Route Weather Resilience and Climate Change Adaptation Plans

London North East and East Midlands

Contents

Purpose of this document

This document sets out a Weather Resilience and Climate Change Adaptation (WRCCA) plan for LNE&EM Route 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 rolling stock operating within the Route is not specifically assessed.

The approach taken is consistent across all Network Rail's Routes, and describes our current planned mitigations, how we intend to develop the plans further, and how we are improving the embedment of WRCCA across the business to deliver *a railway fit for the future*.

Director Route Asset Management statement

There is overwhelming evidence that our changing climate is having an increased impact on the railway system. It is critical to us, our neighbours and millions of customers that we adapt our operation, maintenance and renewal plans to continue the safe and reliable performance of the Route. We must respond to the challenges presented by the changing climate if we are to safely and affordably meet customer expectation and regulatory targets.

Variable and extreme weather presents a high and increasing risk to the Route and our customers have ever more challenging expectations about our ability to cope with extreme weather. With that in mind, where possible we are focusing on reducing the likelihood of incident during extreme weather events, such as flooding and earthwork failures during the storms of 2012. For example, over the past two years we have significantly increased our funding and resource effort on managing and improving our drainage assets; this must continue through CP5 and beyond.

Improvements in weather monitoring and understanding of asset condition through enhanced risk assessment and remote condition monitoring, will allow us to predict incidents and apply control measures where required. We continue to work with our Train Operating Company (TOC) and Freight Operation Company (FOC) colleagues to collectively determine the most appropriate control measures across the Route.

Amending renewals scope to remove or mitigate the impact of flooding, extreme temperature and extreme variation in weather conditions, whilst keeping management of our asset base affordable, is a significant challenge for us. Activities such as scour protection, equipment housing temperature control and improved seasonal preparedness are just part of our plans to meet this challenge. Our Weather Resilience and Climate Change Adaptation plan is a significant step forward, but it remains a live document that will be reviewed as we further integrate climate change knowledge over time.

Kevin Robertshaw
Director Route Asset Management
London North Eastern & East Midlands

Executive Summary

Weather events can cause significant disruption to the operation of train services and damage to rail infrastructure. A move to a warmer climate and a variance in the pattern of precipitation across the year, generally projected by the UK Climate Change Projections (UKCP09), could result in changes in the frequency and intensity of extreme weather events and seasonal patterns. A detailed understanding of the vulnerability of rail assets to weather events, and potential impacts from climate change, are therefore needed to maintain a resilient railway.

LNE&EM Route has developed a Weather Resilience and Climate Change Adaptation (WRCCA) plan based on assessments of weather-related vulnerabilities, identification of root causes of historical performance impacts and an understanding of potential future impacts from regional climate change projections.

Using this information, LNE&EM Route has determined whether previous investments have mitigated weather impact risks, if actions planned during Control Period 5 (2014 to 2019) are addressing these vulnerabilities, and where additional actions could further enhance weather and climate change resilience.

An analysis of Schedule 8 performance costs (the compensation payments to train and freight operators for network disruption) during the period 2006/07-2013/14, clearly shows flooding, wind and snow-related events have had the most significant impact on the Route.

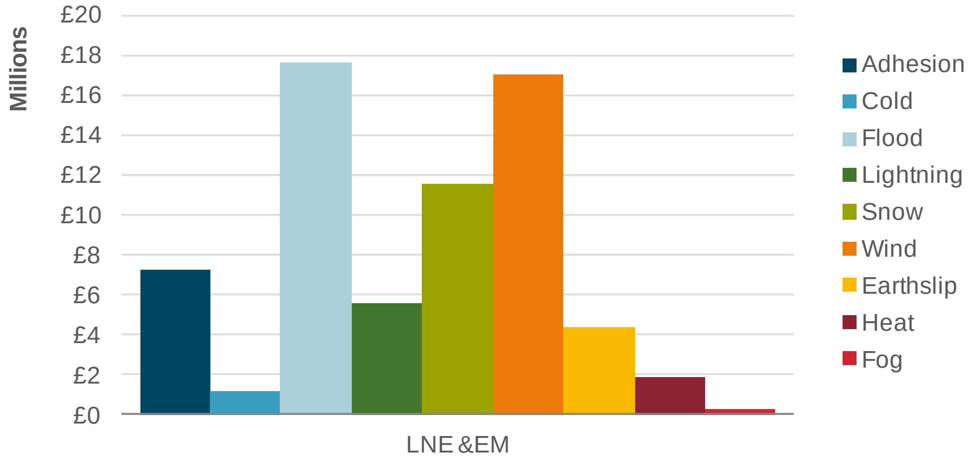

Figure 1 LNE&EM Route weather attributed Schedule 8 costs 2006/07-2013/14

LNE&EM Route is committed to supporting the delivery of improved weather and climate change resilience through Route-specific objectives which aim to:

- undertake quantitative studies to understand the flