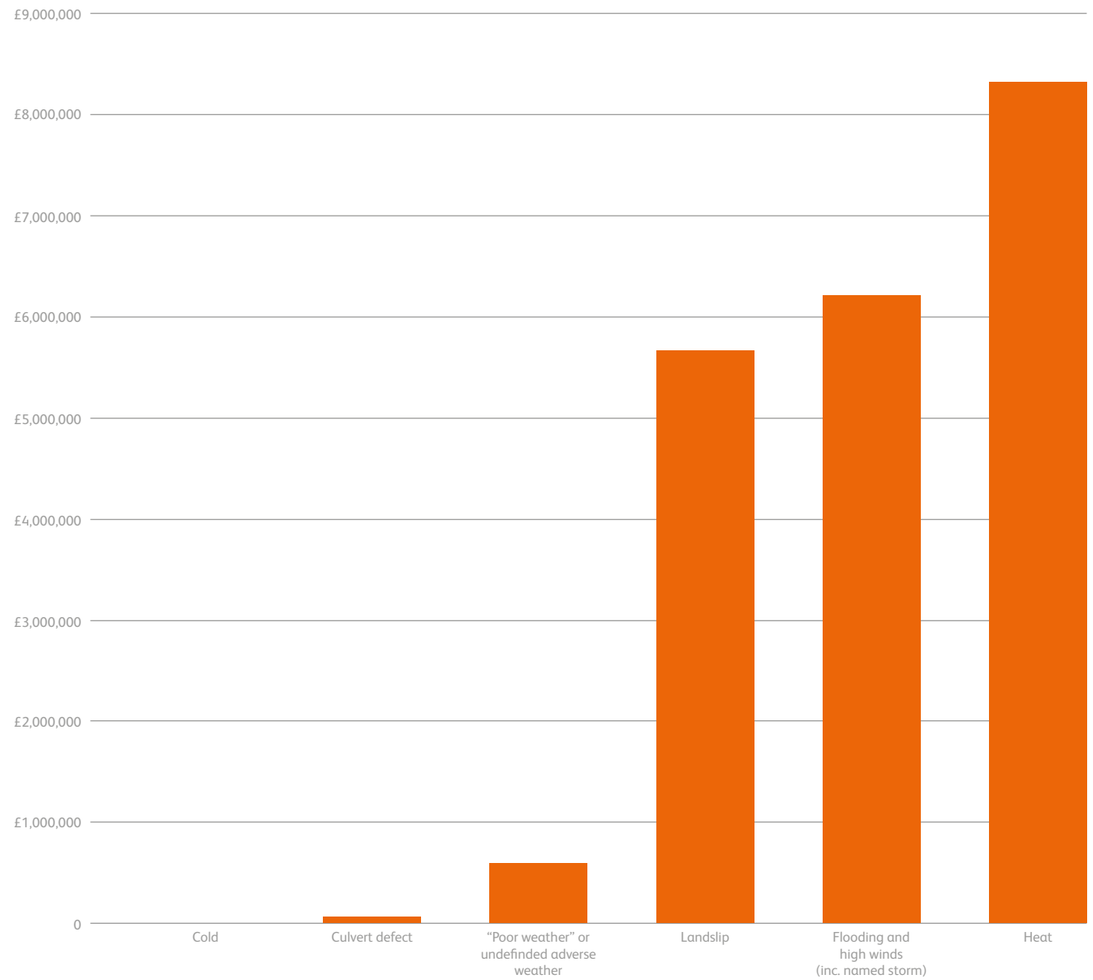


Figure 8) Schedule 4 costs CP6 (2019 - 2024)[7]. **Source and credit:** Network Rail analysis of trust data.

[7]Collation of the full range of schedule 4 costs is problematic and time-intensive, as such, this should not be read as a full representation of all schedule 4 costs in CP6.

3.5. WRCCA strategy

The sustained impact of the changing climate has resulted in action across a variety of Government departments. Incidents, strategies, taskforces and targeted assurance review by the ORR have guided actions within the control period and shaped activity beyond it. These fundamentals of the region's operating environment are set out in the following sub-sections. A timeline is provided below.

Environmental Sustainability Strategy (October 2020)

The national environmental sustainability strategy was published in October 2020 half-way through our existing CP6 WRCCA plan. The requirements within this strategy have been passed into the CP7 plan, mainly the requirements to develop an adaptation pathway, to inform future control period investment decisions. This strategy is available at: ***Environmental Sustainability Strategy – Network Rail***

Weather Risk Taskforce (WRTF): Aberdeenshire derailment (August 2020)

Following the Carmont train derailment on 12 August 2020, where three people tragically lost their lives, Professor Lord Robert Mair and Professor Dame Julia Slingo were appointed to head two independent task forces (Aberdeenshire, Scotland)[8].

The passenger train collided with debris washed from a drain onto the track following very heavy rainfall[9]. In response, Network Rail commissioned an assessment of the impact of extreme weather on the resilience and safe performance of the railway. This became the WRTF. A large focus of this has been the implementation of the recommendations in the region, which span 19 action plans (See Appendix D). This involved work such as slope and crest drainage works at over 200 sites – increasing resource in earthworks slope evaluations, and developing a new earthworks washout risk tool, where runoff and earthworks may adversely interact. Further information is available at: ***Our new Extreme Weather Resilience Task Force – Network Rail***

Office of rail and road: Targeted Assurance Review (TAR) – earthworks and drainage weather resilience (March 2021)

During the CP, the ORR reviewed the NW&C CP6 WRCCA Plan, which is available at: ***NW&C Weather Climate Report 2019-2024 (networkrail.co.uk)*** The ORR said in relation to all CP6 WRCCA Plans: "These documents did not provide enough detail for ORR to understand exactly what engineering solutions, innovations or other means Network Rail have available to improve their weather resilience. Given the national importance of climate change and the unprecedented competition for public funding […] ORR undertook this Targeted Assurance Review to collect examples of how Network Rail can improve its weather resilience and we have distilled these examples into a simple framework"[10]

This Targeted Assurance Review set out 11 levers to improve weather resilience: neighbours and catchment, whole systems, monitoring, forecasting, design redundancy, design reliability, design resistance, intervention extents, asset knowledge, funding and risk, awareness and implementation. We have aligned our funding to these levers in CP7, as set out in section 9 – Control Period 7 (2024 – 2029) Investment Plan.

Adaptation reporting power 3 – climate change act 2008 (December 2021)

During the latter half of CP6, the Network Rail third adaptation report (ARP3) was published in December 2021[11]. Since then, we have integrated this into our working. We have also used the outputs of the integrated ARP3 climate risk assessment to inform our CP7 plan – focusing in on some of the fastest emerging risks in terms of likelihood and consequence. In addition, NW&C has increased seasonal preparedness, taking a more strategic approach to seasonal weather management. This enables route management against key weather risks. NW&C have been active in responding to the changing climate and how we deal with extreme weather during CP6. The next section builds on the policy drivers of this section. The section sets outs our approach to weather and climate management, tactically, strategically and within a governance structure.

August 2020
Carmont De-Railment and the Weather Risk Taskforce

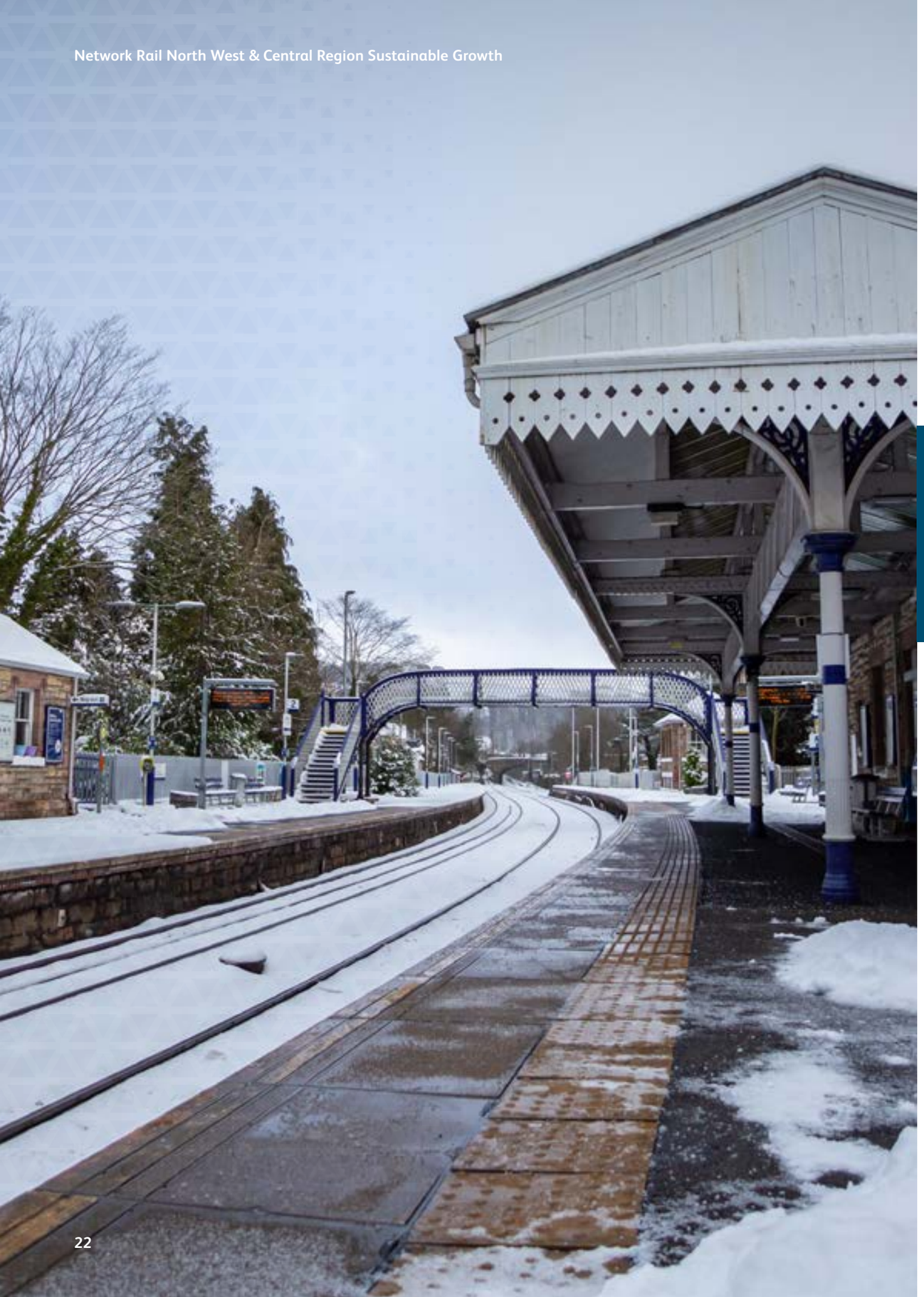
October 2020
Environmental Sustainability Strategy

March 2021
Office for Rail and Road Targeted Assurance Review – Earthworks and Drainage Weather Resilience

December 2021
Adaptation Reporting Power 3 – Climate Change Act (2008)

[8]Scotland, outside the North West and Central region. [9]Report 02/2022: Derailment of a passenger train at Carmont – GOV.UK (www.gov.uk).

[10]Earthworks and Drainage Weather Resilience – Targeted Assurance Review – May 2021 | Office of Rail and Road (orr.gov.uk).
[11]The ARP 3 report and risk assessment is available at: Climate change adaptation – Network Rail.



4. Managing WRCAA

4.1. Weather management

Day to day management of weather impacts is the responsibility of the three routes who manage it through a combination of their operations, engineering and maintenance teams. It involves a combination of:

- Seasonal delivery management, by the seasonal delivery specialists and managers (Figure 10)
- Reactive works to deal with the impacts of the weather events e.g. clearing fallen trees from the line
- Proactive works based on the differing seasonal challenges
- Preparation works e.g. rail head treatment, emergency plans
- Formation of Extreme Weather Action Teams (EWATs), when weather events are forecasted

Interaction with the TOCs and FOCs is also a critical part of weather management due to the need in some cases to operate temporary speed restrictions or reduced timetables. The NW&C joint industry seasonal collaboration groups act as a co-ordination collective to ensure weather management is adequately considered across all stakeholders, before the season starts.

Post weather event reviews are also undertaken, such as in July 2022 after the extreme heat, to help improve preparation for similar events in the future. This is also a feature of the WRTF reports. Learning lessons from these are important because we know we are likely to see an increase in event frequency, magnitude and duration. Using heat by way of example, lessons learnt and acted on from the heat of July 2019 helped maintain performance during the heat of July 2022. One such example was the use of dynamic risk assessments for individual sites rather than blanket speed restrictions, in addition to re-tensioning all OLE around Birmingham that failed in the heat.

Our seasonal specialists in the routes are taking a much more strategic approach to weather management having season-specific plans. They have also interacted and engaged with the WRTF to start implementing use of tools such as the CAT (Convective Alert Tool) and PRIMA tool. The Network Rail weather service tool also provides valuable source of information, including for river levels in relation to structures. NW&C will also be the first region to pilot the new rail operations weather service (ROWS).

4.2. Asset resilience – our approach to risk reduction

During CP6 there has been a programme of asset renewals to replace old and failing infrastructure. The replacing old-for-new nature of this investmen will aid the resilience of the asset to a changing climate. Any drainage, earthworks, track and OLE renewal will be based on the current best practice design criteria laid out in Network Rail standards. Our engineering teams are active in engaging with the standards update process and this programme of updates being led nationally will be fully supported by NW&C.

We know that more needs to be done to make designs more 'climate ready' and our maturity in this area needs improving – so focusing on climate design via assurance of adherence to standards and raising competence will all be key features of our CP7 plan. When new standards are introduced, this will enable us to further improve the resilience of our assets to climate change via the ongoing programme of renewals that will form a key part of our CP7 WRCCA plan.

One aspect of CP7 is to conduct assurance on a series of projects across the engineering disciplines, to constructively evaluate the scope and whether climate risk assessments have occurred during renewals and make activities more climate-ready. This is to ensure renewals are not simply like-for-like, but like-for-better, as underwritten by the latest standards to offer greater resilience. Figure 9 (below) sets out the cabinet office objectives for resilient infrastructure compared to value of service from different route sections, which is likely to underpin investment in maintenance, renewals and enhancements.

Cabinet Office: components of infrastructure resilience

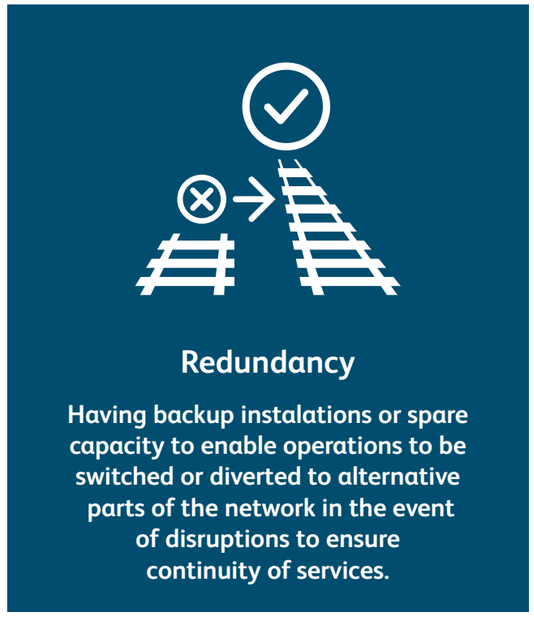
Resistance

Preventing damage or disruption by providing the strength or protection to resist the hazard or its primary impact.

Relibility

Ensuring that the infrastructure components are inherently designed to operate under a range of conditions and hence mitigate damage or loss from an event.

Cabinet Office: components of infrastructure resilience



Redundancy

Having backup instalations or spare capacity to enable operations to be switched or diverted to alternative parts of the network in the event of disruptions to ensure continuity of services.

Response & Recovery

Enabling a fast and effective response to and recovery from disruptive events through thorough planning, preparedness and exercise in advance of events.

Value of Service: A guide to climate change adaption spending?

Reactive Intervention
Ad hoc intervention to maintain basic function.

Resilience
Proportionate investment based on risk, value and function.

Full Protection
Climate agnostic.

Figure 9) Cabinet office expectations of transport infrastructure against strategic route sections and value of service.
Source and credit: Cabinet Office and Network Rail analysis (2023).

Governance

In NW&C, we are guided by the strategies produced by TA on how we should respond to a changing climate. Governance of this sits within the NW&C Directorate of Safety & Engineering (DSE) with oversight provided by our regional business review processes. The associated WRCCA risk is managed via a level 2 enterprise risk register and level 2 periodic assurance meeting.

This governance provides the oversight. For example, the level 2 periodic assurance meeting tracks progress against the milestones in our CP6 plan, which are then reported every six months to the TA for national reporting. NW&C are also a member of the WRCCA collaboration forum – a national forum where best practice is shared and discussed for use back in the region. For CP7 the WRCCA plan will be tracked via the level 2 assurance meeting and overseen by the business review process to ensure delivery of actions and commitments.

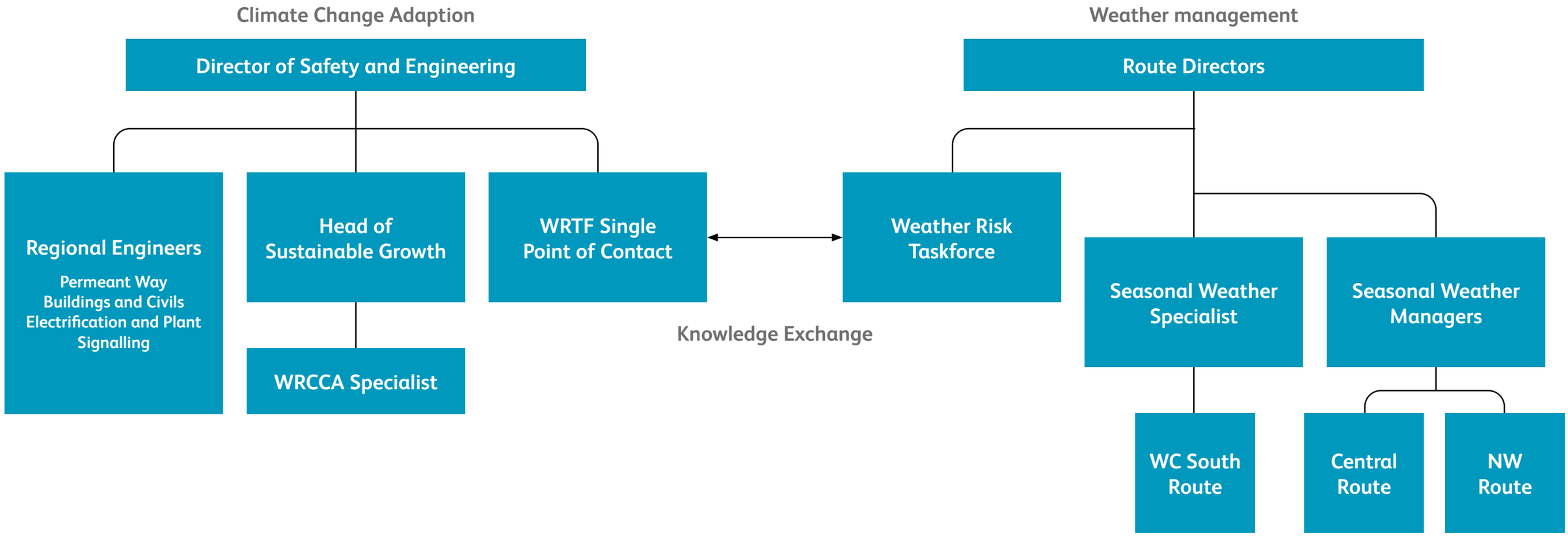


Figure 10) Organisational structure of WRCCA within NW&C. **Source and credit:** Network Rail analysis (2023). See page 29 of the *Network Rail Third Adaption Report December 2021* for the interaction of the this regional structure with the national governance structure.

5. Our Climate Change Risks

5.1. Climate change projections and the region

The latest UK Climate Projections 2018 (UKCP18) indicate that there will be a shift to a pattern of warmer and wetter winters, hotter and drier summers, increases in frequency and intensity of storms and significant changes in sea level (Figure 11). This means that NW&C needs a detailed understanding of our vulnerability, service, assets and activities to enable us to maintain a resilient railway. Harsher climatic conditions will stress test the physical properties of legacy assets and ones built or maintained for the years ahead.

The NW&C region covers a number of UK administrative regions. The climate risk assessment in this plan predominantly covers North West England and West Midlands. The projections for these climate regions share a similar pattern. The North West England projections are shown in the main document and West Midlands can be found in Appendix B. Network Rail uses two climate scenarios modelled by UK Government and is based mainly on the latest UK Climate Projections (2018), and occasionally on the earlier UK CP09 Projections.

Scenario name	UK Climate Projections 2009 (UKCP09	UK Climate Projections 2018 (UKCP18)
Primary Scenario	Medium Emission Scenario 90 % probability	RCP* 6.0 90th percentile
Higher Scenario	High Emissions Scenario 90 % probability	RCP* 8.5 90th percentile

Figure 11) 'Hot spot' sections of track being painted white to reduce heat by solar gain. **Source:** Hot weather and the railway – Network Rail. **Credit:** Network Rail. **Table 1)** Network Rail climate change planning scenarios.

*Representative concentration pathway. [12] How climate change worsens heatwaves, droughts, wildfires and floods – BBC News.

5.2. Temperature

The maximum, average and minimum temperatures are projected to rise in all months of the year across North-West England and West Midlands. This means higher average, maximum and minimum temperatures resulting in less snow, fewer frost days and increasing the risk of hotter and longer heatwaves. Track, cabinets and OLE are susceptible to an increase in the number of 'summer days' in a warming scenario (Appendix B.i, Figure 12). Track can move and buckle in the heat and overhead lines can sag through heat extension. Prolonged dry periods may also increase droughts and the likelihood of fires. Fires in the past have impacted the reliability and safety of the railway. Forestry Commission observed wildfire data shows key risk around Birmingham, Manchester and through the TransPennine route to Liverpool.

What extremes in temperature can mean for assets:

- Increased vegetation growth affecting signals (heat)
- Increased humidity in tunnels affecting masonry (heat)
- Overhead line sags leading to de-wirement (heat) – Damage to OLE from the heat in Summer 2022 led to delays and overnight working to repair affected areas (Figure 15)
- Geometry failures / rough rides from desiccation of clay (heat)
- Track buckles and rail creep (heat)
- Increase in frequency of lineside fires (heat)
- Overheating of signalling controls (heat)
- Accelerated degradation of electrical equipment asset life (heat)
- Ice formation in tunnels (cold)
- Freezing of signalling equipment and points (cold)
- Failure in electrification systems due to ice affecting contacts (cold)
- Rail contraction leading to broken rails (cold)

Some of these are less severe in terms of impact to the safe infrastructure operation, but do come with associated costs. For instance, by requiring the deployment of maintenance teams to unblock frozen points or re-tension OLE. Although we recognise all these risks, our plan for CP7 is to focus on where the risks are most significant and can lead to the most serious risk to the safe running of the railway.

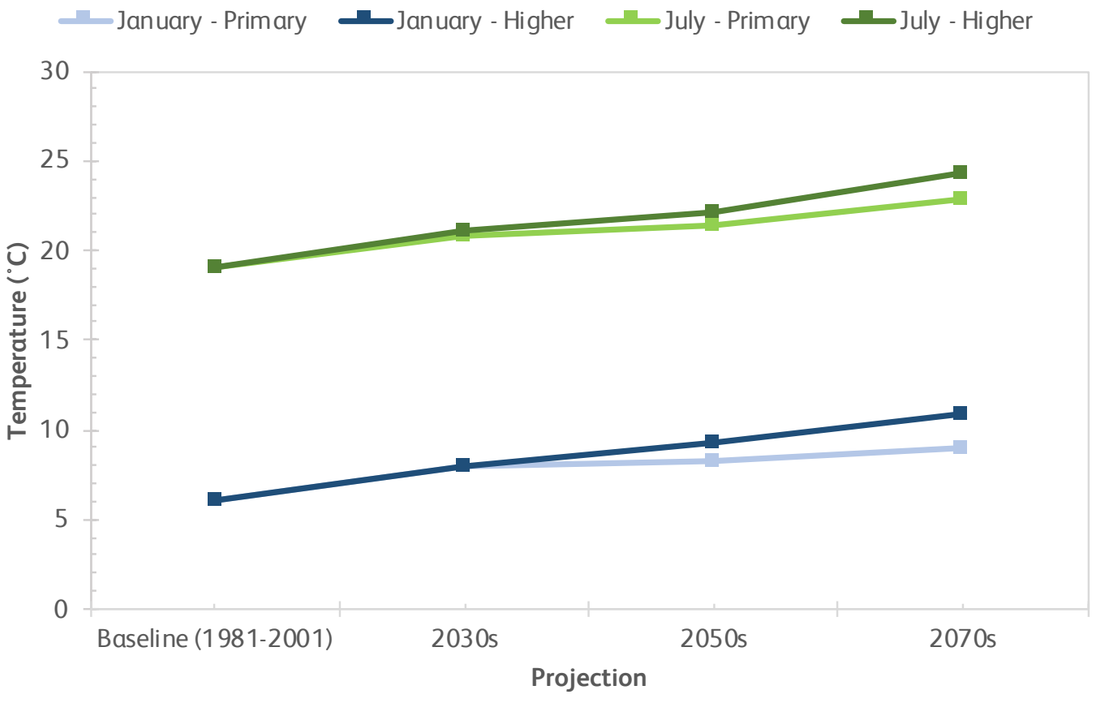


Figure 12) NW England Change in mean daily maximum temperature (˚C). **Source:** UKCP18 (metoffice.gov.uk) **Credit:** Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

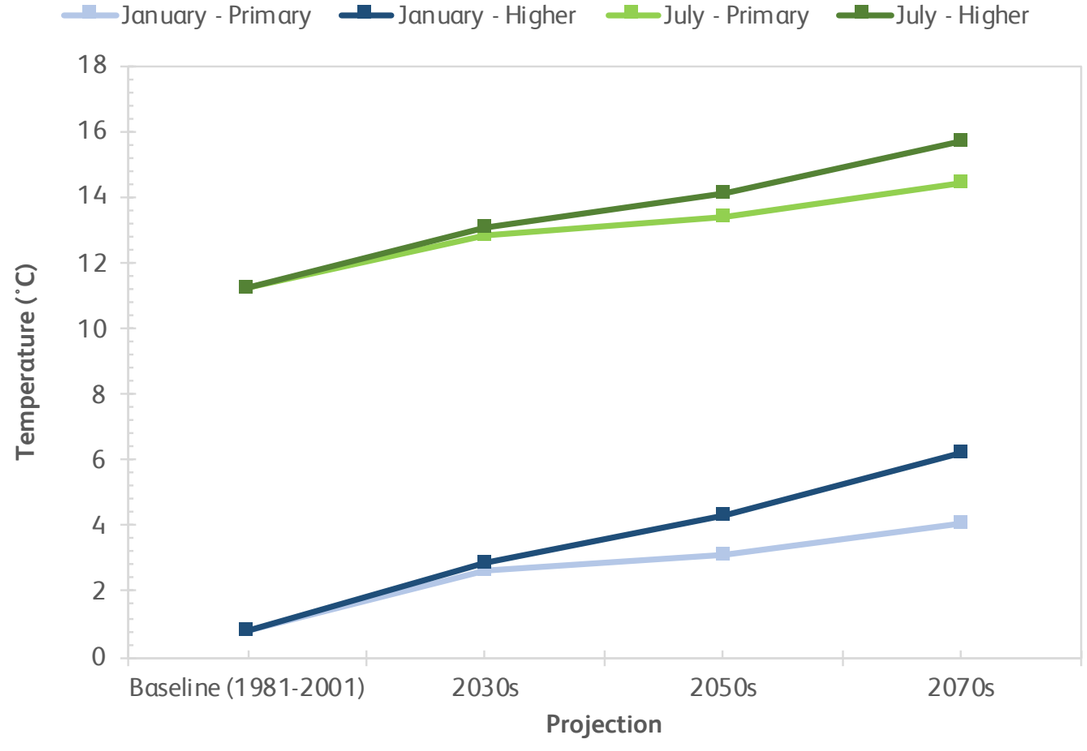


Figure 13) NW England Change in mean daily minimum temperature (˚C). **Source:** UKCP18 (metoffice.gov.uk). **Credit:** Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

5.3. Precipitation and flooding

Global heating results in more heat energy, particularly during summer, where intense summer convective storms are likely to increase, with intense precipitation events (>30mm /hr) projected to rise 5-fold by the century's end[13]. We are likely to see an increase in the number of flood events as rainfall events change in frequency, magnitude and duration – across both winter and summer months. This can lead to flooding from various sources (groundwater, surface water, rivers) and will depend upon numerous local factors as to whether it causes impact to our railway. Scour of structures, embankments, washout of ballast and enhanced degradation of earthworks are a foregoing risk in respect of more 'monsoon' type rainfall events.

The consequence of future projected rainfall is increased peak watercourse flows – ranging from 14 % in the 2050s (higher central) through to 105 % in 2080s (upper end[14]), with projections classified on water management catchment[15]. Low flows, sometimes associated with droughts are also projected. Watercourses are, and will continue to present, more flashy flow regimes, characterised by higher and lower flows – with flood and drought consequence.

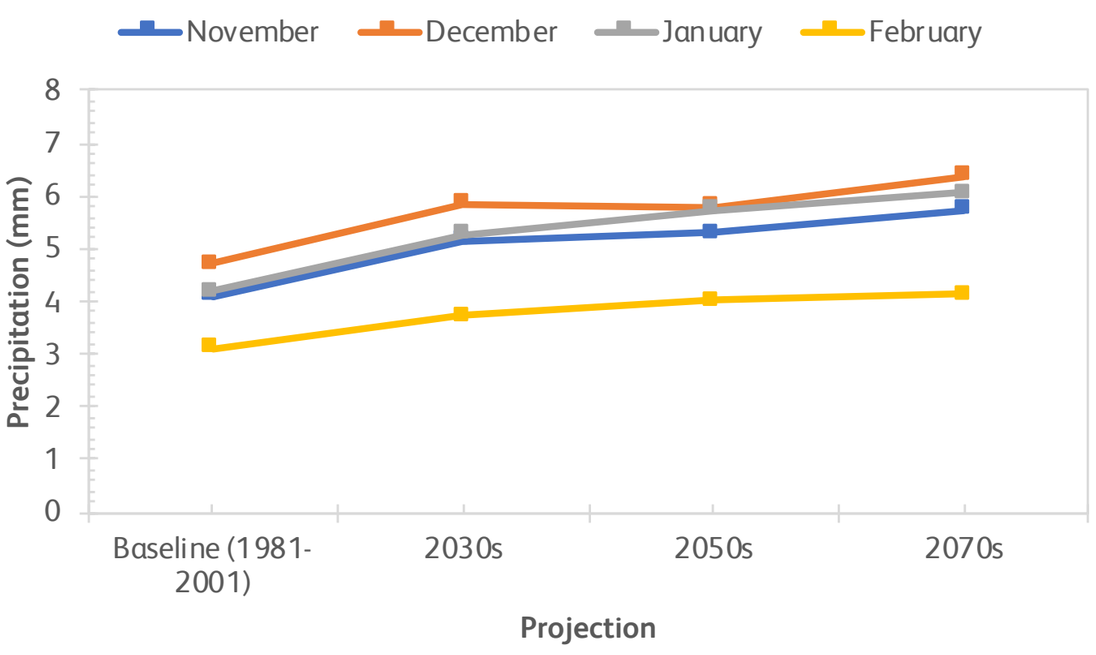


Figure 15) NW England primary scenario change in winter average daily precipitation rate (%) 90th percentile. **Source:** UKCP18 (metoffice.gov.uk) **Credit:** Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

[13]Heavier summer downpours with climate change revealed by weather forecast resolution model | Nature Climate Change.

Figure 14) Site crew inspect OLE after heat damage in Birmingham. **Source:** Birmingham New Street trains resume after heatwave damage (networkrailmediacentre.co.uk). **Credit:** Network Rail

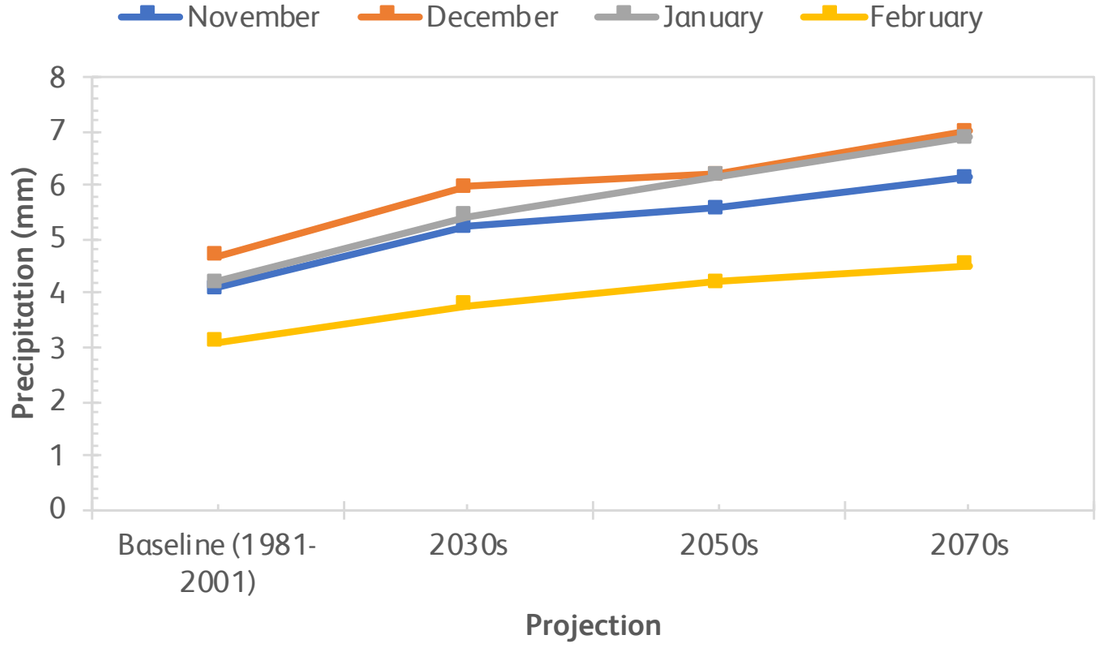


Figure 16) NW England primary scenario change in winter average daily precipitation rate (%) 90th percentile. **Source:** UKCP18 (metoffice.gov.uk) **Credit:** Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

[14]NR currently use 2030, 2050 and 2070, with adaptation Pathways will be looking to 2100, mainly due to asset lifecycles. The peak flow data does not report at 2070, and hence, 2080 is used in its place. [15]Peak river flow climate change allowances by management catchment – GOV.UK (www.gov.uk).

What increased peak flow can mean for assets:

- A range of assets (track, signals, buildings) can be inundated with rain-water and run-off, leaving them unable to operate (tracks and tunnels blocked, electrical equipment damaged, underbridges / culverts blocked or overwhelmed leading to overtopping and attenuation of water against raised embankments not designed to hold water).
- For bridges and structures with passage of water beneath, where unchanged, will result in the carrying capacity or pass-forward flow to be overwhelmed with higher peak flow volumes. Leading to surcharging and exceedance with increase scour risk, overtopping and water acting on foundations and embankments. Sometimes this may even lead to the impoundment and holding of water on embankments not designed to dam waters.
- Drainage may be exceeded, and watercourse power will be increased with higher velocities, resulting in changing erosion and deposition that causes scour and possible greater accumulation of sediment within assets. Erosion on engineered slopes may increase, where lighter more uncompacted soils exist, with greater potential for incision and landslip.
- Standard of protection – where historic assets have not been built to a climate change standard or are built to a legacy 20 % allowance – may be exceeded and could lead to track-bed washout or scour.
- Assets move due to waterlogging – embankments slip that can lead to train derailments.

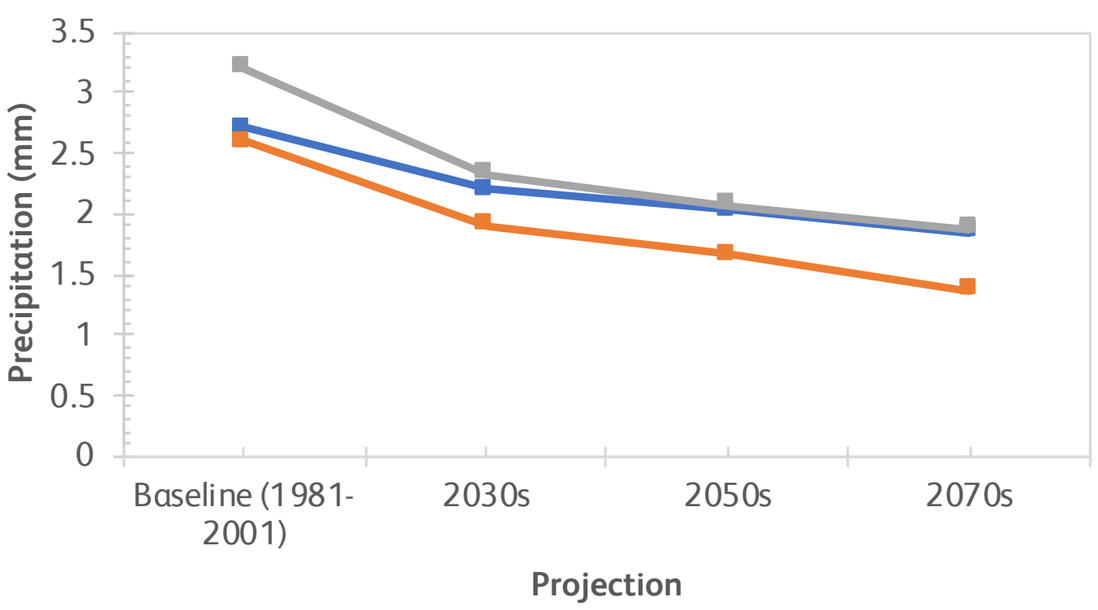


Figure 17) NW England primary scenario change in summer average daily precipitation rate (%) 10th percentile. **Source:** UKCP18 (metoffice.gov.uk). **Credit:** Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

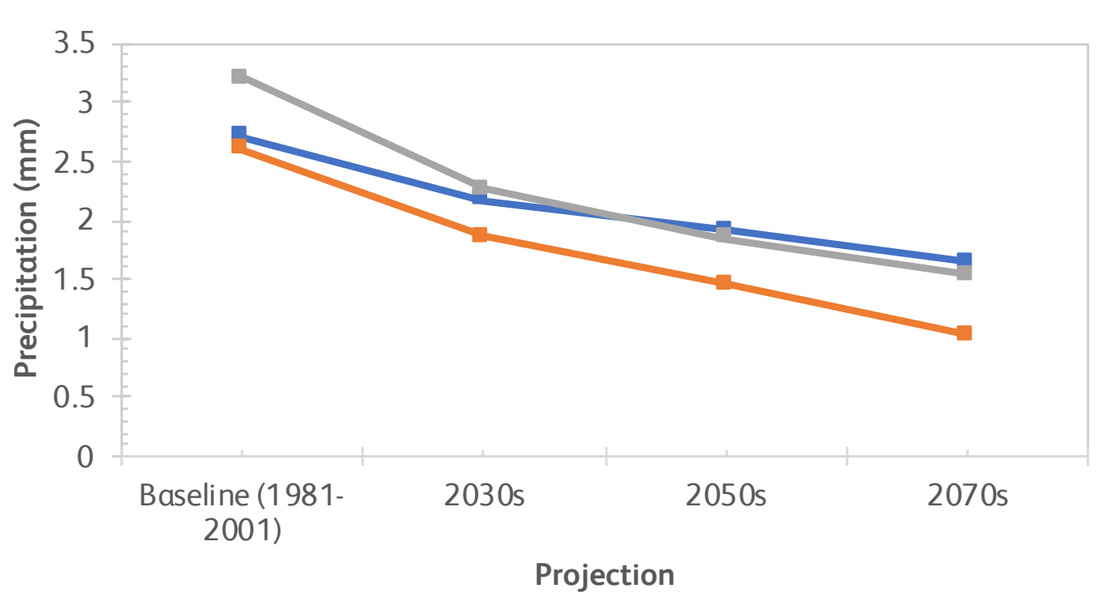


Figure 18) NW England higher scenario change in summer average daily precipitation rate (%) 10th percentile. **Source:** UKCP18 (metoffice.gov.uk). **Credit:** Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

5.4. Sea level rise and erosion

The comprehensive UK tide-gauge network shows that the sea levels have been rising since the 1800s[16]. The NW&C region does contain areas of coastal railway vulnerable to flooding and coastal erosion. Our infrastructure has already been impacted, such as in 2016 when Storm Jonas caused three breaches in the sea wall on the Whitehaven to Workington line at Parton.
In CP7, we need to further develop our understanding of sea level rise and erosion to ascertain when the risk to our coastal railway infrastructure will be realised. Part of this will entail partnerships with relevant local authorities and the environment agency to understand shoreline management plans (SLMP) and the proposals related to railway assets. Parts of the WCML and Cumbrian coastal line are sections susceptible to flooding and coastal erosion.

What sea level rise and erosion can mean for assets:

- A range of assets (track, signals, buildings) can be inundated with sea water, leaving them unable to operate e.g. pipe outfalls unable to discharge, tracks and tunnels blocked, electrical equipment damaged.
- Loss of land and loss or damage of the assets on it, damage of any defences and the assets behind them.

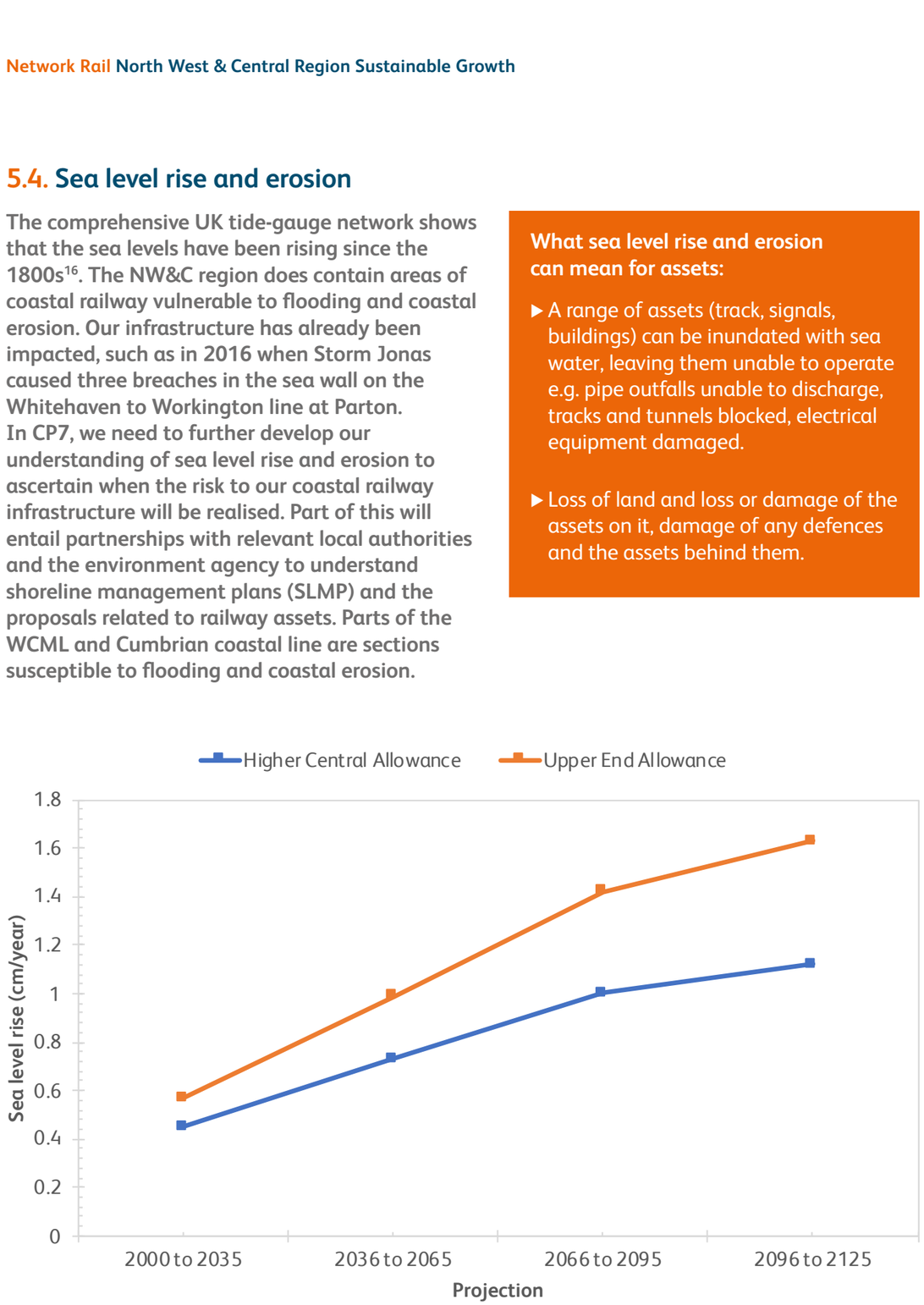


Figure 19) Environment Agency guidance on sea level rise allowance (cm/year) by river basin. **Source:** Flood risk assessments: climate change allowances – GOV.UK (www.gov.uk)[17]. **Credit:** Environment Agency

[16]New data reveals British sea level records stretching back 200 years – News – Faculty of Science and Engineering – University of Liverpool. [17]NB The Cumulative rise 2000 to 2125 (cm) is 101 cm and 141 cm, for the higher central and upper end allowance. Baseline = 1981 to 2000 l Higher central – 70th percentile of RCP 8.5 – use as our Primary scenario l Upper end – 95th percentile of RCP 8.5 – use as our Higher scenario.

Summary

This section contains a snap-shot of the likely changes in the future from our changing climate. For how to apply these projections in asset management, please consult the Network Rail guidance note: Climate change projections – available on Safety Central.

Climate change is set to enhance the deterioration of £35bn of third-party flood defence assets, with potential consequences to Network Rail[18]. This was demonstrated in Haddiscoe, when an embankment washout beneath a railway occurred, in part due to low spots in the nearby flood defence, which Network Rail were unaware of[19]. The rail accident investigation branch (RAIB) completed an investigation of this, and made a series of recommendations.

Figure 20) Cumbrian Coast near Whitehaven. **Source:** Cumbrian coast line near Whitehaven (networkrailmediacentre.co.uk). **Credit:** Network Rail.

[18]Impact of climate change on asset deterioration – GOV.UK (www.gov.uk). [19]Haddiscoe is south east of Norwich and south west of Great Yarmouth and belongs in the Eastern region of Network Rail. Report 07/2023: Embankment washout under a passenger train at Haddiscoe – GOV.UK (www.gov.uk).

Figure 21) Cumbrian coastal line storm damage repair. **Source:** Cumbrian Coast line reopens – seven repairs highlights – Network Rail. **Credit:** Network Rail.

6. Climate Projection Risk Assessment: Assets

6.1. Introduction

Since the publication of our CP6 WRCCA Plans, Network Rail has put a lot of effort into enhancing our understanding of our weather and climate change risks. We have continued to gather and analyse data on our weather impacts (for example our delay minutes as shown Figure 6, Figure 7 and Figure 8) and have worked closely with the WRTF as discussed in section 4.5 and 9.

In addition, we developed our Integrated Climate Change Risk Assessment in 2020. The full details of its development can be found in our Third adaptation report to Defra (ARP3). The full climate risk assessment to railway assets is accessible via Appendix C, for both the NW&C region, as Appendix C.i, and for a full range of assets and comparisons to other regions in Appendix C.ii.

As the executive summary, delay minutes and closures data show, weather delays are increasing. This presents a rising cost burden which draws resource from investment more widely in the region. Data shows SAFs are increasing because harsher conditions are driving asset deterioration[20]. Earthworks are particularly sensitive to these changes with the tragic derailment at Carmont demonstrating the impact of extreme weather on the network, and highlighting the need for us to do more in CP7. Table 2 (Pages 42-43) summarises the impact weather has on each of the asset types that make up the railway system.

Section 5 sets out the changing nature of the climate in NW&C. This section places a risk score against the climate scenarios, based on weather type and assets (Figure 19, PG. 38). The risk scores range from 1/minor to 25/Severe and for the purposes of informing this plan (Table 3) only risk scores of 9/Moderate and above the medium confidence level have been considered at this stage. More work will be done in the final year of CP6 to fully align with the risk approach in the national integrated ARP4 climate risk assessment. This will outline how these risks impact on NW&C and what actions are being undertaken in CP7 to address them.

[20]See Heatwaves (PG. 78) in Network Rail Third Adaption Report December 2021.

	Precipitation	Heat	Storms/Wind	Adhesion
Track	Localised flooding and track failure.	Ballast management. Track buckles or breaks. High risk with jointed track. Temporary Speed Restrictions.		Track circuit reliability Reduced traction.
Drainage & off-track	Blockage and overflows leading to localised flooding. Vegetation washout.	Increase in vegetation mortality or growth. Lineside fires.	Vegetation and trees on track.	
Signalling, level crossing and telecoms	Flooded equipment.	Equipment overheating lineside S&T equipment rooms struggling to provide a workable environment for Supply batteries failure. Sun – glare on signals.	LX Barrier Failures.	Disruption to signalling.
E&P	Electrical faults from water ingress.	OLE sags and dewirements.	Overhead line damage. Lightning strikes on power distribution.	
Buildings	Drainage blockages and subterranean flooding. Flooding, Electrical hazard from water ingress.	AC failures in op buildings and offices affecting. Uplift of platform surfaces.	Damage to roofs – glazed roofs, listed canopies Damage to decorative panels (footbridges).	
Structures	Highway flooding at under bridges and saturated formation on underbridges. Bridge scou.r	Swing bridge expansion causing them to become stuck. Risk of metal buckling. Tunnel humidity impacting masonry.	Damage from overtopping.	
Earthworks	Cutting washout or failure. Scour damage to embankment toes. Groundwater leading to cutting failures. Softening and failure of clay embankments.	Clay bank desiccation.		

Table 2) Impact of the weather on railway assets

The risk assessment undertaken for this plan builds on the 2020 national Integrated Climate Change Risk Assessment carried out for ARP3. In tandem with the other regions, we have carried out a regional review of the national assessment and re-scoring exercise to identify regional variations in the asset risks and their levels of severity. This used the Network Rail climate change planning scenario of RCP6.0 90 % and the same method as the national assessment (Table 117, See our Third adaptation report to Defra) to review all asset risks with a current score of 8 or above, and where the confidence is above medium.

These scores are shown in the tables below, set out in the categories of weather: High Winds and Storms (including lightning), Precipitation and Flooding, Sea Level Rise, Heat, Snow and Ice and Autumn Leaf Fall.

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/Severe	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

Table 3) Risk scoring matrix of impact against likelihood (horizons: 2050, 2080).

Regionally, we then took these risks to our regional engineers for each discipline. See Figure 10 for Regional Engineering (REs) discipline categories. Those REs scrutinised these risks, the scores and the region's geography against its asset base and weather upon it. Where scores are above the national ARP3 scores, they are shown in red text. An additional narrative column has been added to set out why those scores are higher than the national ARP3 scores. The results from this exercise have been fed back into the national risk assessment and have been used in the following paragraphs which discuss our regional WCCA risks and their prioritisation.

As Table 4 sets out, the years ahead present increasing risk, which challenges renewals and maintenance to develop the most resilience measures that are cost-effective and proportionate[21]. This is reflected in our observed SAFs related to weather, shown in Figure 21. ARP3 projections show the changing risk profile for ARP3 assessed assets, shown in Figure 22. In the transition into CP7, further work will be undertaken to assess ARP4 regional risk. In the forthcoming sections we present asset climate risk now and into the future by weather category, to compartmentalise the climate challenges.

Our changing risk profile

Without adaption we will see more damage and greater disruption to our railway system with an increase in rish across all assets and weather impacts.

[21]Enhancements are funded outside the periodic review process – to which this document relates. The TransPennine route upgrade is an example of an enhancement project.

Examples of risks that were higher	Examples of risks seen to be lower
Coastal flood risk, in part because of the Cumbrian coastal line and WCML risk from the Irish Sea.	The consensus of engineering colleagues was that few risks were assessed as decreasing.
Flood risk from watercourses passing underneath and above the railway, as peak flows increase, the pass-forward capability of these assets maybe over-whelmed leading to railway flooding.	Ice and snow risk in a warming climate. However, route services, have observed no discernible decrease in winter management i.e. ploughing and rail head ice treatment.
Track and points failure from extreme heat on high tonnage high usage strategic route sections.	
Wire tensioning in OLE during hot weather with a risk of dewirements (experience in 2022).	
Scour, with numerous incidents in CP6. Reddish Viaduct (TTA2-18), and Eden Brow (SAC – Settle and Carlisle Line) are two examples.	
Earthworks shrinkage through heat and erosion through intense rainfall.	

Table 4) Overview of regional risk table.

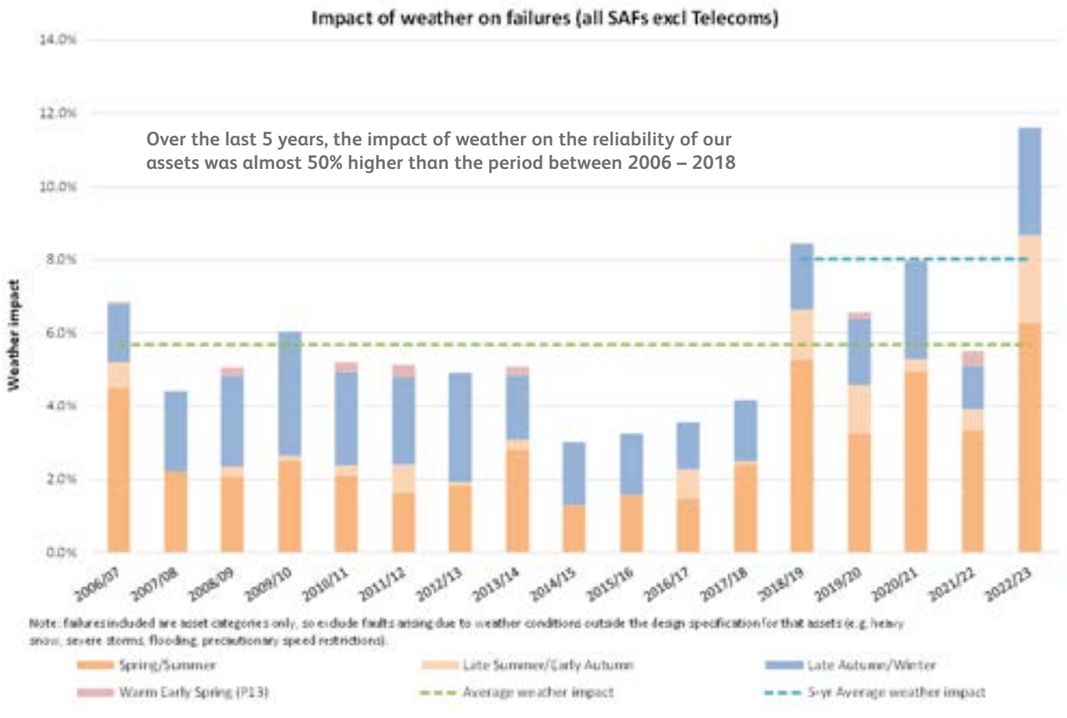


Figure 23) Impact of weather on national asset failures. **Source:** Technical authority – climate change adaptation. **Credit:** Network Rail.

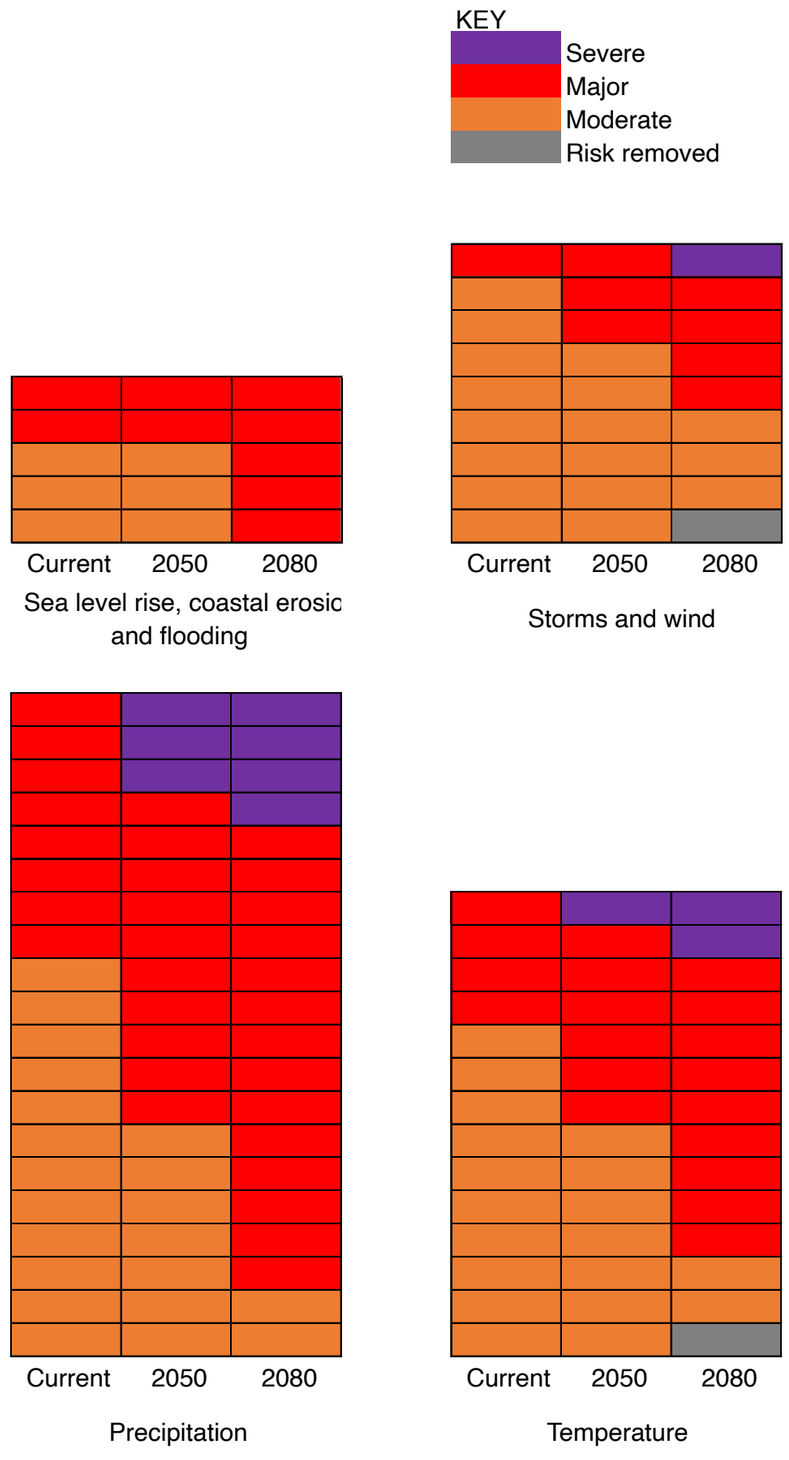


Figure 22) The increasing nature of climate risk to national railway assets. **Source:** Network Rail Third Adaption Report December 2021. **Credit:** Network Rail.

6.2. Asset risk by weather category

6.2.1. High winds & storms (inc. lightning)

Figure 11 shows the shift in climate to global heating, which in part is implicit in putting much more energy into storms that bring lightening, high winds and storms – such as Storm Arwen which led to TSRs affecting passengers and freight. The table on the next page outlines the key asset risks.

Risk status

- There are risks to the OLE from tree 'strikers' as well as other objects blown over from lineside neighbours' properties. However, generation of future projections for wind pose some uncertainty[22].

Lessons from CP6

- Vegetation management can be extremely effective at reducing risks. Between Preston and Carlisle, a vegetation management approach was undertaken to remove tree strike risk. This enabled us to increase the windspeed threshold for imposing speed restrictions from the more regular 60mph up to 70mph. Consequently, speed restrictions were less frequent on this length of line. Yet, to-date vegetation management in CP6 has run behind overall target, with track access and the cost of works being barriers to realising the CP6 objective.
- Third party tree risk is still a hard risk to manage and involves a high degree of stakeholder engagement to achieve. Third party risk is assessed annually by maintenance teams and is prioritised in-line with our modernising maintenance programme and Varley recommendations[23].
- Ash dieback (Hymenoscyphus fraxineus), a fungus killing back the crown of ash trees, leading to dead wood, is becoming an ever-growing threat which highlights the need to be aware of future climate, disease and pest changes. Other tree diseases including water mould (Phytophthora ramorum) is likely to increase the threat to conifers and some shrubs including rhododendron. The Forestry Commission have regulatory powers to require management of these diseases, including statutory plant health notices which may require vegetation management.
- Damage to the delivery unit at Banbury that saw the roof blown off during a winter storm has raised the increasing risk to our buildings estate and this has resulted in winter preparedness briefing notes being developed to ensure that stations are safe for passengers and staff (Figure 23).

Asset	Risk	Risk – current score	Risk scores for 2050^s	Risk scores for 2080^s	NW & C score arrow and justification*
Rail vehicle – rolling stock	Vehicle derailment due to vegetation obstruction on the line.	10/major	12/Major	16/Major	
Staff, OLE and trees	High winds blow trees over causing risks to passengers and staff, potential for OLE strike. Safety and performance risks and repair costs.	10/major	10/major	12/Major	▲ OLE dewirement is a major impacting event, the current tree strike risk in storms should be '10-major' rather than 8-moderate. NW&C has had 14 de-wirements this year, causing delays, passengers having to be de-trained, large scale OLE restoration taking more than 8-hours.
Buildings	High wind speeds present a risk to buildings, particularly those with corrugated roofs elevating sea levels. These large waves can overtop coastal defences and cause inundation, erosion, scour, loss of stability and structural damage.	12/Major	15/major	20/Severe	▲ Branbury roof an example (Figure 23), station canopies a major challenge.
Coastal and estuary protection	Adverse and extreme coastal event causing storm surges, large waves and strong wind.	12/Major	16/Major	20/Severe	▲ The Cumbrian coastal line and the WCML impacted by the Irish sea and scour, in CP5 and 6 this has led to line closure and impacted the nuclear sites in the area.
Level crossing	Failure of barriers, exposed areas will be particularly vulnerable.	9/Moderate	9/Moderate	12/Major	
Power distribution	A direct lightning strike will damage electrical equipment, yet it is an unlikely occurrence.	8/Moderate	8/Moderate	8/Moderate	
Signals structures	High winds cause signal structure failure, particularly on some of the NW Route which has older assets.	9/Moderate	10/major	12/Major	▲ Signal structures does not appear in ARP3 and this is an addition. The age of many assets in the NW Route are around 50 years old and are at risk of failure due to metal corrosion.

Orange text indicates a regional change in score. ▲▼▶ indicates an increase, decrease or no change in the score.

[22]ukcp18-fact-sheet-wind_march21.pdf (metoffice.gov.uk) [23]Network Rail vegetation management review: valuing nature, a railway for people and wildlife – GOV.UK (www.gov.uk).

Figure 24) A network rail delivery unit roof blows off during Storm Eunice – resulting in Chiltern Railway services being suspended. **Source:** https://twitter.com/networkrail/status/1494697757684215812?lang=en **Credit:** Chilterns Railway.

Figure 25) Tree blocking the west coast main line after a fire in Harrow (July 2022) **Source:** Tree blocking the West Coast main line after fire in HArrow (networkrailmediacentre.co.uk) **Credit:** Network Rail.

Next Page: Figure 26) 4km of drainage and ballast on the WCML **Source:** West Coast main line journeys better protected from flooding (networkrailmediacentre.co.uk) **Credit:** Network Rail.

6.2.2. Precipitation and flooding

The physical geography of the NW&C region, with the orientation of Pennines and influence of the Lakeland fells, make it susceptible to westerly rainfall weather fronts. Outside of Western Scotland, the region receives some of the highest rainfall totals of the UK,. The table below outlines the key asset risks.

Risk status

- Many of these risks have been realised in CP6, particularly flooding from rivers and surface run-off which have caused the biggest impact to NW&C.
- In the majority of cases, the risk impact will increase as the climate changes, as water is in constant state of change.
- There will also be lower risks that bring smaller operational, financial and safety risks such as design capacity of roofs being exceeded resulting in leaks.

Lessons from CP6

- As the learnings have highlighted from the tragedy at Carmont, asset knowledge, particularly related to earthworks, is critical. The implementation of recommendations from the Lord Robert Mair report, including increasing drainage inspection capability and capacity to increase BaU capacity will be important to reduce the risk in this area.
- In addition, implementing aspects of the WRTF action plans such as using the CAT will support operations teams in how to manage intense rainfall storms. The Central route in NW&C will be the first to trial the newly developed Rail Operations Weather System (ROWS).
- In relation to structures such as bridges and tunnels, the focus has been on more reactive works, repairing damage and this is likely to continue in to CP7 due to the high CAPEX nature of these schemes. Where there is investment available the focus will be on the highest risk scour sites, and incorporation of climate allowances into new design and built.
- Improvements have been made to cabling – such as using aluminium cables with a water blocking compound embedded in the structure of the cable for better water-proofing in signalling power – and has been adopted in to Regional Asset policies.
- Our whole environment-systems approach has developed through CP6. This is evidenced via partnership projects such as Thrimby (Cumbria) river restoration. We partnered on this with the Eden Rivers Trust and Environment Agency to re-landscape a length of the river to reduce scour risk to the railway earthworks whilst also incrementally decreasing downstream flood-risk (Figure 28, PG. 9).
  - See here for more information: West Coast main line protected as Cumbrian river restored back to its original course (networkrailmediacentre.co.uk)
- Our approach to Biodiversity Net Gain (BNG) was developed in CP6, which will be conitnued in CP7. We partnered with Mersey Rivers Trust, as part of the Headbolt Lane Railway Station (Kirby, Liverpool) new development. This was to put more nature in than would be taken out during development. Together we removed an artificial river bank and bed (concrete half pipe) and rejuvenated some existing ponds and reed beds. In CP7 we need to achieve BNG alongside recognising the cooling and shading services vegetation provides for heat, and runoff management for earthworks.
  - See here for more information: Mersey Rivers Trust – Headbolt Lane BNG
- Drainage is critical to many other assets with signalling, electrical, buildings, earthworks, structures and track all at risk from flooding. The work to complete drainage asset management surveys in CP6 is a large step forward in understanding our cross-asset drainage risk. Schemes such as the Kilsby scheme demonstrate an integrated approach to working across the track-bed and drainage (Figure 24).
- Sustainable Drainage Systems (SuDS) are already utilised in NW&C, such as on the Culcheth (Warrington) goods yard section where use of voided stone allows the sub-base to flood and maintain access to the track; or the permeable car park sub-base at Ordsall Chord (Salford).

Asset	Risk	Risk – current score	Risk scores for 2050^s	Risk scores for 2080^s	NW & C score arrow and justification*
Rock cuttings, soil cuttings, embankments inc. impacts to mobile plant and rolling stock	Increased extremes of wetting and drying increase the rate of asset deterioration, demonstrated through research programmes[24]. A prolonged wet period (e.g. winter 2013/14) will cause problems that become immediately apparent and interrupt operations, but also create longer term problems with a large proportion of assets that have been extensively stressed, but not quite to the point of failure.	12/Major	25/Severe	25/Severe	▶ Additional asset deterioration narrative added.
Tunnels	Water ingress in tunnels leading to an increase in defects (e.g. open joints, spalling and missing bricks) as well as increase demand on track drainage.	12/Major	16/Major	20/Severe	
Pump	Pump failure due to work rate/failure to keep pace with rising water. Pump fouling through muddy flood water clogging screens impacting pump rate.	12/Major	12/Major	12/Major	▶ The Mersey rail tunnel beneath the river is critically reliant on pumps that have a high energy demand.

Orange text indicates a regional change in score. ▲▼▶ indicates an increase, decrease or no change in the score.

[24]Impact of climate change on asset deterioration – GOV.UK (www.gov.uk).

Asset	Risk	Risk – current score	Risk scores for 2050^s	Risk scores for 2080^s	NW & C score arrow and justification*
Track/earthwork drainage	Design capacity of drainage network exceeded, and system surcharges are potentially compromising parent assets – inc. potential ballast mobilisation.	12/Major	12/Major	12/Major	
Non-return valves (both river and coastal outfall)	Wet winters increase river levels and flows in systems, resulting in flap valve levels becoming inappropriate, leading to flooding through surcharge. Concurrent high-waves and sea storms can result in valve levels too low to discharge resulting in flooding.	12/Major	16/Major (river) 12/Major (coastal)	16/Major	
Flood defences/revetments	Increased river/estuarine flows resulting from longer wetter winters result in flood defences being challenged and overwhelmed with resulting flooding of the railway.	12/Major	12/Major	16/Major	
Buildings, stations and platforms	Potential flooding of stations. Overwhelming of building drainage potentially resulting in ingress along with slippery ground conditions – posing a risk to staff and passengers.	9/Moderate	12/Major	12/Major	▲ Signal structures does not appear in ARP3 and this is an addition. The age of many assets in the NW Route are around 50 years old and are at risk of failure due to metal corrosion.
Culvert and underbridge	Design capacity of culvert exceeded and system surcharges with potential for resulting damage to surrounding earthwork, and or flooding track.	9/Moderate	12/Major	16/Major	
Bridges, culverts and retaining walls	Scour, with increased peak flows and intense storms the velocity and erosive power of water is increased, acting on structural vulnerable points and unconsolidated spots.	9/Moderate	9/Moderate	12/Major	
Bridges, culverts and retaining walls	Hydrodynamic loading (including debris impact and buoyancy), in times of high flows, greater forces of water exerted on structures, particularly during watercourse trash screen (partial) blockage scenarios.	12/Major	16/Major	20/Severe	▲ Numerous examples of scour incidents available. Large volume of high-risk sites. Reddish Viaduct (TTA2-18), and Eden Brow (SAC – Settle and Carlisle Line).
Tunnels and subways	Rising sea levels and increased river flows can lead to flooding to tunnels. These could result in scour to tunnels affecting their functionality. Increased groundwater levels, from prolonged rainfall, may outpace pump infrastructure de-watering rates.	9/Moderate	12/Major	16/Major	
Condunctor rail	Flooding affects electrical equipment.	8/Moderate	8/Moderate	10/Moderate	▲ Conductor rail electrification is affected by flooding NW&C have Merseyrail and Euston – Watford conductor rail electrified lines.
Power distribution	Flooding impact power supplies, where insulation is compromised or where levels exceed cabinet base levels – lead to ingress into equipment.	9/Moderate	9/Moderate	12/Major	▲ Deferral of CP6 Signalling Power renewals north of Preston leave vulnerable assets co-located with higher rainfall risks
Track	Flooding and landslip/subsidence/washouts including of ballast shoulder – Failure mechanisms tend to be sudden and have the potential to result in derailment and track asset damage.	8/Moderate	8/Moderate	12/Major	▲ Conductor rail electrification is affected by flooding NW&C have Merseyrail and Euston – Watford conductor rail electrified lines.

Orange text indicates a regional change in score. ▲▼► indicates an increase, decrease or no change in the score.

6.2.3. Sea level rise

The NW&C region operates over coastal and low-lying estuary environments which make it particularly susceptible to sea level rise and coastal erosion, particularly on the northern elements of the WCML and the Cumbrian Coastal Line. The table below outlines the key asset risks.

Risk status

- Coastal flooding is a challenge on the Cumbrian coastal line. A landslip between Whitehaven and Bootle in November 2018 is a reminder of the risk[26].
- A greater understanding of shoreline management plan policy options e.g. hold the line or managed retreat, may need to be understood in context of vulnerable assets.

Lessons from CP6

- We still need to better understand our risks from coastal flooding. We know that in earlier control periods there were no significant delay events caused coastal erosion and waves impacting the line.
- As we continue to develop our understanding in CP7, we will also explore alternative approaches to protecting coastal assets such as using nature-based solutions – as well demonstrated elsewhere[27]. Value of service will guide investment.

Asset	Risk	Risk – current score	Risk scores for 2050^s	Risk scores for 2080^s	NW & C score arrow and justification*
Coastal defences/ revetments	Sea level rise resulting from global sea level rise and isostatic change[25] will challenge flood defences increase railway flood risk.	12/Major	16/Major	20/Severe	▲ Cumbrian coastal line: CBC2-9. 12 week closure of the CBC2 line due to asset failure. Part of the WCML at risk from coastal flooding too. Combined high-tide and river flooding could present particularly challenging situations.
Non-return valves (coastal outfall)	Rising sea levels resulting in flap valve levels becoming inappropriate, leading to flooding through inability to discharge.	12/Major	16/Major	16/Major	
Rolling stock (T&RS), track and power distribution	Subsidence and track wave-strike over-topping during storms, resulting in risk to passengers and staff, safety of trains and mobile plant and potential impacts to power distribution.	9/Moderate	9/Moderate	12/Major	

Orange text indicates a regional change in score. ▲▼► indicates an increase, decrease or no change in the score.

[25]Isostatic sea level change is the result of an increase or decrease in the height of the land. When the height of the land increases, the sea level falls and when the height of the land decreases the sea level rises. Isostatic change is a local sea level change whereas eustatic change is a global sea level change. Source: Sea Level Change (geographyas.info) [26]Mammoth project to move 50,000 tonnes of earth on West Cumbrian coast line (networkrailmediacentre.co.uk) [27]Working with natural processes to reduce flood risk – GOV.UK (www.gov.uk).

6.2.4. Heat

The records for air temperature during the 2019 and 2022 heatwaves were not set in the NW&C region, instead they were set in the Eastern and Southern region. Yet, the frequency, tonnage and usage of the WCML presented real temperature management challenges in CP6. Not just to track and OLE, but also to plantrooms containing electrical equipment. The table below sets out the key asset challenges relates to heat.

Risk status

- Two notable instances of excessive heat in 2019 and 2022 – with the latter seeing record temperatures – does highlight that this is a realised risk and for short periods can severely affect the safe running of the railway.
- During these spells lineside fires, OLE sagging and track buckles occurred as well as some instances of damage to stations such as platforms rising at joints.
- The largest risk potential – clay shrinkage of embankments – is projected to increase in the future.

Lessons from CP6

- Excessive heat affects all assets and during CP6 has been a contributor to performance issues. The use of the Network Rail air operations team (Figure 30) and train-board Automated Intelligent Video Review (AVIR) has enabled risk-based monitoring of track temperatures and catenary weights for OLE.
- Most issues align with older infrastructure. The most effective way of managing excessive heat moving forward is via an effective renewals programme including improving standard details and specifications.
- Effective maintenance – particularly of the ballast shoulder to reduce track buckles and OLE tensioning – has also been found to be a contributing factor in post event reviews.
- Measuring tension in fixed OLE is currently being baselined, before onward monitoring will be undertaken via maintenance tasks for seasonal preparations. Although, it is recognised that we will need to improve the way we measure tension and proactively address low tension issues, rather than being reactive. Learning from the HS2 sensor approach, termed digital twin, is one area of learning.
- In relation to rail, CEN60 is more heat tolerant. Moving to more of this rail will improve resilience, as will moving away from jointed track.
- We are moving to Unattended Geometry Measuring Systems (UGMS) onboard passenger trains to help with desiccation detection on earthworks.
- With regards to signalling equipment, the move away from mechanical to more electronic equipment will increase the breadth of assets susceptible to heat. However, with the move to ETCS, less and less equipment will be lineside.
- Lineside buildings housing critical signalling equipment that are sensitive to temperature changes will see a move to specifying more insulated buildings rather than relying on cooling systems. Shading and greenery is also observed in studies to abate heat stress.

[22]ukcp18-fact-sheet-wind_march21.pdf (metoffice.gov.uk).

Asset	Risk	Risk – current score	Risk scores for 2050^s	Risk scores for 2080^s	NW & C score arrow and justification*
Rock cuttings, soil cuttings, embankments	Repeated periods of hot dry weather lead to drying of soils and shrinkage as part of cyclical processes such as seasonal shrink/swell in tandem with seasonal wetting. This can cause degradation and failures with other age driven processes. Clay shrinkage of embankments will result in deterioration of track geometry and subsequently performance impacts.	12/Major	25/Severe	25/Severe	
Wire run fixed termination	Loss of tension in the wire, leading to pantograph hook over. Through heat extension of cables or through earthworks shrinkage impacting foundations of catenary masts resulting in set-back.	12/Major	12/Major	12/Major	▲ Risk is increased in 2050 from 8/Moderate to consistent major and is contingent on investment. AVIR aids in monitoring risk.
Mobile plant, rail vehicle – rolling stock	Derailment due to track buckle.	10/Major	12/Major	15/Major	
Track (jointed, CWR and S&C)	Track buckles – more likely in jointed but also with Continuous Weld Rail (CWR) if maintenance works cannot be undertaken due to extreme heat.	9/Moderate	9/Moderate	12/Major	
Track and S&C	Destabilised track and poor track quality causing speed restrictions or line closure.	12/Major	9/Moderate	12/Major	▲ There are examples where track has lost its normal geometry in the heat, in part because of earthworks change.
Location case, modular buildings	Components housed within the location case can overheat.	9/Moderate	12/Major	12/Major	▶ Experiences in CP6 have shown that heat presents a challenge.
Rail vehicle – rolling stock	OLE de-wirement due to sag in OLE from high temperatures.	9/Moderate	9/Moderate	12/Major	▶ This also has internal train cooling risks.
Trees and invasive species (inc. Japanese knotweed)	Potential for increased mortality in drought and heat stress resulting in line obstruction or OLE damage. Increased fire risk. The pace of invasive species spread may increase impacting the Permanent way (P-way) inc. track and ballast.	9/Moderate	9/Moderate	9/Moderate	
Staff	Staff welfare. Staff can develop heatstroke, sunburn and can quickly become dehydrated and fatigued loosing concentration. This can have severe health and safety implications.	8/Moderate	9/Moderate	10/Moderate	
Buildings, platforms and level crossings	Overheating affecting internal operations of buildings and presenting human health and fire risk, platform heave may occur impacting use of stations. For level crossings, control and peripheral equipment could overheat.	6/Moderate	9/Moderate	12/Major	

Orange text indicates a regional change in score. ▲▼▶ indicates an increase, decrease or no change in the score.

6.2.5. Snow and ice

The terrain of the NW&C region, with the Pennines, and TransPennine trains and the Lakeland Fells, and the WCML and Cumbrian Coastal Line, make parts of it more vulnerable to snow and ice. The key risks, which follows those of ARP3, are set out below.

Risk status

- The North West of our region in particular has been impacted by snow and ice events during the control period. We also know that the risk from extreme spells akin to the 2018 'Beast from the East' are likely to occur again.
- Although global heating is in effect, at present snow and ice events demonstrate this risk is still in-effect. The December 2023 snow in Cumbria led to lines being closed between Lancaster and Carlisle until the plough train could reach the area . Due to the general impacts from snow, the Police declared a major incident with power cuts and wider disruption to other transport networks. This underlines the interconnected nature of Network Rail systems to wider society.

Lessons from CP6

- Continuing to innovate with advances such as an overhead line de-icer trial at Penrith to reduce the risk of ice forming on contact wires and causing wear of train pantographs.
- Deliver improvements in water management in tunnels – a key cause of ice formation when the temperature drops.
- The recognition that building insulation will become ever more important rather than just relying on cooling. This will require work to be done on building specifications.
- Focus on removal of jointed track to reduce incidents of broken fishplates due to rail contraction.

6.2.6. Autumn leaf fall

Autumn leaf fall does remain a large cause of delay due to adhesion issues and affecting track circuit connectivity; and in some extreme cases a cause of train derailment. However, it is not anticipated that autumn seasonal patterns will change drastically in CP7. Autumn management will continue to be run via our seasonal weather managers and programme of rail head treatment trains.

Asset	Risk	Risk – current score	Risk scores for 2050^s	Risk scores for 2080^s	NW&C score arrow and justification*
Rock cuttings, soil cuttings, embankments	Long term degradation due to age-driven/cyclical processes such as freeze thaw and snowmelt.	12/Major	25/Severe	25/Severe	
Building, bridges, culverts and retaining walls	Deterioration of asset condition.	9/Moderate	9/Moderate	6/Moderate	
Tunnels	Ice formation within shafts, and bores, leading to risk to both operational trains and the workforce.	12/Major	12/Major	12/Major	
Conductor rail	Ice formation on conductor rail prevents trains from drawing power and increases electrical arcing.	8/Moderate	5/Moderate	4/Moderate	▲ Conductor rail electrification is affected by severe snow or ice. NW&C have Merseyrail and Euston – Watford conductor rail electrified lines. Much of NW&C conductor rail does not have heating.
Buildings, inc. floors, pavements, platforms and associated staff and passengers	Excessive snow accumulation on roofs, stressing structures and increasing asset deterioration rate. Risk of slips, trips and falls and deformation of floor surfaces. Risk of station closure.	8/Moderate	9/Moderate	10/Major	

[28]Cumbria snow: Thousands lose power as disruption continues – BBC News.

6.2.7. Asset interdependencies

These occur when railway system infrastructure is reliant on the infrastructure of other organisations, or other organisations are reliant on rail system infrastructure. Cascading impacts emerge when failure of a component or organisation within these inter-connected asset systems occur. Figure 26 outlines the range of multiple dependencies that exist across various sectors. There are numerous examples of where asset independences have become apparent in CP6, with consequent cascading risks emerging. The sub-sections below set out examples of:

- Energy infrastructure being reliant on the railway.
- The railway being impacted by the downstream erosion risk from emergency reservoir draw-down (pumping water-out).
- Degradation of rural flood defence assets that protect the railway.

CP6 examples of asset interdependencies and cascading risk

Flood and scour risk from a third-party reservoir: Manchester to Sheffield (Hope Valley line)

Todd Brook reservoir (Whaley Bridge, Peak District) partial breach August 2019.

- Following heavy rainfall between 27 July and 1 August 2019, the spillway at Toddbrook Reservoir failed. This could have resulted in a lethal uncontrolled release of floodwater downstream, without intervention. 1,500 people were evacuated immediately downstream and the rapid draw-down on the reservoir was commenced, increasing flows in local downstream watercourses. Network Rail assets across and alongside those downstream watercourses were consequently susceptible to flooding and scour risk. As a safety precaution, the Hope Valley line between Manchester and Sheffield was closed for 3 days, resulting in £2.2m weather delay payments[29]. In 1964 and 1977 there were spillway and erosion incidents for this Toddbrook Reservoir dam[30].

Funding

- £13.4m of funding exists for scour mitigation on underbridges and culvert structures in CP7 (Appendix A.ii). Climate change projections (Section 7) for more flashy flow watercourse flow regimes present a challenge in this space. In CP7, the Train Accident Reduction Risk (TARR) element of the regional scorecard will be replaced by 20 Passenger Safety Milestones, which will inform scour mitigation approaches. The focus will shift to passenger safety miles.

Coastal flooding and erosion impacting the nuclear industry: Cumbrian coastal line

Storm damaged Cumbrian coast line, from Storms Desmond, Ciara, Dennis and George

- High tides, strong winds and heavy rain brought by Storms Ciara, Dennis and Jorge caused structural damage to a bridge carrying the railway at Parton. This serves the low value of service Cumbrian coastal line. Both the up and down line were closed in March 2020, so the bridge could be completely replaced to make the railway safe and reliable again[31]. Nearby, in CP5, a section of a Victorian embankment collapsed onto the Cumbrian coast line, in-part through saturation. These examples outline the consequences of climate not just on passengers on lower revenue generating lines, but also for freight operating companies serving critical infrastructure. In particular, removal of nuclear waste via the railway is a time-sensitive activity given potential degradation of radioactive material. Numerous nuclear facilities exist on the Cumbrian coastal line, including nuclear power generation, post-processing sites and disposal sites[32]. Many are linked by the railway and rely on it. The risk here is the need to continue to support the movement of nuclear material, despite the line being a low revenue route section, compared to the WCML. This is a challenge, as the Cumbrian coastal line runs along hilly, rugged terrain exposed to the elements of the Irish Sea. It is therefore heavily engineered and susceptible to extreme weather. Figure 26 outlines the overall high climate risk dependency from the power supply on network rail infrastructure.

Funding

- £0.4m CAPEX exists for coastal defence refurbishment on the NW route, which is a ‘repair and fix’ investment rather than addition of further resilience (Appendix A.ii).
- Climate change adaptation pathways aims to address risk, costs and options. Including potentially for lower revenue route sections – such as the Cumbrian coastal line (Appendix A.i).

[29]https://www.gov.uk/government/publications/toddbrook-reservoir-incident-2019-independent-review [30]Heading 1 (britishdams.org) [31]Storm damaged Cumbrian Coast line set to reopen in one month (networkrailmediacentre.co.uk).

[32]Work underway at Low Level Waste Repository to prepare nuclear waste for final disposal – GOV.UK (www.gov.uk) [33]Whitehaven railway tunnel testing to seek source of mystery orange water (networkrailmediacentre.co.uk).

Mine waters with a tidal pattern: Cumbria's Whitehaven tunnel (2022)

- Whitehaven Tunnel has recently been challenged with seasonal track flooding. The site and area have a long and complex mining history. The floodwater on the track bed and on the rail contains iron ochre, which could be from historic mine workings in the area[33]. In CP6 it was set for a drainage renewal with pre-existing funding, yet the complication is the remediation of this water before discharging into the harbour. The additional complication to this site is the tidal pattern in the floodwaters, that has been ascertained from CCTV monitoring. Currently there is a Train Speed Restriction (TSR) for the tunnel, yet if levels rise, further closure may be required. Again, the local nuclear industry is reliant on this route section to move material. Yet, there is an up and down line on the Cumbrian coastal route, and hence, this would only effect the 'up' line north of Sellafield.

Funding

- At present, the potential need to pump mine water out of the tunnel or treat it to prevent pollution exists. This may extend beyond original CAPEX and OPEX budgets in CP6, which had only planned for plain-line track renewal – not treatment of mine waters and wider mining investigation. In the transition between CP6 and 7, options for securing funding for this enhancement will be explored with the Environment Agency and Coal Authority partners.

CP7 emerging risks

There is a plethora of climate risks in CP7 to railway assets, outlined in the risk assessment above, and will be further developed as part of the Adaptation Reporting Power 4 exercise set to take place during the onset of CP7. One apparent example risk, is the interaction of rural flood defence systems and railway assets.

Figure 27) A river Mersey flood defence embankment offering protection to the New Mills and Cheadle Branch line (NMC) Close inspection of the flood defence mound shows signs of erosion **Source and credit:** Network Rail.

Degrading rural flood defences protecting rail infrastructure

- Re-connecting rivers to their floodplains, and seas to coastal marshes, is evidenced to increase wildlife, improve water quality and reduce flood risk to properties[34]. These types of approaches are termed Nature based Solutions (NbS). Consequently, a reduction in maintenance by flood risk management authorities to enable degradation of these rural defences is possible. This is in order to enable floodplain reconnection and derive associated environmental benefits. Figure 25 shows erosion of one of these defences, which in turn offers protection to the New Mills – Cheadle Branch Line. As no active intervention may occur on these third-party assets, flood risk to rail assets is likely to increase. The route section located behind the defence in Figure 25 is mainly used by rail freight. In CP7 collective action and work with the TA will take place to understand more about this risk.

- Embankment washout under a passenger train at Haddiscoe[35], in part, occurred because of the no active intervention approach to rural flood defences[36]. During Storm Christoph (2021) a severe flood warning was issued by the Environment Agency[37], where a risk to life was present should a flood defence over-top or breach.

Funding

- The TA and regions will work in CP7 to understand more on the nature of this risk and whether flood warning capability could be expanded to cover vulnerable line sections.

- Funding exists for quantitative risk assessments in CP7 along with implementing the WRTF recommendations, which advances Network Rail's forecasting and warning capability (Appendix A.i).

[34]Working with natural processes to reduce flood risk – GOV.UK (www.gov.uk) [35]Between Northwich and Lowestoft, Eastern region. [36]Report 07/2023: Embankment washout under a passenger train at Haddiscoe – GOV.UK (www.gov.uk) [37]The Prime Minister visits Didsbury following Storm Christoph – Creating a better place (blog.gov.uk).

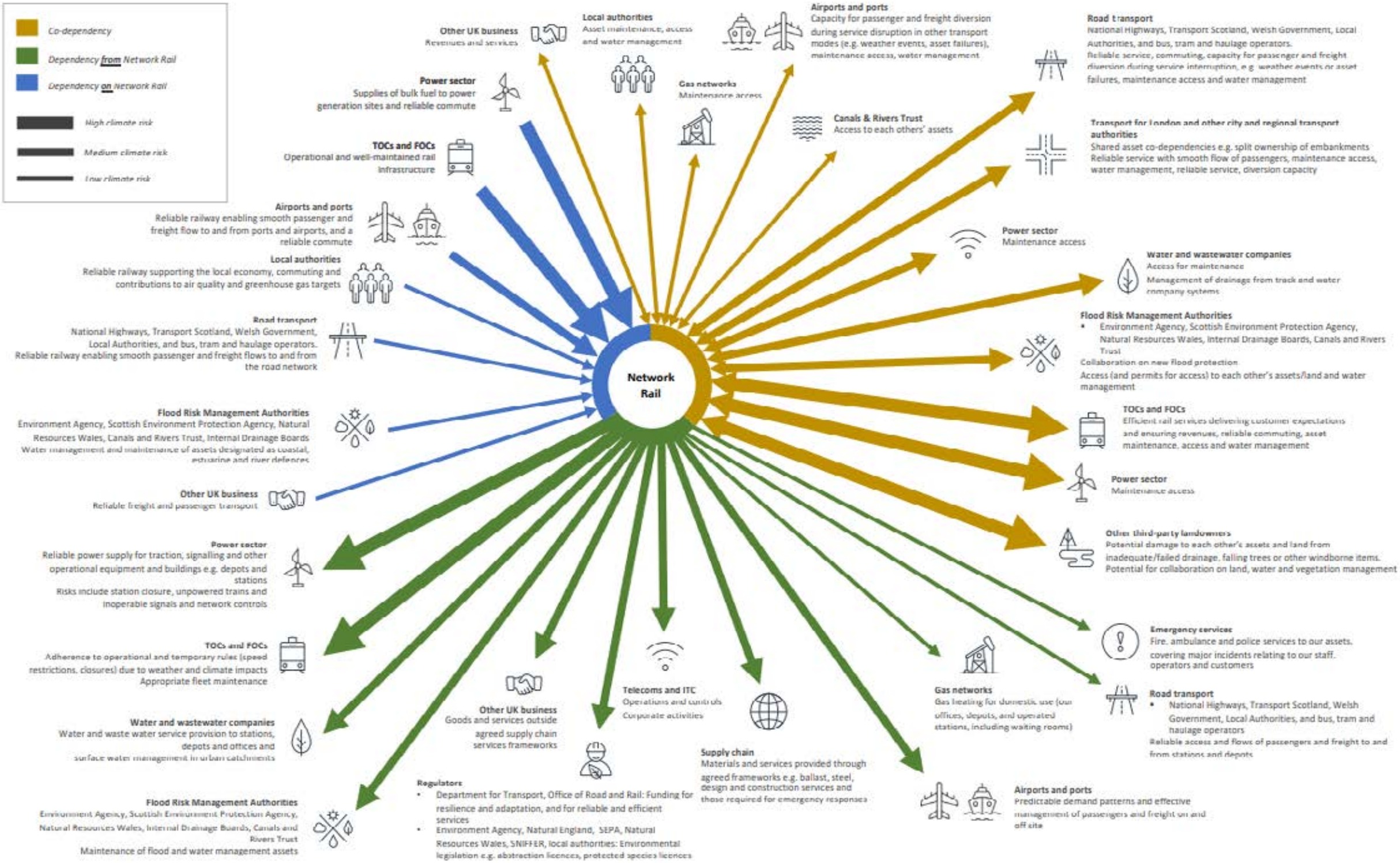


Figure 28) Climate interdependencies **Source:** See the interdependencies section of the Adaptation Reporting Power submission for more information. **Credit:** Network Rail.

7. Control Period 6 (2019 – 2024) Delivery

Context

In CP6 the region has learned from climate risks and events, and in recovering, changed the way it works in re-building assets. Figure 27 demonstrates this. Previously, the electrical signalling cabinets were flooded in Carlisle during Storm Desmond (2015-2016, Figure 2, PG. 14). This resulted in 14 days of closure for repair and recovery, adversely impacting train companies, passengers and freight.
During the re-build, electrical cabinets were elevated above the most probable floods.
So, when Storm Ciara and Dennis (2020) struck, recovery took 24 hours rather than 14 days.
It is worth noting the different magnitude of Storm Desmond, Caira and Dennis – when comparing events and rail-system impacts.

Figure 29) Signalling cabinets on stilts at Caldew junction (N. Carlisle) **Source:** Signalling equipment on stilts helping storm-proof West Coast main line (networkrailmediacentre.co.uk) **Credit:** Network Rail.

Nature based solutions

Many route sections within the region have had watercourses historically straightened to run alongside the railway. This can present an erosion risk to the toe of embankments that support the railway, as well as presenting an OPEX cost for scour and erosion repair. These straight often features-less 'fire-hose' type channels rapidly convey flood waters and create few areas of slower flow – providing valuable habitat refuge for wildlife. In Cumbria, we worked with Eden Rivers Trust, Environment Agency, Natural England and landowners to return the watercourse to its original route. This aimed to reduce the risk of scour, downstream flooding and provide more wildlife habitat (Figure 2). In Merseyside, we worked with Mersey Rivers Trust to achieve BNG, through river, reedbed and pond restoration, as part of a new station development.[38]

We will look to increase the use of NbS when undertaking resilience improvements and will collaborate with third parties to support activities undertaken outside the railway boundary (e.g. catchment based flood management schemes). Willing landowners, the Environment Agency, Rural Payments Agency, Natural England, Local Authorities and the charities sector are key stakeholders in achieving NbS delivery on the ground. Line 7 of the regional asset led activities (Appendix A.ii) sets out our BaU commitment to NbS in CP7. This approach will be vital if we are to achieve our regional targets for BNG, with its consequent benefits to both natural and railway systems. The ORR have recommended greater investment in drainage resilience, and hence, investment in drainage has increased, while NbS budget has decreased. NbS will still be actively pursued during renewals, maintenance and enhancement projects and feature in our operational publications such as habitat management plans.

Barriers to NbS

- The cost and volume approach governs much of the renewals process at Network Rail. It is a means by which the business measures renewal output. This covers the delivery of the volumes discussed in this document.

- At present, the volumes from BNG have started to be counted. Yet most volumes for NbS are not available, and hence, the benefits are not counted or incentivised by the business. This is despite resilience benefits. The Environment Agency and others have developed metrics, including flood resilience and volume of floodwater attenuated.

[38]See section 7> Climate Projection Risk Assessment: Assets > Precipitation and Flooding > Learning for CP6 for more detail.

CP 6 progress tracking

We have progressed against the deliverables in the CP6 WRCAA plan, we worked with the regions' and Route Teams to track our activities against the original plan milestones.

NW&C have been through both putting passengers first, modernising management and now the simpler better greener process which has seen notable changes to team structures compared to when the CP6 plan was created. Modernising management resulted in a dedicated weather resilience and climate change adaptation specialist entering post in the final year of CP6.

Our progress was reported quarterly to the ORR, via the TA. Delivery milestones are recorded against a status, as set-out in the subsections below. We note that our CP6 plans evolved throughout the control period to reflect changing needs and to respond to key events. These events, such as earthwork failure, have required investigation, monitoring and construction. It is for this reason that delivery milestones are categorised. This includes a completed 'works not required' category – which is where alternative action was taken under a managed change control process.

Since the arrival of the WRCCA specialist in the region, work has been underway to develop a climate ready culture and manage corporate risk through the enterprise risk register control process. Already, 250 colleagues have been reached through training and awareness raising efforts. The lead discipline engineers, who lead during the renewals phase, are also briefing their engineering direct reports on climate risk and control measures.

Figure 30) Thrimby Grange River Leith Restoration. **Source:** West Coast main line protected as Cumbrian river restored back to its original course (networkrailmediacentre.co.uk) **Credit:** Network Rail Air Operations Team.

The delivery of CP6 WRCCA milestones is set out below.

Where delivery is 'partial' or 'delivered late' this can be where an unplanned draws budget from a planned renewal, or where inflation has challenged the delivery of existing volumes planned at the start of the CP.

Completed (delivered early)

Wind resilience

- Development and implementation of high wind weather alerts for the buildings portfolio.

Flood resilience Drainage

- Completion of drainage asset data collection to permit targeted maintenance. We have also completed the majority of the WRTF milestones, as tracked by the CMO compliance system, including Action Plans 6, 7 & 8; to increase capability in the Routes and Maintenance to manage drainage inspections and basic maintenance (Appendix D). This work will continue into CP7 (Section 8 – next section)

E&P and signalling

- Elevation of electrical power and signal cabinets above probable flood depths, as driven by the latest standards for a 1-in-200-year return storm event. This has enabled no loss of function during flood events as well as a quicker recovery following a flood. See the introduction to this section for an example case study, and compare Figure 2 to Figure 27.

Completed (as planned)

Heat resilience Track

- Track Renewals programme phasing review to allow greater provision for rail stressing.

E&P and signalling

- All renewal of signalling and electrification plant in lineside buildings to be considered for incorporation of cooling systems.

OLE

- Changes to working practices to enable rail stressing ahead of excessive hot weather.

- Re-tensioning of contact wires for OLE. All high-risk OLE wires have been re-tensioned, including failure sites from the 2019, affected by the European heatwave. Automatic intelligent video recording (AIVR), surveys, OLE engineers and seasonal delivery specialists combine information to assess OLE balance-weights. AVIR has enabled a wider more-efficient surveying of balance-weights.

Flood resilience

- Completion of drainage asset data collection to permit targeted maintenance.

- Inclusion of scour prevention works to all locations assessed as Scour Level 1 sites.

- A dedicated flooding star chamber in North West route – focused on known flood hotspots in the North West. This chamber is between the Principal Route Engineering (PRE) Team, Maintenance Team and Performance Team to discuss all active flooding sites within the North West. Each site has a short-term mitigation and long-term solution assigned with actions on each.

Subsidence resilience

- Implementation of remedial works portfolio at locations at risk of earthworks failure.

- Partnership working with stakeholders such as the Environment Agency and Local Authorities in known high risk locations – including funding to maximise financial efficiency of works. Thrimby Grange represents a good example, outlined above.

Scour

- Closure of high-risk scour sites is a L1 policy requirement with an established process for identifying and managing scour risk. Regional KPI's and the TARR measure track the risk reduction. Immediate risk is mitigated through minor work intervention. The number of high-risk sites fluctuates as we complete scour risk assessments, with some sites being classed as provisionally high risk subject to further investigation of foundation depths. The number of sites and target are re-set at the start of each year, and we are currently set to achieve the Year 5 target.

Heat, subsidence, wind and adhesion resilience

- Management of vegetation on high-risk route sections across c. 20 % of the route mileage.

- Vegetation management between Preston to Carlisle trial has enabled an increase in the windspeed threshold for imposing speed restrictions from the more regular 60mph up to 70mph. Consequently, speed restrictions are less frequent on this length of line.

Climate change planning

- A dedicated Weather Resilience & Climate Change specialist, now in-post, as part of the Modernising Management programme.

Seasonal management and cross-asset working

- Dedicated route-based preparation plans for all seasons, not just autumn, and then full review after each season. There is now an increase in post event reviews and lessons learnt by maintenance, operations and engineering teams.

- More focus on longer term planning such as the North West route strategic advice – a document designed to support decision making on climate adaptation.

Completed (partial)

Subsidence resilience

- Identification and prioritisation of solution subsidence risk.
  - Ongoing review of high-risk locations with some desk studies and ground investigations (GI) completed. Remedial works were not progressed due to re-prioritisation of route budgets.

Completed (works not required)

Flood resilience

- Merseyrail network: Improvements to the pumping system for the underground elements of the network.

Alternative action

- Mersey Tunnel Water Ingress: Active water control in tunnels through improvement works including deflector sheeting, guttering, downpipes and water holding tanks. A case study of the works is available online: Engineers build 'dance floor' to fix Merseyrail underground tunnel (networkrailmediacentre.co.uk)

Completed (delivered late)

Subsidence resilience

- Vegetation management and embankment remedial works at Blackthorn & Piddington and Althorp embankments, as well as vegetation management between Preston and Carlisle, increasing operational efficiency.
  - All works are complete at Blackthorn & Piddington. A TSR remains at Althorp, pending the installation of a long-term monitoring regime.

Wind resilience OLE tree-strikers

- Completion of vegetation surveys to understand and manage high-risk assets, especially relating to dead, dangerous or diseased vegetation exacerbated by climate change. This included a trial between Carlisle and Preston, removing strike risk vegetation, that enabled a 10mph increase in windspeed thresholds for train speeds – reducing disruption and delays.

- Reduction of tree strike risk to reduce blanket speed restrictions. Elevation of critical wind speed for imposition of ESRs.

Heat resilience Track

- Greater stressing of track during renewals phase has provided a local increase in resilience and fewer TSRs. The Network Rail Air Operations team flyovers (Figure 30) and new measurement train, which can detect track defects, has enabled more dynamic management of risk. Maintaining the track support zone, where shrinkable soils exist that effect track geometry, has proved to be trickier and has resulted in an increase in heat TSR in places such as Althorpe embankment in the West Coast South region (see vegetation management below).

E&P and signalling equipment

- The cooling system requirement for renewals, including Uninterrupted Power Supply (UPS), is built into each renewal to improve asset performance and prevent damage. UPS can take over when the main power supply is cut, minimising delays to passengers[39]. We most recently introduced them on the West Coast, and will continue to do so as part of ongoing re-signalling schemes. There is a need to acknowledge the OPEX cost and carbon emission consequence of this cooling. Through climate change adaptation briefing work by the WRCCA specialist, discussion on building design and solar gain mitigation has occurred with the engineering community.

[39]Signals and points failure – Network Rail.

On-track

Subsidence resilience

- Installation of slope movement monitoring equipment, with a trial site underway between Watford and Cleverley, and tilt sensor installation at procurement stage.

Heat resilience

- As part of the WRTF work, Simon Lane wrote a review on the management of extreme heat, which follows successive heatwaves impacting rail operations. The report recommended key aspects to improve performance including operational scenario planning (38/40/52 degrees Celsius air temperature), updates to standards and strengthening of the assurance process. These recommendations span all assets, as set out in Appendix D. The implementation of recommendations in the region is in effect and being tracked through the CMO Compliance system, in CP6 and into CP7 (Appendix A.i). The main assets this relates to is track, OLE and E&P systems, yet it requires a perspective on maintaining the track support zone as part of an interlinked systems engineering approach.

Heat, subsidence, wind and adhesion resilience

- Management of vegetation on high-risk route sections across c. 20 % of the route mileage. Digital lineside inspection technology has been valuable in enabling wide-scale screening and management of vegetation. Removal of vegetation on the Althorpe embankment, to enable the installation of slope monitoring equipment, has also taken away “thirsty trees”. These trees can exacerbate soil shrinkage, making the track support vulnerable and bring about train speed restrictions (see the heat > track subsection above).

Heat, subsidence, wind and adhesion resilience

- Management of vegetation on high-risk route sections across c. 20 % of the route mileage. Digital lineside inspection technology has been valuable in enabling wide-scale screening and management of vegetation. Removal of vegetation on the Althorpe embankment, to enable the installation of slope monitoring equipment, has also taken away “thirsty trees”. These trees can exacerbate soil shrinkage, making the track support vulnerable and bring about train speed restrictions (see the heat > track subsection above).

Subsidence resilience

- We have delivered more renewal volume over CP6 than originally planned. We have actually spent nearly £190m on remedial works which includes ~£40m in responding to asset failures within the control period which were not budgeted for at the beginning of CP6 (£150m)[40].The emergency schemes are asset failures, or nearly asset failures, that had an impact on the safe running of the railway within CP6.

- The 38 emergency schemes are projects which were not in the baseline delivery plan for CP6 and as such funding for these schemes needed to be provided from route/regional re-allocation or re-prioritisation of the existing planned works, including the Geotech planned workbank. The emergency schemes have contributed to more resilience to the network (post failure) than originally planned in the CP.

- As a result, the remaining £8m for Althorpe and £5m for mining has been re-prioritised to part-fund the £40m additional spend on emergency works within the control period as well as cost increases (against baseline budgets) for other projects during the control period.

- Embankment remedial work at high-risk locations e.g. Blackthorn and Piddington embankments.

Asset interdependencies

- The WRTF 19 action plans and the ORR 11 levers have been fundamental in driving systems change in the region. This is in addition to the environmental strategy and ARP 3 process (Section 4.5: WRCCA Management In CP6). For the WRTF the 19 action plans have been tracked regionally and most have been completed (Appendix A.i). This has resulted in greater refinement in weather forecasting, greater slope movement monitoring and alarms, including at Watford and Cleverley (CGJ6), as well as better tracking and targeting of drainage maintenance activities.

- One example of this in practice was the roll out of the CAT and PRIMA. Together, this means that when intense rainfall is predicted, train speeds are dynamically reduced to manage asset failure risk. This aligns to the WRTF action plans following Carmont.

The delivery of activity against the CP6 commitments, and our response to unplanned events, such as earthworks failure or mine-water ingress into tunnels, has enabled us to learn about asset priorities for CP7. In the next section, our CP7 investment approach is set out.

[40]These are not 2023-24 cash prices, rather prices tallied from within the CP.

8. Control Period 7 (2024 – 2029) Investment Plan

Approach to climate resilience in CP7

Despite a strong resilience approach being taken in CP6, performance could have been better.

During the first UK heat weather warning event of 2022, TSRs were implemented on the WCML, impacting passengers and freight users. This was to safely manage passage, particularly over track at risk of buckles or deformation. Or, where OLE was under-tensioned, through cable extension caused by heat, and presented a dewirement or pantograph hook-over risk (Figure 1).

Flood also impacted the region's network, as section 4.4: Weather Impacts For The NW&C region sets out. Extreme weather is a rising cost and risk challenge that CP7 investment must address through intervention or monitoring and train-speeds.

We are following a whole system approach to adapting to climate change in CP7 using:

Learning from CP6 – what went well and what did not go so well.

- The Network Rail climate change risk assessment (section 6 and 7) is used to scrutinise CP7 spend and whether this is an adequate control of risk.
- Development of the climate change adaptation pathways, focussing on the highest areas of climate risk to the network (Figure 29).
- Undertaking internal masterclasses with colleagues on climate adaptation, and starting to make climate adaptation part of performance management for roles whilst ensuring standards (NR, ISO and EN) are adhered to during renewals or enhancements.
- The 11 levers developed by the ORR for managing earthworks. This moves the maturity of thinking from single, asset specific actions to cross asset and third-party management (Figure 33, PG.61).
- Making the action plans of the WRTF BaU within the region, as well as trailing new seasonal weather management tools, such as the Rail Operations Weather Service (ROWS).
- Where possible, use digital monitoring technology to support asset management decisions.
- Our value of service approach to investment planning in CP7 – a new approach that prioritises investment in the strategic route sections that generate the most service from railway operation.

As we undertake renewals, we shall be making the railway more resilient. This is because we plan to upgrade our assets based on what we know today in relation to climate resilience, which differs to when most of these assets were originally installed. This of course does come with limitations, because we shall only be undertaking interventions based on current knowledge and standards. This demonstrates the importance of delivering an adaptation pathway, so that our knowledge of what we need in the future will continue to mature and develop as we move in to CP8.

Climate change adaptation pathways approach

Adaptation pathways are a sequence of adaptation investments or policy actions that work coherently to efficiently and affordably achieve resilience over time. The pathways approach supports strategic, flexible and structured decision-making. It allows decision makers to plan for, prioritise and stagger investment in adaptation options with trigger points and thresholds helping to identify when to revisit decisions or actions.

The methodology for undertaking the adaptation pathways' work in Network Rail is in development, building on the lessons learned during the pilot project undertaken in Southern in 2023. A multicriteria screening will be undertaken of all operational route sections of the rail network to identify those at highest risk from extreme weather and climate change. The outputs of this prioritisation work will be reviewed by asset managers and combined with their understanding of where the highest risk lies prior to shortlisting locations to go through a rapid adaptation pathways assessment. This will include a high-level review of the key risks and adaptation options for a particular location. Those areas deemed to be highest priority from a risk/criticality perspective will be put forward for a detailed adaptation pathways assessment with modelling of adaptation solutions.

The output of the adaptation pathways work will be detailed understanding of where and when investment will be required in the railway setting out the pathways for achieving the strategic objective.

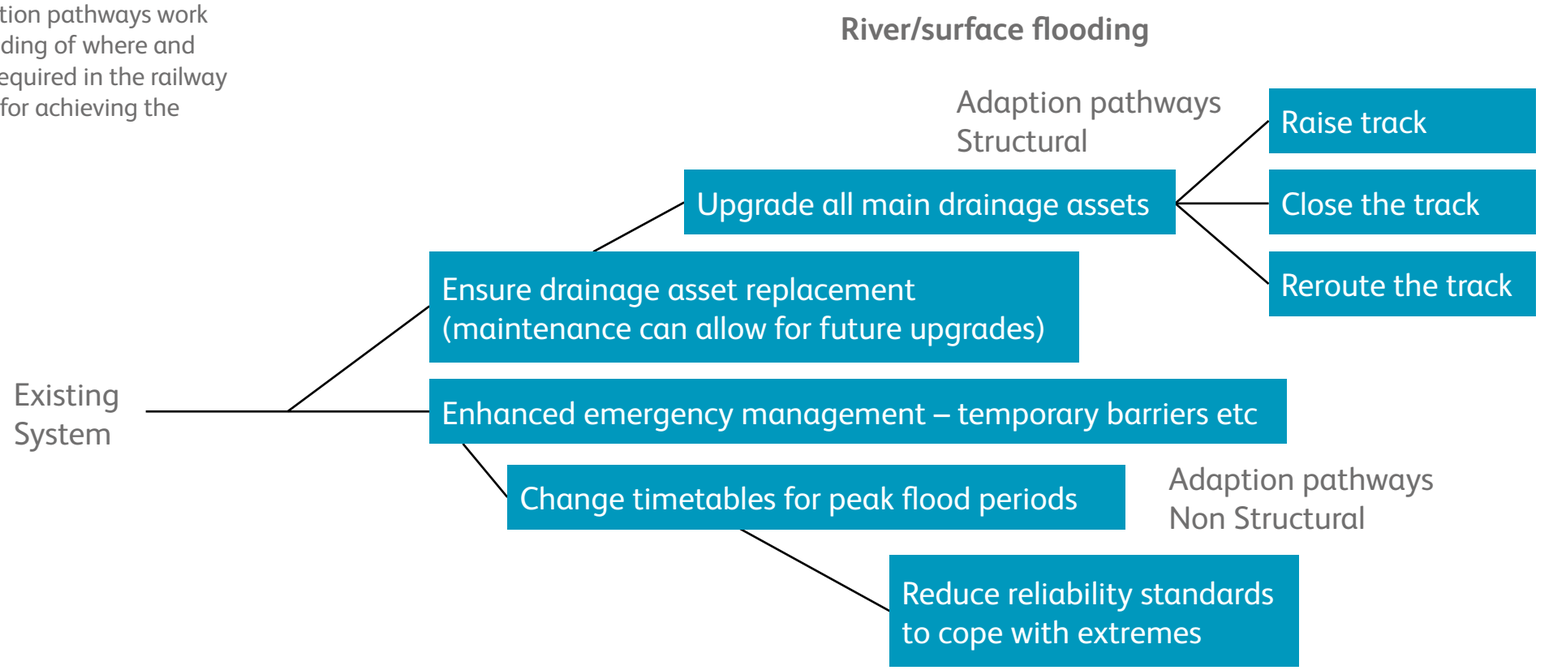


Figure 31) A climate change adaptation pathway: rail schematic for flood risk management. **Source:** Climate Adaptation | Climate Sense. **Credit:** Climate Sense.

[41]enhancements are funded separately.

Investment scale and residual risk

The case for climate adaptation comes with renewed salience, in the wake of Carmont tragedy, and a series of recommendations from the multiple reports (Lord Robert Mair, Dame Julia Slingo, Sir Douglas Oakervee, Simon Lane)[42]. Our investment plan will improve resilience where a renewal, maintenance or monitoring technology is targeted. When considering the range and extent of all assets in the region, the current CP7 investment will intervene at a small number of sites out of the total number that exist overall.

Our approach to asset resilience over the next five years does as much as is practicable with the available funding. As in other industries with large asset bases with long operational lives, the investment profile for asset renewals is not always smooth. In making trade-offs across our asset base, renewals investment has generally been targeted to the most vulnerable assets, with work-banks transitioning from more full renewals to a blend of full renewals and life extending interventions.

We have made tough trade-offs and choices in our plans to maximise the funding available. Safety risk and strategic route sections will serve to guide investment based on the value of service model.

Residual risk associated with this approach will be mitigated by applying more targeted refurbishment and maintenance interventions, with activities focussed on maintaining levels of safety and reliability. We'll also expand the use of remote monitoring, surveying techniques (e.g. helicopter, lidar and train-borne CCTV) and improve our forecasting capabilities to manage residual weather and climate-related risks. Targeted investment in areas of climate risk is proportionate to the understanding of climate risk itself. This is presently problematic, as the climate risk assessment (Section 7) is currently qualitative, not quantitative. Investment in CP7 will enable a better definition of climate risks, through conducting a quantitative climate risk assessment, this is discussed in the next section (Section 10 > Climate Change Adaptation > Resourcing).

Digital tools will be crucial to asset monitoring, supported in some cases by site observation. Together these will enable safe and intelligent based management of timetables and train accident risk. Investment will be tactical with safety and reliability at the forefront of thinking.

[42]See: Our new extreme weather resilience task force – Network Rail.

General investment

From a weather and climate resilience perspective, our plans focus more on where resilience can be accrued as an indirect benefit when intervening on assets, as opposed to pure resilience schemes driven by known weather and climate-related challenge. Although primary and pure resilience projects exist, with examples including our NbS and drainage schemes, or ROWS trials. Tackling the more extreme, longer-term risks associated with climate change will be challenging during the next control period. The bullet points below broadly categorise our spend.

- Spend directly linked to weather resilience and long-term climate adaptation e.g. scour remediation schemes or flood risk management schemes.
- Renewals or maintenance works where weather resilience is the primary benefit e.g. a drainage renewal (Table 5).
- Renewals or maintenance works where weather resilience is the indirect or a lesser benefit e.g. an OLE upgrade.

Investment can be categorised and assessed by the three means above. In the next two sub-sections, we set out spend from a regional and national perspective, as part of BaU activities. It is important to note that this investment does not represent 'new' investment.

Primary benefit

- Pure resilience schemes – these are activities that are being undertaken solely for the purpose of improving our network's resilience to extreme weather.
- Business as usual asset schemes with resilience – these are activities which are driven by poor asset condition as well as weather condition challenges. Undertaking this work delivers an improvement in asset condition and a clear improvement in weather resilience (i.e. a primary benefit of the work is improved resilience to extreme weather).

Table 5 in the next sub-section sets out total CP7 asset led spend, and the associated primary benefits of that spend.

Regional framework (bottom-up)

The tables in Appendix A.i (Regional Activities) and A.ii (Specific Activities) set out our spend in CP7, based on the ORR 11 levers. These levers are set out in more detail in the next section –Investment Framework. This investment information was formulated in consultation with the routes and regional engineers (Figure 10) and represents local insight into investment where WRCCA benefits are anticipated to occur, even if the investment is not driven in response to weather or climate. For instance, Continuous Welded Rail on the Cumbrian coastal line may be installed to offer greater track resilience to heavy freight trains. Rather than combat the design reliability challenges of heat, which it is more resilient to, compared to jointed track (Appendix A.ii: P-Way > Specific Activities).

Our plans will continue to develop and iterate during CP7, particularly to reflect more detailed information that will likely develop at design stage e.g. schemes that may be delivered in partnership or integration of technology from national programmes.

National framework (top-down)
The TA has led a piece of work to better understand the resilience benefit of business-as-usual investment in asset management. Working with WRCCA leads across regions, network technical heads of asset engineering teams and the cost and volumes team in finance, a review of the key volume lines (KVL) within the CP7 work-banks was undertaken to determine the resilience benefit of each activity. This analysis includes activities where weather resilience is a primary benefit of the maintenance or renewals (Table 5).

Investment drivers

Section 4.5 – WRCCA Management In CP6 – sets out how our investment has been driven by extreme weather events. We have learned from these events, and governance structures have changed following the drivers from the WRTF and ORR Targeted Assurance Review (TAR). Table 5 shows the amount of funding planned for CP7, which will indirectly improve climate resilience across the various work types.

Total spend across all work types is £4,134m, from which £523.67m primary benefits are predicted. Due to the needs and nature of the various work types, there was a significant range in spend planned across the region. Signalling and Track rank the highest, and Off-Track ranks the lowest. To realise the full resilience benefits of this investment, climate risk assessments, and implementation of identified controls, is crucial. The principle standard which enables a railway to be built fit for the future is: NR/L2/ENV/015: Environment and Social Minimum Requirements – Design and Construction[43]. Compliance to this standard is crucial as infrastructure assets have long-lives, so climate resilience needs to be built in now. Based on current rates of replacement, 85 % of rail assets could be in place by 2055 – during a period where the extremes are likely to be more challenging than today[44].

Asset type	CP7 total renewal spend (£m)	Primary Benefit (£m)
Track	975	2.3
Off Track	58	
Level Crossing	117	
Signalling	1,061	27.23
Structures	519	15.17
Earthworks	316	246.13
Drainage	163	156.42
Telecoms	58	0.01
Electrification and F. Plant	373	76.41
Buildings	398	
Other renewals	96	
Total	4,134	523.67

Table 5) Primary WRCCA benefits table. NB Total spend is presented as post-efficient cash.

Permanent-way (P-way)

Track renewal and extreme heat resilience

- In Section 6 – Our Climate Change Risks (Heat Section) – we set out the risk heat is causing to track. This risk is underlined by the first hot weather warning in Summer 2022 and the increasing heat delays shown in the data (Figure 5,PG. 10 and Figure 8, PG. 12). Our ARP3 assessment demonstrates the increasing climate risk to track, switches and crossings (S & C, Heat > Table > Track). Monitoring including UGMS and the New Measurement Train (NMT), which uses lasers and cameras to detect faulty track components as the train passes over them, can inform targeted and risk-based maintenance (Figure 30, below). Maintenance is often the first line of defence to enabling effective train movement. Yet, to develop longer asset resilience, renewals are required to the latest standards which deliver design resistance and reliability. This is set out on the ORR 11 levers table below, Figure 33 and in full detail in Appendix A.ii (P-Way > Track). The renewal highlights in CP7 for extreme heat design resistance and reliability are:
  - Upgrade of track to latest standards on high speed (CEN56 – 60), high tonnage SRS including the WCML – for 62km
  - Upgrade of track to Continuous Welded Rail (CWR) on the Cumbrian coastal line and elsewhere ad hoc – for 9 km.

Track drainage renewal and flood resilience

- In Section 6 – Our Climate Change Risks (Precipitation and Flooding) – we set out the risk intense rain is causing to track. This risk is underlined by the Storm Denis, Ciara and Jorge and the increasing rain and flood delays shown in the data (Figure 5, PG. 10 and Figure 8, PG. 12). Our ARP3 assessment demonstrates the increasing climate risk to track (Precipitation and Flooding > Table > Track). Monitoring by the ellipse platform, as well as pipe and watercourse surveys using sonar craft, can inform targeted and risk-based maintenance. Maintenance is often critical to enabling drainage to prevent line flooding. Yet, to develop longer asset resilience, refurb, renewals and inspection are required – to the latest standards – which deliver awareness and implementation. This is set out on the ORR 11 levers table below, Figure 33 and in full detail in Appendix A.ii (P-Way > Track). The renewal highlights in CP7 for extreme precipitation design resistance and reliability are:
  - Track drainage renewal – over 66,000 metres; refurb over 29,000 metres and inspection over 38,500 miles. Together this will prevent line flooding as well as prevent the saturation of earthworks, thereby increasing resilience.

[43]S.4 Environmental and Social Management Process; S. 6.11 Weather Resilience and Climate Change Adaptation (WRCCA).
[44]Second National Infrastructure Assessment – NIC.

Building and civils (B&C)

Earthworks: Rain (washout) and heat (desiccation) resilience

- In Section 6 – Our Climate Change Risks – we set out the risks rain and heat are causing to earthworks. This risk is underlined by the £40m additional CP6 investment in addressing earthworks failure beyond the original plan (Section 6 > An Overview of CP6 Highlights > Subsidence Resilience). In 2019 – 2020 heavy rain caused several delays. 14,112 minutes of delays occurred because of a landslip on the WCML between Warrington and Crewe[45] (Figure 31 – below). Our ARP3 assessment demonstrates the increasing climate risk to earthworks from rain which goes to severe risk status beyond 2080 (Table > Precipitation and Flooding > Rock cuttings, soil cuttings embankments …). The installation of tilt sensors, our slope washout tool and the implementation of the WRTF recommendations, including CAT and PRIMA tool is allowing risk-based management. To develop asset resilience, the riskiest earthworks are to be monitored and those vulnerable to failure subject to maintenance and refurbishment. This aligns to the monitoring ORR levers in the table below and Figure 33. Appendix A.ii (B & C > Earthworks: Embankments, rock cuttings & soil cuttings) provides the detail to this activity. The scale of earthworks monitoring, maintenance and refurb is:
- 5 chain lengths of failure monitoring equipment, maintenance and refurbishment – to manage and prevent earthwork failure and its associated consequences.

Figure 33) Landslip at Dutton Viaduct near Warrington. **Source:** Railway landslip forces section of West Coast main line near Warrington to close (networkrailmediacentre.co.uk) **Credit**: Network Rail.

[45]4.23, PG. 53 in North West & Central region – Annual assessment of Network Rail April 2019 – March 2020 (orr.gov.uk).

Lineside and station buildings: Rain and wind resilience

- In Section 6 – Our Climate Change Risks – we set out the risks rain and wind are causing to buildings. This risk is underlined by Storm Eunice resulting in the Banbury delivery unit roof being blown off and onto the station tracks resulting in Chiltern Railway cancelling its service for the day (Figure 23, PG. 27). Our ARP3 assessment demonstrates the increasing climate risk to buildings (Table > High Winds and Storms). Nationally the chief engineers are updating standards in respect of climate change, which is intended to ensure resilient renewals, including for the buildings standards. Some of the oldest buildings will be subject to renewal and refurbishment. This aligns to the design resistance and reliability ORR levers in the table below and Figure 33. Appendix A.ii (B & C > Buildings) provides the detail to this activity. The scale of building refurbishment, including to roofs, is:
- 14,138 m2 of station roof refurbishment, 6,825m2 of lineside building refurbishment and 1 entire station roof renewal.

Residual risk: track susceptible to extreme heat

- The confirmation of vulnerable track to heat. The quantitative climate risk assessment will aid in identifying where these at-risk locations are (See section 7, PG. 24 > Climate Change Adaptation Resourcing). In the future, the potential for heat disruption may migrate north, affecting the NW Route.

Lineside and extreme storm (wind) resilience – trees

- In Section 6 – Our Climate Change Risks (High Winds & Storms) – we set out the risk storms are causing to track. This risk is underlined by the Storm Arwen in Winter 2021 resulting in TSRs on the WCML and wind featuring prominently in train delay attribution (Figure 5,PG. 10 and Figure 8, PG. 12). Our ARP3 assessment demonstrates the increasing climate risk to track from storms which can affect rolling stock (Table > Track). Digital Lineside Inspection (DLI), a topographical scanning and hyperspectral analysis technique is planned to identify Dead, Dangerous or Diseased Trees which can inform targeted and risk-based vegetation management (Appendix A.i > DLI). Vegetation management is often a crucial step to enabling effective train movement. To develop asset resilience therefore, vegetation encroaching the line needs to be sensitively managed. This aligns to the monitoring ORR lever, in the table below and Figure 33. Appendix A.ii (P-Way > Lineside Vegetation Management) provides the detail to this activity. The highlight vegetation management work in CP7 is:
- Vegetation management – this manages tree strike risk on OLE or track obstruction – over 18,400,000 square metres.

Heat resilience

- Vegetation management needs to be performed in-line with habitat management plans to ensure the cooling and shading services of vegetation is maintained. This cooling and shading can benefit a variety of assets susceptible to solar gain or overheating. This aligns to the John Varley independent review of Network Rails approach to vegetation management: Network Rail vegetation management review: valuing nature, a railway for people and wildlife – GOV.UK (www.gov.uk).

Figure 32) Aerial thermal image showing heated points on approach to Wolverhampton station. **Source:** Aerial thermal image showing heated points on approach to Wolverhampton station – Network Rail Air Operations team (networkrailmediacentre.co.uk) (networkrailmediacentre.co.uk) Credit: Network Rail Air Operations Team.

Structures: Coastal and estuarial defences – coastal flooding and erosion

- In Section 6 – Our Climate Change Risks – we set out the coastal flood risk to the railway. This risk is underlined by coastal erosion scour combined with other events on the Cumbrian coastal line which challenged the time-bound removal of nuclear waste from Sellafield (Subsection: Coastal Flooding and Erosion Impacting Exportation of Nuclear Waste: Cumbrian coastal line). Our ARP3 assessment demonstrates the increasing climate risk to coastal defences (Table > Sea Level Rise). This adds to rises observed nationally from a comprehensive tide-gauge network, going back to 1820. A rise of about 20 cm over the 20th century link up to the present rate of sea level rise over 3 mm/yr[46], with a most recent accelerated rise. This presents risk to coastal and estuarine rail assets, whilst requiring design resistance and reliability in renewals as guided by the ORR levers in the table below and Figure 33. Appendix A.ii (B & C > Structures: Coastal and estuarial defences) provides the detail to this activity. The scale of this resilience is:
- 350m of defence refurbishment, with structures policy requiring resilience to the 1-in-200-year storm event. Only a short section of coastal defence on the WCML N will be benefited.

Residual remaining risk: coastal flood defences set for no active intervention – NW route

- In CP5, 14 schemes were identified to maintain coastal resilience, through new defence construction, by an external flood risk consultant.
- To date, these schemes are still not included in our plan, with no new defences installed or planned. Emergency repair and fix funding will be applied reactively. This presents a risk to parts of the NW Route, with the Cumbrian coastal line particularly vulnerable. The funded CP7 climate change adaptation pathways will be vital in defining planning options for low value of service, but strategically significant, routes such as the Cumbrian coastal line. We will actively monitor risk in CP7.

Residual remaining risk: 3rd party flood defences set for no active intervention – region

- It is predicted that many rural third-party flood defences protect railway assets. Many of these defences were built decades ago for the benefits of multiple stakeholders, including farmland. Although most were not built by Network Rail, many of these are likely to be dilapidating for natural flood management purposes (Figure 25 on page 43). National funding in CP7 has been allocated to map and identify this risk of these defences dilapidating or breaching. Repair and fix funding may be accessible to the route, to repair defence breaches, post-event and subject to land access. We will continue to monitor this risk throughout CP7 and should it materialise, we plan to take a reactive maintenance approach to maintaining this asset.

Structures: Tunnels – water ingress

- In Section 6 – Our Climate Change Risks – we set out the tunnel water-ingress risk to the railway. This risk is underlined by mine water ingress into Whitehaven tunnel resulting in a TSR and potential closure (Subsection: Mine Waters with a Tidal Pattern: Cumbria's Whitehaven Tunnel (2022)). Despite active water management on Mersey Rail in CP6, there is still significant operating cost pumping water out of the tunnel under the Mersey River. Alongside weather delay payments, energy OPEX may also increase. Our ARP3 assessment demonstrates the increasing climate risk to tunnels from water ingress (Table > Precipitation and flooding). Some of the most vulnerable tunnels will be subject to resilience investment. This aligns to the whole systems, design resistance and reliability ORR levers in the table below and Figure 33. Appendix A.ii (B & C > Structures: Tunnels) provides the detail to this activity. The scale of this resilience is:
- 5,400m2 of active water control, which includes preventative repair and hazard management, this will give resilience against water ingress and ice formation. It may also derive heat resilience for brick mortar which can become damaged during extreme heat.

Residual remaining risk: Whitehaven and Mersey rail tunnel

- At present, both Whitehaven Tunnel and Mersey Rail tunnel have water ingress (Figure 32). The mine water complication at Whitehaven is likely to render works an enhancement – which was not originally budgeted for. For Mersey Rail tunnel, under the river, the current indications are that energy OPEX is likely to increase. Options for heat energy recovery from the pumping are being explored as a potential means to provide additional energy resilience and reduce OPEX.

Structures: Underbridges and culverts

- In Section 6 – Our Climate Change Risks – we set out the risks rain and flood cause to structure. Our ARP3 assessment demonstrates the increasing climate risk (Table > Precipitation and Flooding). Managing structures with high-risk scour score of ≥15.8 provides protection to a 1-in-50-year flood event. This aligns to the funding and risk ORR levers in the table below and Figure 33. Appendix A.ii (B & C > Buildings) provides the detail to this activity. The scale of building refurbishment, including to roofs, is:
- Achieve the annual TARR target measure, to manage high-risk scour sites.

Figure 34) Water ingress at Whitehaven Tunnel **Source:** Whitehaven railway tunnel testing to seek source of mystery orange water (networkrailmediacentre.co.uk) **Credit:** Network Rail.

[46]New data reveals British sea level records stretching back 200 years – News – Faculty of Science and Engineering – University of Liverpool.

Electrification and plant (E&P)

OLE: Catenary enhancement and renewal – heat resilience

- In Section 6 – Our Climate Change Risks – we set out the heat risk to OLE which enables effective operation of electrified trains. This risk is underlined by train speed restrictions and Birmingham diversions on the WCML during the Summer 2022 heatwave that delayed passengers and freight. Despite re-tensioning of all OLE that led to TSRs or diversions during the 2022 heatwave, more work is to be done in making assets resilient. Our ARP3 assessment demonstrates the increasing climate risk to OLE from extreme heat (Table >Heat > Fixed Wire Termination Run). Some of OLE on the higher revenue strategic route sections will be subject to resilience investment. This aligns to the whole systems, design resistance and reliability ORR levers in the table below and Figure 33. Appendix A.ii (OLE: Catenary, contact systems) provides the detail to this activity. The scale of this resilience is:
- Circa 705 STK (Single Track kilometres) on the WCML North for the renewal of contact and catenary overhead line wires within the NW renewal workbank and WCML North programme. At Birmingham New Street, 10 STKs will be mid-life refurbished on the MK1 equipment.

Residual risk: OLE susceptible to extreme heat

- The confirmation of vulnerable OLE to heat. The quantitative climate risk assessment will aid in identifying where these at-risk locations are (See section 7, PG. 24 > Climate Change Adaptation Resourcing). In the future, the potential for heat disruption may migrate north, affecting the NW Route.

UPS: Air conditioning plantrooms – heat resilience

- In Section 6 – Our Climate Change Risks – we set out the heat risk to buildings and plantrooms, which can serve to provide UPS that enable effective signalling to trains through the network – that in turn minimises delays. This risk was underlined in part by the heatwave delays experienced in 2019 and 2022. We know electrical assets perform less well during extreme heat and our staff maybe put at risk entering buildings that are hot. Our ARP3 assessment demonstrates the increasing climate risk to OLE from extreme heat (Table >Heat > Location cases, modular buildings & power infrastructure). Some of the buildings on the higher revenue strategic route sections will be subject to resilience investment, though this is likely to contribute to carbon emissions and increased OPEX. This aligns to asset knowledge ORR levers in the table below and Figure 33. Appendix A.ii (OLE: Catenary, contact systems) provides the detail to this activity. The scale of this resilience is:
- 96 plant rooms will be targeted for air conditioning, which will help prevent electrical failures during extreme heat and extends the design battery life.

Residual risk: buildings susceptible to extreme heat

- The confirmation of buildings vulnerable to heat. The quantitative climate risk assessment will aid in identifying where these at-risk locations are (See section 7, PG. 24 > Climate Change Adaptation Resourcing). In the future, the potential for heat disruption may migrate north, affecting the NW Route.

Dis-benefit

- The use of air conditioning is generally power intensive compared to passive technology and is likely to increase operating costs, if the energy is from a non-renewable source.

Signalling

Train detection: Flood resilience

- In Section 6 – Our Climate Change Risks (Precipitation and Flooding) – we set out the risk intense rain is causing to signalling (See also Figure 2, PG 7, Figure 27, PG. 45). This risk is underlined by the Storm Desmond, Denis, Ciara and Jorge and the increasing rain and flood delays shown in the data (Figure 5, PG. 10 and Figure 8, PG. 12). Our ARP3 assessment demonstrates the increasing climate risk to signalling (Precipitation and Flooding > Table > Power Distribution, See also ARP 3[47]). This is set out on the ORR 11 levers table below, Figure 33 and in full detail in Appendix A.ii (Signalling > Train Detection). The renewal highlights in CP7 for extreme precipitation asset knowledge are:
  - The installation of axle counters over 90 sections as part of the Colwich to Rugeley re-signalling, these improve the resilience of train detection, for flooding.

Data (links): Heat and lightening resilience

- In Section 6 – Our Climate Change Risks (Heat & High Winds & Storms) – we set out the risk heat and lightening present to signalling. The related delays shown in the data (Figure 5, PG. 10 and Figure 8, PG. 12). Our ARP3 assessment demonstrates the increasing climate risk to signalling (Heat & High Winds & Storms > Tables > Signalling, See also ARP 3[48]). This is set out on the ORR 11 levers table below, Figure 33 and in full detail in Appendix A.ii (Signalling > Data – Links). The renewal highlights in CP7 for design reliability are:
  - The installation of fibre optic cable on re-signalling schemes on the NW, Crewe and Carlisle high revenue route sections as part of the Kingsmore and Basford Hall re-signalling. The installation of new fibre optic data links reduces the risk of heat and lightening related failure.

Signalling (life extension): Autumn leaf fall

- In Section 6 – Our Climate Change Risks (Autumn Leaf Fall) – we set out the autumn leaf fall presents to safe operation of trains. The related delays shown in the data (Figure 5, PG. 10 and Figure 8, PG. 12), including data for Signals Past at Danger (SPADs) reported via the National Operations Centre (NOC) daily report. Our ARP3 assessment demonstrates the increasing climate risk to signalling (See ARP 3[49]). This is set out on the ORR 11 levers table below, Figure 33 and in full detail in Appendix A.ii (Signalling > Life Extension). The renewal highlights in CP7 for design reliability are:
  - The installation of track circuit loggers and new interlocking functionality as part of renewals and life extension projects. This is set to be over two schemes. We will improve resilience of train detection due to leaf fall identification and improved resilience in the interlocking to reduce delays.

[47]See Signalling in the The ARP 3 risk assessment at: Climate change adaptation – Network Rail [48]See Signalling in the The ARP 3 risk assessment at: Climate change adaptation – Network Rail [49]See Signalling in the ARP 3 risk assessment at: Climate change adaptation – Network Rail.

Interdisciplinary and non-asset drivers

Whilst the investment is set out in disciplines above, the reality is that certain investment will benefit other assets. For instance:

Drainage and earthworks

- The drainage investment resilience will also in-part apply to the lineside estate and benefit earthworks resilience (P-Way >Track drainage renewal and resilience and Appendix A.ii). This is pertinent given the findings of the WRTF Lord Robert Mair Review and Rail RAIB report[50].

Vegetation management and OLE

- The vegetation management investment will not only benefit P-Way though the prevention of obstruction – but also prevents strike risk on OLE (P-Way > Lineside and extreme storm (wind) resilience and Appendix A.ii). This is pertinent given the findings of the WRTF Simon Lane report on extreme heat. Vegetation has a cooling and shading effects to many assets, which can be balanced against the operational railway and to maximise benefits if done in-line with habitat management plans.

There are many other examples of investment that give provide multi-asset benefits, such as enhanced forecasting for autumn leaf fall or advances in signalling that improve train detection. These interdependencies of investment, as part of a systems engineering approach, are set out in the next section. Further non-asset led investment is set out in the next section (10 > climate change adaptation > resourcing) and in the regional activities table in Appendix A ii.

Investment framework

Our investment approach is guided by the ORR 11 levers, set out in Figure 33. Each investment, as set out in the tables of Appendix A.i (Regional Activities – none asset led) and A.ii (Specific Activities – asset led), is linked back to 1 of the 11 levers. A summary table of the investment related to the 11 levers is provided below. WRCCA covers climate change, climate change adaptation and weather management. Today's extreme weather, which may occur over a day or series of days, is associated with climate change, which has occurred over many years and decades.

Consequently, weather management is often short-term and responsive, whereas climate adaptation deals with investments over a design life which can be over many decades. It is during these future decades that assets will be challenged by much harsher conditions. The NW&C investment is therefore linked to the WRTF 19 action plan recommendations, as set out in Appendix D (Action Summary). This has increased the capability within the Routes to manage drainage inspections and conduct basic maintenance. It has also enabled more joint working of drainage, maintenance and earthwork colleagues. In train timetable terms, this has enabled a more dynamic management of train speeds in respect of the rainfall forecast and earthworks risk (see forecasting, table on the next page).

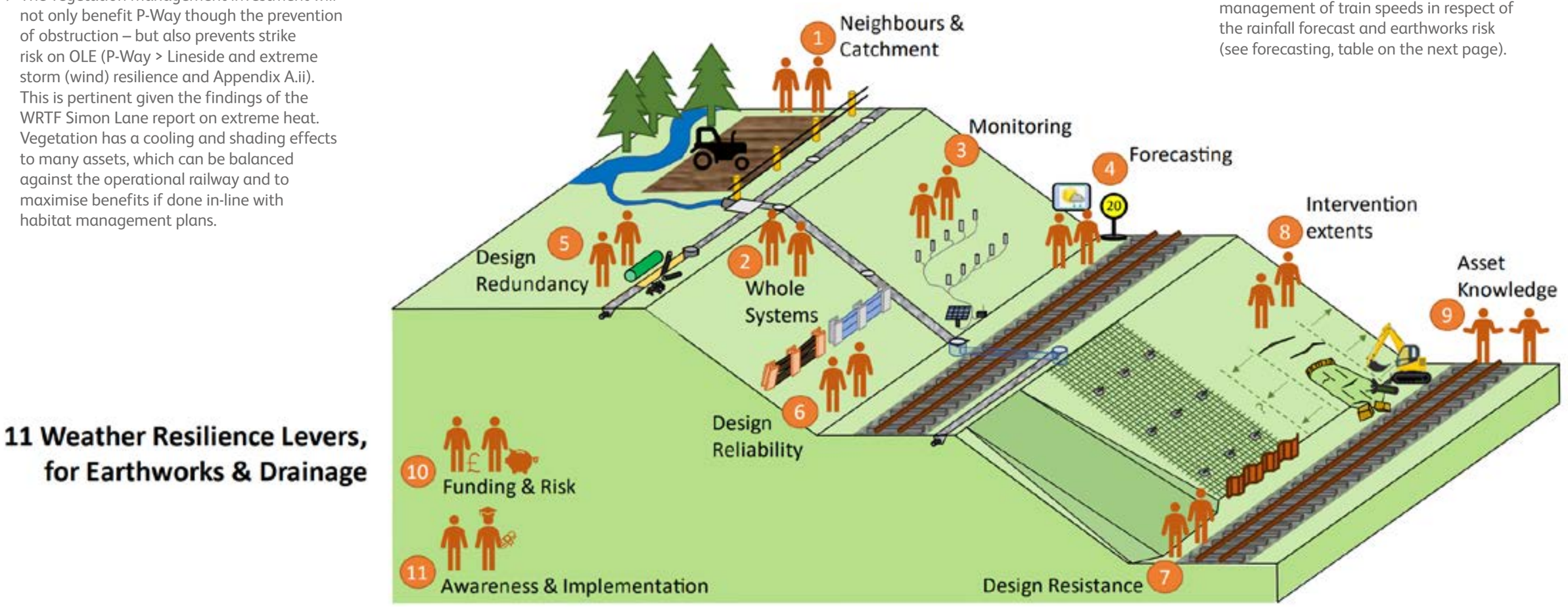


Figure 35) Summary of eleven Network Rail levers, to manage weather resilience for earthworks and drainage. **Source:** Earthworks and Drainage Weather Resilience – Targeted Assurance Review – 25 May 2021 (orr.gov.uk) **Credit:** ORR.

[50]Report 02/2022: Derailment of a passenger train at Carmont – GOV.UK (www.gov.uk).

Lever	Initiative	Benefit
Neighbours and catchment	Co-developing NbS partnership schemes where possible.	Multiple – benefits including scour, flood and water quality risk reduction.
Whole System	Lineside vegetation management.	Improved punctuality through reduction of adhesion, blockage and OLE strike.
Monitoring	Installation of earthwork failure monitoring equipment.	Data and intelligence to help monitor and manage potential safety and performance risks.
Forecasting	Trial of the new ROWS platform. Implementation of CAT and the Proportionate Risk Response to Implementing Mitigating Speeds to Assets (PRIMA) tool, to dynamically manage train speeds against risk.	Development of risk-based management of train speeds in relation to earthworks and drainage. PRIMA is a tool that ensures the most effective operational response is made for each type of rainfall event.
Design resistance / redundancy	WCML track upgrade from CEN56 to CEN60 at high speed and high tonnage sections.	Indirect benefits of heat resistance.
Design reliability	Replacement of jointed track with CWR – Cumbrian coastal line and ad hoc locations.	Indirect benefit of heat resilience, through better management of Critical Rail Temperatures (CRT).
Intervention extents	Renewals conducted in a joint way across the disciplines, where possible and practicable e.g. drainage and track renewals.	Efficient delivery of works and enhanced resilience of assets.
Asset knowledge	Climate change adaptation pathways development, so the highest risk assets are identified and decision trees formulated.	Evidence based risk identification and management.
Funding and risk	Refurbishing coastal defences on Cumbrian coastal line and WCML.	Flood and coastal erosion resilience. Proactive renewal of assets to prevent failure based on past learning.
Awareness and implementation	Sufficient capacity for drainage and lineside, and development of a competency framework (Mair and Slingo).	More efficient asset management.

9. Climate Change Adaptation Governance

Organisational adaptation

Adaptation, the process of changing to suit different conditions, requires sustainable asset management decisions. Sustainable decisions are made when an organisational structure enables climate risks to be identified and controlled as part of BaU activities. Awareness raising of climate change adaptation, training and assurance will be key to ensuring that renewals are building a railway fit for the future and resilient for the intended design life. The following sub-paragraphs set out the structure and management systems which enable adaptation to occur.

Accountability and monitoring

Climate change adaptation
The Director of Safety and Engineering (DSE) is accountable for oversight and tracking assurance of this plan. The specific renewal elements, as set out in Appendix A.ii, sit with each of the three routes, which are managed by Route Directors (Figure 3, table below.

Appendix A.ii is categorised by location, for ease of reference. The strategic direction is provided by DSE, yet routes hold the budgets and are responsible for delivery of asset renewals and maintenance activities.

Progress on delivery will be reported every six months (April - September and October - March each financial year) through the TA to the Climate Change Adaptation Steering Group and to ORR. The specific asset led regional activities set out in Appendix A.ii were formulated in consultation with the regional engineering teams, who in-turn consulted route colleagues. Each activity is recorded by discipline, and can be tracked as such, with the regional WRCCA specialist providing support in providing plan delivery updates to the TA and ORR. The non-asset led regional activities are set out in Appendix A.i, are cross-disciplinary and will span delivery by multiple teams and functions, across the region and the routes.

Operational weather management
The Route Directors are responsible for seasonal delivery specialists and managers who support rail operations through forecasts. Seasonal delivery management now extends beyond simply autumn, with its associated leaf fall and rail-head adhesion risks. It now includes the snow and named storms of winter and tackling operational heat challenges in summer. These small teams exist in each route. They work collectively across routes, to enable collaboration and knowledge-exchange. These teams are supported technically, by the weather director and head of seasonal weather and resilience which exist in the system operator and network services[51].

Region	Route	Investment Information
The Director of Safety and Engineering (DSE)	North West Route Director Central Route Director West Coast South Route Director	• Routes hold the budgets for renewals, seasonal delivery specialists and managers ultimately report to Route Directors. • The DSE team provide thought leadership and information investment in respect of climate change adaptation.

[51]See figure 3.3. WRCCA Governance Structure in Network Rail Third Adaption Report December 2021.

Responsibility

Climate change adaptation spans a range of disciplines, operations, and teams within the region. The WRTF, TA, Sustainability Committee and Executive Leadership Team provide input to the regions, including via external reviews[52].

Climate change adaptation

The DSE delegates responsibility to the Regional Engineers for the relevant disciplines to collate and track climate change adaptation activities. Investment is ultimately a route-level decision, however. Day-to-day climate adaptation strategy, policy and approaches to training, level 2 assurance, risk mapping and adaptation sits with the singular dedicated WRCCA specialist who reports progress via the Regional Head of Sustainable Growth. To ensure knowledge exchange, between shorter term operational weather management and longer-term climate adaptation, there is a dedicated single point of contact within DSE for the WRTF. Figure 10 provides a diagram of this structure (Chapter 5, PG. 15).

Resourcing

Primary WRCCA benefits are set out in Table 5 (PG. 54) above and in Appendix A.i (Regional Activities) and A.ii (Specific Activities). Many of these benefits are by-products of existing renewals rather than targeted WRCCA spend to purely increase resilience. Yet, a very small percentage of the overall investment in CP7 is targeted at WRCCA. The investment objectives are set out in the sub-sections below.

Climate change adaptation

- £1.4m Operating Expense (OPEX) has been allocated to climate change adaptation projects in CP7. This funding needs to address 3 key themes:
  - Undertaking climate risk assessments and developing a long-term adaptation pathway strategy and plan.
  - Pure resilience projects.
  - Partnership funding.

Pure resilience and partnership projects may occur together (e.g. on a NbS scheme) and this is likely to be funded by asset-led investment. If OPEX funds remain outside of the climate risk assessment and adaptation pathway, these may serve to support partnerships and resilience.

Weather risk taskforce

- £94.6m OPEX has been allocated to deliver the WRTF action plans, set out in Appendix D. Action plans 6,7 and 8 have been prioritised:
  - 6: Integrated approach between Geotech, drainage and vegetation management.
  - 7: Sufficient drainage inspectors under control of route asset managers.
  - 8: Dedicated drainage maintenance teams across all routes.

CP7 plan implementation

The delivery of asset renewals at a site level, and a change of activity, based on present-day requirements is ultimately a route-level decision made by regional engineers who directly report to the DSE and provide governance and cross-route insight. Delivery of asset volumes will be tracked through a report of authorised investment of activities providing resilience benefit. Unless identified as a standalone line item, as set out in the tables of Appendix A.i (Regional Activities) and A.ii (Specific Activities), individual projects will not be reported in favour of an overarching view of activity within different asset functions. This process will also enable us to demonstrate where asset volumes are providing indirect resilience benefit and it is expected that cumulative investment in resilience during CP7 will be higher than what is forecast in this plan.

[52]See figure 3.3. WRCCA Governance Structure in Network Rail Third Adaption Report December 2021.

Appendix

A. Appendix 1: Regional and specific activities in CP7 which address climate change

i. Regional activities

We recognise that there are cross cutting enabling activities that apply to all assets and all of the 11 levers and these will be delivered as programmes of work across the region. These activities are non-asset led and exist across a variety of budgets, including regional or dedicated investments. For instance, for implementing the WRTF recommendations, following the Carmont tragedy.

Asset Information		Action Information					Action Target			Delivery Year					Climate Adaptation/Resilience		Monitoring	
Asset Class/ Lead Team	Sub-Asset Class	Category	Name	Location	Description	Cost (£m)	Target	Unit	Monitoring	1	2	3	4	5	Benefit	Risk Addressed	Monitoring Regime	Linked 11 levers
All	All	Competency, Risk Management, Knowledge	Climate Change Adaptation (inc. pathway)	Region	£1.4M Operating Expense (OPEX) has been allocated to climate change adaptation projects in CP7. This funding needs to address 3 key themes: • Pure resilience projects; • Partnership funding; • Undertaking climate risk assessments and developing a long term adaptation pathway strategy and plan.	£1.4m	1	Strategy / Report				1				Practically, a sub-set of very high-climate risk locations exposed to climate risk (e.g., coastal erosion) will be identified. These will be locations where a complex long term strategy will be required to manage the climate risk(s) of concern.	The objectiw is to locate the highest risk sites on key strategic route sections		Awareness and implementation, Asset Knowledge.
All	All - though mainly earthworks, drainage, track, OLE and operational forecasts.	Regions, Intelligent Infrastructure	Weather Risk Taskforce	Region	Implement the weather risk taskforce action plans, recommendations, trials and learning. OPEX has been allocated to deliver the WRTF action plans, set out in Appendix C. Action plans 6, 7 and 8 have been prioritised: • 6: Integrated approach between Geotech, drainage and vegetation management; • 7: Sufficient drainage inspectors under control of route asset managers; • 8: Dedicated drainage maintenance teams across all routes.	BAU	Ad hoe – to action plan.									Lessons learned from the WRTF. NW&C railway more resilient to the changing climate, particularly through forecasting.	Extreme weather impact – predict and prevent; drainage risk, earthworks risk (desiccation/washout), competency, maintenance regimes and inspection, strategy and policy (mainly drainage and earthworks).	Board, CMO Compliance System.	Awareness and implementation.
Off-track	Lineside vegetation	Intelligent Infrastructure	Digital Lineside Inspection	Region	Identification of Dead, Dangerous or Diseased trees and vegetation encroachment – as a decision support tool. The use technology to will assist in the management of weather resilience. Particularly, in the identification of vegetation wlnerable to high wind-speeds, which may lead to obstruction – or sources adhesion. Intelligent Infrastructure technology embedded into the business, specifically Digital Lineside Inspection (DLI), which makes used of cyclical Light Detection and Ranging (LIDAR) and hyperspectral Analysis.	£147m	2,014	miles		403	403	403	403	403	Increased asset information leading to more informed asset investment decisions.	Hazardous wgetation management which has interplay with extreme weather.	Through defined project milestones.	Forecasting. Monitoring.
All	All	Efficiency	Efficiency ‘musts’	Region	As part of NW &C’s strategic efficiency ‘must’ attempts will be made to find more efficient approaches to delivery throughout the work-bank.	BAU		N/A							More efficient use of funding.			Funding and risk.
All	All	Competency, Risk Management, Knowledge	Climate Ready Colleagues	Region	Develop a plan and route to WRCCA competency programme of activity to build the awareness, knowledge and competence of NW&C key colleagues. This has interaction with the WRTF weather academy.	BAU	Majority of staff competent in key roles.	Percentage (%) of targeted roles.	HR Systems and session tracking tables.		50	60	70	75	Workforce capability dewloped to build WRCCA in to day to day business decisions	Knowtedge of climate risk and capable of applying risk reduction measures.	HR, online performance management system – Oracle	Awareness and implementation, Asset Knowiedge.
All	All	Renewals	Assurance	Region	During a renewal the designer is required assess the impact of climate change on the project/works. This requirement is set out in the Environment and Social Minimum Requirements – Design and Construction (NR/L2/ENV/015). To ensure climate risk is assessed and managed, an annual level 2 assurance exercise is to occur that will investigate whether risk assessments have been undertaken and appropriate controls implemented.	BAU	1	Strategy/ Report p.a.	Peer review by quality managers within governance, risk and assurance.	1	1	1	1	1	Renewals are built resilient to be resilient to climate change risks	Climate change risks at the location of a renewal are quantified and controlled/ mitigated.	Via the integrated assurance plan and through the assurance process.	Awareness and implementation.

ii. Specific actions related to the 11 levers

Much of our management is 'business as usual' in relation to making the railway more resilient to climate change each day. However, there are important initiatives that require tracking and monitoring to ensure we are making progress in these critical areas. These activities are asset led.

Asset Information		Action Information					Action Target			Delivery Year					Climate Adaptation/Resilience		Monitoring	
Asset Class/ Lead Team	Sub-Asset Class	Category	Name	Location	Description	Cost (£m)	Target	Unit	Monitoring	1	2	3	4	5	Benefit	Risk Addressed	Monitoring Regime	Linked 11 levers
P-Way	Track	Cat 1A,1 and 2 track. Replace, renewal	CEN56 – CEN60 Upgrade	Mainly WCML	Upgrade of CEN56 to CEN60, focussing on high speed and high tonnage, SRS inc. WCML. This allows the CRT to increase by 4 deg C, for the same SFT. This investment is not being targeted at areas of heat risk primarily, yet rather SRS, tonnage and speed – which equates to the value of service.	£140m	62	km	90% of full renewals on Cat. 1A, 1 and 2.	12	12	12	13	13	CEN60 has a higher CRT compared to CEN56, by 3 dec C, therefore whilst the investment is not primarily being targeted at areas of known heat issues, a co-benefit is increased future heat resilience. Particularly, on the highest traffic route.	Heat/temperature, safety and performance of key SRS.		Design Resistance
P-Way	Track	Refurb and renewal	Continuous Welded Rail (CWR)	Cumbrian Coastal Line, and renewal elsewhere – ad hoc.	Replacement of jointed track with CWR, which enables better management of CRT and hot weather/temperatures by up to 6 deg C.	£14m	9	km		2	2	2	2	1	This investment is being made based on life-expired assets and to alleviate maintenance costs and safety challenges – i.e. reduced boots on ballast. CWR can be monitored by train borne inspection – a form of remote condition monitoring. A by-product of this investment, is a new section track more reliant to heat or extreme temperatures.	Heat /temperature, safety and performance. Maintenance costs – reduced OPEX.		Design Reliability
P-way	Lineside: Vegetation management	Maintenance and management	Vegetation management	Region	Vegetation management and tracking of vegetation maintenance activities via ellipse.	£10.2m	18,406,552	square metres		3,507,817	3,683,180	3,726,890	3,792,870	3,695,796	Management of dead, dangerous or diseased trees which can present a strike risk to OLE. A blockage risk to passing trains, and risks to wider interconnected rail-system assets. Invasive plants such as Japanese knotweed or Himalayan Balsam which present operational challenges can be managed through this programme. Vegetation management in CP6 has enabled improved punctuality along key route sections.	All	Tacked via the ellipse software.	Whole System.
P-Way	Drainage	Renewal	Track drainage renewal	Region	Track drainage renewal.	£90m	66,000	metres		13,200	13,200	13,200	13,200	13,200	Increased resilience to flooding.	Precipitation		Funding & Risk
P-Way	Drainage	Resilience renewal and new build	Drainage asset resilience	Region	Drainage – resilience.	£46m	29,000	metres		5,800	5,800	5,800	5,800	5,800	Increased resilience to flooding.	Precipitation		Funding & Risk

Asset Information		Action Information					Action Target			Delivery Year					Climate Adaptation/Resilience		Monitoring	
Asset Class/ Lead Team	Sub-Asset Class	Category	Name	Location	Description	Cost (£m)	Target	Unit	Monitoring	1	2	3	4	5	Benefit	Risk Addressed	Monitoring Regime	Linked 11 levers
P-Way	Drainage	Inspection and maintenance including improving conveyance	Drainage asset optimisation	Region	Inspection and maintenance, including tracking of drainage activities via ellipse to monitor progress.	£3.8m	38,535	miles		7,674	7,682	7,706	7,728	7,745	Increased asset information leading to more informed asset investment decisions.	6 flood risk partnership schemes with the EA which were originally programmed to increase flood resilience have since been removed with rationalisation of work banks due to a risk based management approach.	Tacked via the ellipse software.	Whole Systems
P-Way, Buildings and Civils, E & P	All	Partnerships	Flood and scour risk reduction partnerships	Region	Co-development of flood and scour risk management schemes in CP7. NW&C will seek to develop schemes where joined partnership investment presents a mutual efficiency to both partners. Opportunities will be perused as part of a BAU approach, with a particular focus on NbS, that can give biodiversity benefits.	BAU	0	schemes		0	0	0	0	0	More efficient use of public resource. Wider catchment management leading to more optimal solution. At present, following funding restrictions there has been a reduction in the number of schemes, yet regional drainage colleagues are collaborating in Lostock (Bolton) and Carlisle (Cumbria) to reduce flood risk to infrastructure.	Precipitation		Neighbours & Catchments
Buildings and Civils	Earthworks: Embankments, rock cuttings & soil cuttings	Renew, Refurb and Maintain	Earthworks resilience	Region	Renewals intervention of embankments, soil/rock cuttings that will improve extreme weather resilience. Delivery year subject to access availability.	£70m	302 Nr. 5 Chain Lengths	Number 5 chain Length of in-terventions or mitiga-tions.	Change Control and RF process	69	65	88	154	90	Will reduce the risk of landslips, failures and degradation brought about from adverse extreme weather. By improving condition of assets they will become resilient against prolonged heavy rainfall, and extreme temperatures.	Addresses safety concerns and significant performance impacts due to asset degradation, failure, and deterioration of track geometry due to flooding, scour washout, saturation and seasonal cyclical processes shrink/swell, freeze/thaw.	Schemes delivered, volumes reported through investment authority process, sign off of reports etc.	Funding & Risk
Buildings and Civils	Earthworks: Embankments, rock cuttings & soil cuttings	Monitoring	Earthworks failure monitoring	Region	Installation of earthwork failure monitoring equipment.	£8m	109 Nr. 5 Chain Lengths	Number 5 chain Length of in-terventions or mitiga-tions.	Change Control and RF process	22	22	22	24	24	Increased asset information leading to more informed asset investment decisions	Data and intelligence gathering to help monitor and manage potential safety and performance risks.	Schemes delivered, volumes reported through investment authority process, sign off of reports etc.	Monitoring
Buildings and Civils	Buildings: Franchised Stations	Renew, Refurbishment	Station roof renewal and refurbishment	Region	Renewal of roofs and canopies at various stations. Works are a mix of strengthening and refurbishment and include, where required, renewal of rain water goods.	£73m	14,138 m2 reported volume	Square metres of treated area.	Change Control and RF process	3,066	405	5,975	3,003	1,689	Increased asset resilience against wind and rain	Safety of passengers and staff from falling debris (roof coverings).	Schemes delivered, volumes reported through investment authority process, sign off of reports etc.	Funding & Risk

Asset Information		Action Information					Action Target			Delivery Year					Climate Adaptation/Resilience		Monitoring	
Asset Class/ Lead Team	Sub-Asset Class	Category	Name	Location	Description	Cost (£m)	Target	Unit	Monitoring	1	2	3	4	5	Benefit	Risk Addressed	Monitoring Regime	Linked 11 levers
Buildings and Civils	Buildings: Lineside Buildings	Refurbishment	Building refurbishment	Region	Refurbishment of deteriorating assets, to improve their resilience to rain and temperature.	£15m	6,825 m2 reported volume.	Square metres of treated area.	Change Control and RF process	0	0	2,460	2,235	2,130	Increased asset resilience against wind, rain and temperature.	Structural repairs and refurbishment to improve the resilience of numerous assets against all weather types.	Schemes delivered, volumes reported through investment authority process, sign off of reports etc.	Funding & Risk
Buildings and Civils	Buildings: Managed Stations	Renew, Refurbishment	Station roof renewal and refurbishment	Region	Roof repairs and drainage refurbishment.	£0.5m	2,090 m2 initial estimate but will be based on design development. Euston Station (1 asset).	Square metres of treated area.	Change Control and RF process	1,452	638	0	0	0	Increased asset resilience against wind and rain.	Safety of passengers and staff from falling debris (roof coverings).	Volumes reported through investment authority process, sign off of reports etc.	Funding & Risk
Buildings and Civils	Structures: Underbridges, Culverts	Replace, Scour	Scour mitigation	Region	Undertake physical mitigation to provide resilience against scour and flood events This target includes sites that are included in the high-risk scour database, tracked through the Regional TARR measure, as well as other sites where intervention works will improve an asset's resilience, e.g. works to medium & low-risk sites and to culverts. The cost includes all schemes that contribute to improving network resilience, whilst the targets will measure progress against TARR.	£13.4m	Achieve the annual TARR target measure.	No of schemes	TARR Measure	Target set annually	Target set annually	Target set annually	Target set annually	Target set annually	Managing structures with high-risk scour score of ≥15.8 provides protection to a 1 in 50 year flood event.	Improved resilience against scour and extreme weather events. Protection against increased water flows to prevent potential passenger, public and workforce safety risk.	TARR glidepaths, schemes delivered, volumes reported through investment authority process, sign off of reports etc.	Funding & Risk
Buildings and Civils	Structures: Coastal & Estuarial Defences	Refurbishment	Coastal defence refurbishment	North West Route – CGJ7	There is significant erosion taking place and essential preventative works are required to protect the operational line from speed restrictions, closure or potential wash out. Final delivery year subject to access, consents and licences.	£0.4m	350m reported volume.	Metres (length) of track stabilised by works undertaken.	Change Control and RF process		350				Structures policy is to provide CERD resilience against 1 in 200 year storm events.	Washout, scour and erosion risk due to frequent storm surges, high winds and rising sea levels which could potentially impact safety and performance.	Scheme delivered, volume reported through investment authority process, sign off of reports etc.	Funding & Risk
Buildings and Civils	Structures: Tunnels	Active water control (Preventative, Repair, Hazard Management)	Tunnel ingress management	Region	Improve resilience to water ingress due to extreme prolonged rainfall and ice formation due to low temperatures. Delivery year subject to access, consents and licences.	£7.5m	5,400 m2 reported volume.	Square metres of internal treated area.	Change Control and RF process	1,080	1,080	1,080	1,080	1,080	Tunnels policy is to use extreme weather plans to identify structures at risk of ice formation. Active water control also prolongs the life of other systems.	Addresses safety and performance risks primarily associated with prolonged and/ or heavy rainfall and extreme temperatures.	Schemes delivered, volumes reported through investment authority process, sign off of reports etc.	Funding & Risk
E & P	OLE: Catenary, contact systems	Renewal	Contact and Catenary renewal	WCML North programme (renewal)	Deliver west coast north aluminium catenary replacement to copper to increase design temperature.	£52m	465	Single Track Kilometre (STK)				155	155	155	OLE more resilient to extreme heat. Change from -18 deg C to 38 deg C to -12 deg to 43 deg C, in anticipation of standards change from TA, yet also to make the line more resilient to extreme heat.		AIVR (Automatic Intelligent Video Recording) – smart way of monitoring compliance in a safe way versus site inspections. More frequent coverage on non yellow stock.	Design Reliability

Asset Information		Action Information					Action Target			Delivery Year					Climate Adaptation/Resilience		Monitoring	
Asset Class/ Lead Team	Sub-Asset Class	Category	Name	Location	Description	Cost (£m)	Target	Unit	Monitoring	1	2	3	4	5	Benefit	Risk Addressed	Monitoring Regime	Linked 11 levers
E & P	OLE: Catenary, contact systems	Renewal	Contact and Catenary renewal	NW renewal	Deliver west coast north aluminium catenary replacement to copper to increase design temperature.	£26m	240	Single Track Kilometre (STK)		48	48	48	48	48	OLE more resilient to extreme heat. Change from -18 deg C to 38 deg C to -12 deg to 43 deg C, in anticipation of standards change from TA, yet also to make the line more resilient to extreme heat.	Heat	AIVR (Automatic Intelligent Video Recording) – smart way of monitoring compliance in a safe way versus site inspections. More frequent coverage on non yellow stock.	Design Reliability
E & P	OLE: Contact systems	Refurbishment	MK1 mid-life refurbishment	Central	Re-tensioning programme at Birmingham New Street.	£12.91m	10.1	Single Track Kilometre (STK)			3.039	2.667	2.192	2.227	OLE more resilient to extreme heat, through re-tensioning, fixed termination line with no balance weights is resilient -5 deg C to 50 dec C.	Extreme heat		Design Reliability
E & P	UPS	Heat resilience, plant room and UPS	Air conditioning plantrooms	Region	Adding air conditioning to plant rooms to cool electrical equipment and maintain performance during extreme heats. Assumption of 1 unit per location.	£10.66m	96	Location		22	16	11	31	16	Performance of equipment and prevention of failures, this extends to the designed battery life.	Extreme heat		Design Reliability
E & P	Signalling and power	Renewal, upgrade	Cable water blocking on new cables	Region	All new cables have water blocking components, so during of times of cable damage though hydraulic action cables can self seal. This the implementation of a new standard on renewals.	BAU												
Signalling	Train detection	Renewal	Colwich to Rugelely re-signalling	WCS Colwich to Rugeley	Installation of axle counter train detection.	BAU		Sections	BaU as part of signalling commission	90					Improve resilience of train detection.	Flooding		Asset Knowledge
Signalling	Data – links	Renewal	Kingsmoor resignalling Basford Hall resignalling	NW Crewe Carlisle	Installation of new fibre optic data links on re-signalling schemes.	BAU		Schemes	BaU as part of signalling commission		1	1			Installation of new fibre optic data links on re-signalling schemes reduces the risks of heat and lightening related failures.	Heat & Lightening Risk		Design Reliability
Signalling	Life extension	Renewal	Track circuit renewals SSI life extension	Central	Installation of track circuit loggers and new interlocking functionality as part of renewals and life extension projects.	BAU		Schemes	BaU as part of signalling commission					2	Improve resilience of train detection due to leaf fall identification and improved resilience in the interlocking to reduce delays.	Autumn leaf fall		Design Reliability
Off-track, OLE, E & P, P-Way	Catenary, contact systems, track	Guidance	Habitat management Plans	Region	Implementation of vegetation and habitat management plans to better control vegetation risk.	BAU	100% compliance in place in relation to sites where work is being undertaken.	BAU							More effective ongoing maintenance to reduce vegetation risk to inter-connected rail systems.			Asset Knowledge
All assets	Geotech, drainage, vegetation management, drainage inspection and maintenance.	Guidance, systems thinking	WRTF	Region	Implement WRTF action plans – see regional activities table.	As required	As required	BAU	CMO Compliance System						NW&C railway more resilient to the changing climate. See regional activities table.	Forecasting, rainfall slope washout, drainage asset performance, earthworks monitoring, cross-discipline working.		Forecasting, Whole Systems

B. Appendix 2: Climate change risk tables

i. Temperature projections

Change in mean daily maximum temperature (˚C) (UKCP18)

UK administrative region	Climate change scenario	January				July			
		Baseline (mm)	2030s (%)	2050s (%)	2070s (%)	Baseline (mm)	2030s (%)	2050s (%)	2070s (%)
North West England	Primary	6.1	1.8	2.2	2.9	19.1	1.7	2.3	3.8
	Higher		1.9	3.2	4.8		2.0	3.1	5.2
West Midlands	Primary	6.7	1.8	2.2	3.0	21.3	2.4	3.4	5.0
	Higher		2.1	3.0	4.4		2.8	4.5	6.8

Baseline 1981 to 2001

Source: UKCP18 (metoffice.gov.uk).
Credit: Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

Change in mean daily maximum temperature (˚C) (UKCP18)

UK administrative region	Climate change scenario	January				July			
		Baseline (mm)	2030s (%)	2050s (%)	2070s (%)	Baseline (mm)	2030s (%)	2050s (%)	2070s (%)
North West England	Primary	0.8	1.8	2.3	3.3	11.2	1.6	2.2	3.2
	Higher		2.1	3.5	5.4		1.9	2.9	4.5
West Midlands	Primary	1.0	1.9	2.7	3.8	11.4	1.6	2.5	3.6
	Higher		2.3	3.6	5.3		1.9	3.2	5.0

Baseline 1981 to 2001

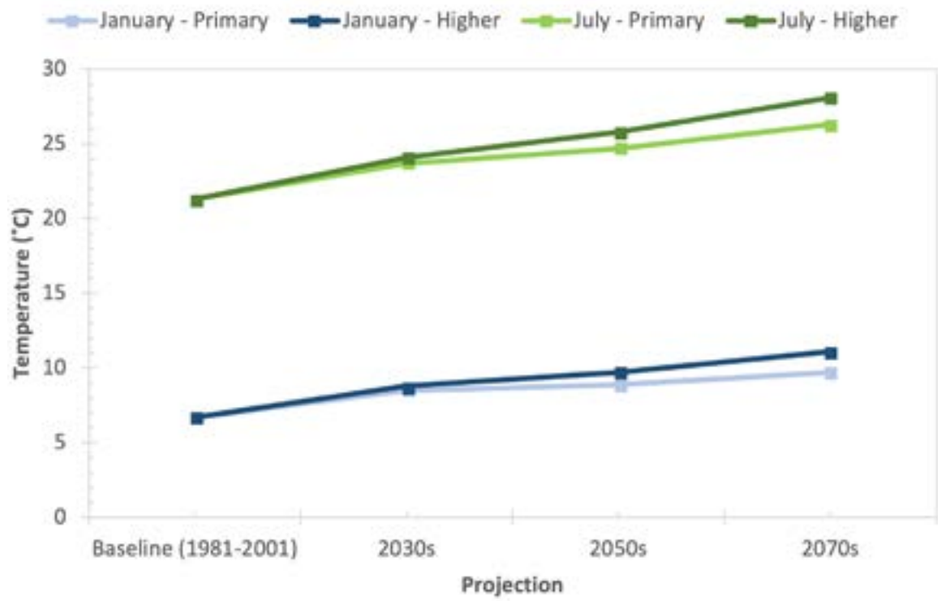
Source: UKCP18 (metoffice.gov.uk).
Credit: Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

Number of 'Summer days' each year in a 2˚C global warming scenario

Baseline 1981 to 2001

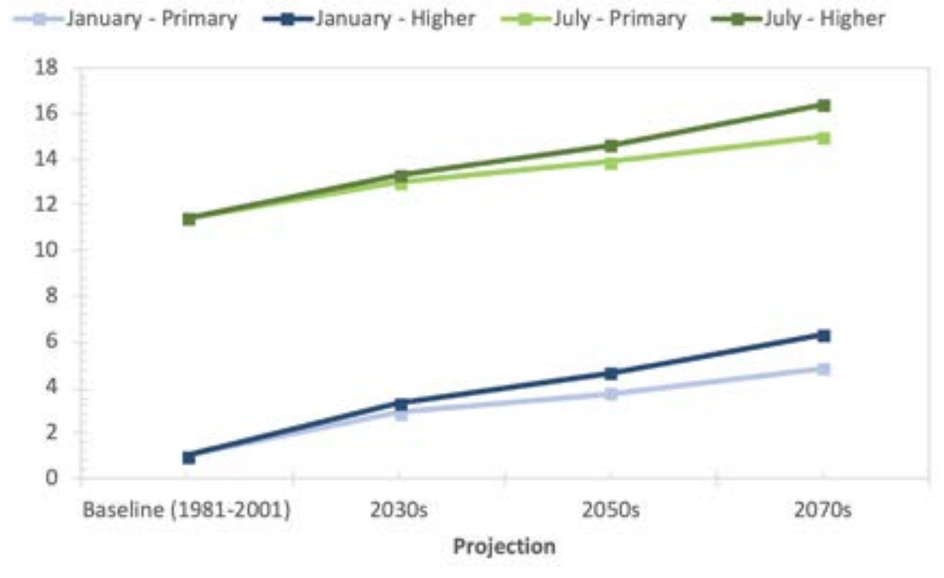
Source: New Climate Data Portal makes data more accessible – Met Office **Credit:** Met Office.

Change in mean daily maximum temperature (˚C)



Source: UKCP18 (metoffice.gov.uk).
Credit: Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

Change in mean daily minimum temperature (˚C)



Source: UKCP18 (metoffice.gov.uk).
Credit: Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

ii. Precipitation projections

Change in winter average daily precipitation rate (%) 90th percentile (UKCP18)

UK administrative region	Climate change scenario	November				December				January				February			
		Baseline (mm)	2030s (%)	2050s (%)	2070s (%)	Baseline (mm)	2030s (%)	2050s (%)	2070s (%)	Baseline (mm)	2030s (%)	2050s (%)	2070s (%)	Baseline (mm)	2030s (%)	2050s (%)	2070s (%)
North West England	Primary	4.1	25.9	29.1	39.6	4.7	24.5	23.1	35.7	4.2	25.1	36.3	44.5	3.1	19.7	29.3	33.3
	Higher		27.6	36.2	49.8		27.1	32.1	48.9		29.2	46.9	63.9		21.8	35.6	**45.4**
West Midlands	Primary	2.4	32.6	34.7	49.6	2.6	18.3	21.5	35.7	2.4	27.7	33.7	45.8	1.6	23.7	31.0	37.1
	Higher		34.6	42.4	63.7		20.8	27.8	46.3		31.5	42.9	62.4		26.0	39.3	**52.0**

Baseline 1981 to 2001 Baseline units = mm

Source: UKCP18 (metoffice.gov.uk).
Credit: Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

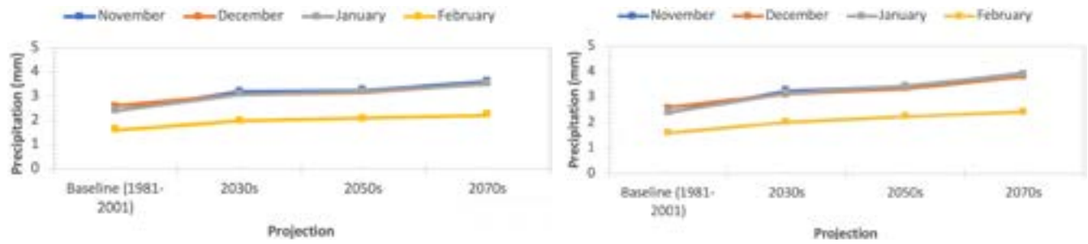
Change in summer average daily precipitation rate (%) 10th percentile (UKCP18)

UK administrative region	Climate change scenario	June				July				August			
		Baseline (mm)	2030s (%)	2050s (%)	2070s (%)	Baseline (mm)	2030s (%)	2050s (%)	2070s (%)	Baseline (mm)	2030s (%)	2050s (%)	2070s (%)
North West England	Primary	2.7	-18.6	-25.0	-31.7	2.6	-26.7	-36.0	-47.6	3.2	-27.3	-35.3	-41.4
	Higher		-19.7	-29.2	-39.2		-28.3	-43.9	-60.4		-29.4	-42.1	-52.0
West Midlands	Primary	2.0	-30.1	-42.1	-48.9	1.6	-32.7	-40.2	-46.2	2.1	-33.4	-37.1	-54.5
	Higher		-32.2	-47.8	-59.8		-35.8	-48.3	-60.1		-35.7	-44.6	-64.9

Baseline 1981 to 2001 Baseline units = mm

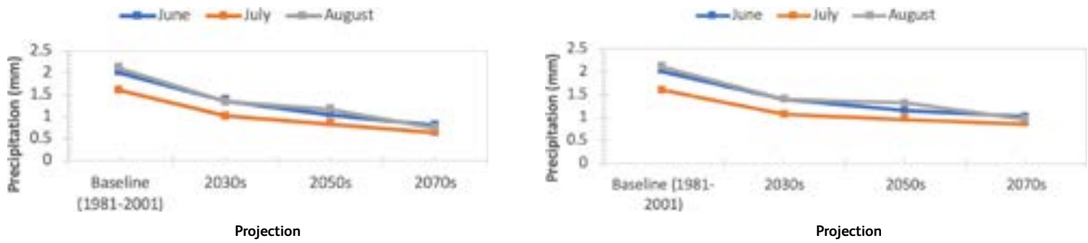
Source: UKCP18 (metoffice.gov.uk).
Credit: Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

Change in winter average daily precipitation rate (%) 90th percentile (UKCP18)



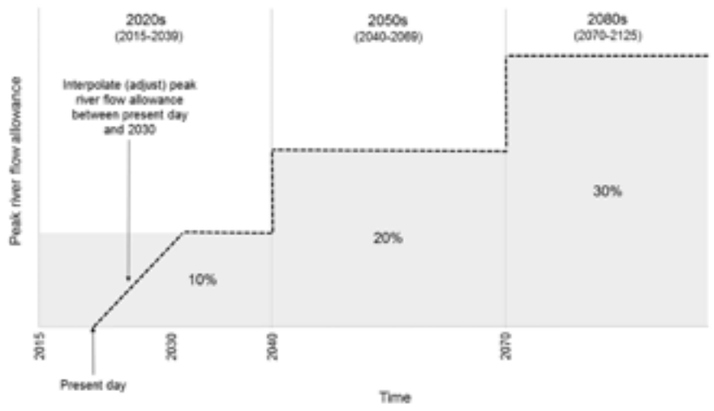
Source: UKCP18 (metoffice.gov.uk)
Credit: Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy

Change in summer average daily precipitation rate (%) 10th percentile (UKCP18)



Source: UKCP18 (metoffice.gov.uk).
Credit: Met Office, Environment Agency, Department for Environment Food and Rural Affairs, Department for Business, Energy and Industrial Strategy.

Conceptualising future peak watercourse flow allowance



Source: Flood and coastal risk projects, schemes and strategies: climate change allowances – GOV.UK (www.gov.uk).
Credit: Environment Agency.

i. Sea level rise projections

Environment Agency guidance on sea level rise allowance (cm/year) by river basin (UKCP18)

Area of England	Allowance	2000 to 2035 (cm/yr)	2036 to 2065 (cm/yr)	2066 to 2095 (cm/yr)	2096 to 2125 (cm/yr)	Cumulative rise 2000 to 2125 (cm)
North West	Higher Central	0.45	0.73	1.00	1.12	101.00
	Upper End	0.57	0.99	1.42	1.63	141.00

Baseline = 1981 to 2000

Higher central – 70th percentile of RCP 8.5 – use as our Primary scenario.
Upper end – 95th percentile of RCP 8.5 – use as our Higher scenario.

Source: Flood and coastal risk projects, schemes and strategies: climate change allowances – GOV.UK (www.gov.uk).
Credit: Environment Agency.

The above table provides a summary of sea level rise allowance, yet there are many other aspects to consider from coastal erosion and flooding. Factors such as shoreline management plans, windspeed and extreme wave height allowance may also compromise an existing natural or man-made standard of protection from flooding. More information can be found on the UK Government Flood and coastal risk projects, schemes and strategies: climate change allowances.

- Link: Flood and coastal risk projects, schemes and strategies: climate change allowances – GOV.UK (www.gov.uk).

C. Appendix 3: Integrated climate risk assessment

i. Direction to further information: NW&C

Section 7 of the main report sets out principal climate risks to assets with a higher risk and confidence of impact. This does not present the plethora of assets at risk, which includes those at lower confidence or impact in the region.

This more comprehensive climate risk assessment is available via the links below.

Link

- NW&C NR ARP3 Integrated Climate Risk Assessment – Jun 23 Adaptation.xlsx

ii. Direction to further information: Integrated Climate Risk Assessment

Since ARP3, additional further assets have been identified as at risk and more scrutiny of risk and confidence has occurred with engineering specialists. The main plan does not set out other regional scores, compared with NW&C, or additions to the asset lists gained through inter-disciplinary consultation within and across regions. Therefore, a full integrated climate risk assessment is available via the links below.

Link

- https://www.networkrail.co.uk/wp-content/uploads/2022/01/APPENDIX-A-integrated-ARP3-climate-risk-assessment.xls

Directory route:

- Network Rail Website > Climate Change Adaptation Sub Page > Integrated Climate Risk Assessment 3 Sub-Section

D. Appendix 4: Weather risk taskforce – action summary

Recommendations and action plans

In response to the WRTF reports and recommendations, action plan 6,7 and 8 have been prioritised (see the table below). This is to ensure cross disciplinary governance, increase capability in the routes, and ensure maintenance to manages drainage inspections and delivers basic maintenance.

Recommendations and action plans

To ensure the action plans are fully implemented through CP6 and 7, the WRTF single point of contact has embedded actions and sub actions into the regional business systems, with dedicated owners and completion status tracking.

Weather risk taskforce work packages and action plans

Work Package	Action Plan	Synopsis
Water Catchment & Concentration Features	1	Improved modeling of surface water threats.
Intelligent Infrastructure Programme	2	I to deliver workstream requirements of Geotechnics.
	3	II to deliver workstream requirements of Drainage.
People (culture, competency, & organisation model)	4	Asset management culture.
	5	Competency & resources.
	6	Integrated approach between Geotech, drainage, and vegetation management.
	7	Sufficient Drainage inspectors under control of Route Asset Managers.
	8	Dedicated drainage maintenance teams across all routes.
Policy & controls	9	Update earthworks policy.
	10	Review / update earthworks bowties – COMPLETE.
	11	Technical strategy for drainage system.
Asset failure & weather diagnostics	12	Improved earthworks failure reporting.
Lope Safety Review Group	13	Platform to focus in on regional challenges. Develop failure resilience plans. Strengthen decision making.
Innovation	14	Identifying and responding appropriately to changes outside the railway boundary.
Examination & evaluation	15	Improvements to earthwork examination system.
	16	Increased resources for site-based earthworks evaluations.
Slope assessment & observational monitoring	17	More specific requirements for slope assessments.
	18	Increasing site investigations and slope assessments.
Weather services & operations management	19	Better weather forecasting and operational responses.

Source: Weather Risk Task Force (networkrail.co.uk).
Credit: Network Rail.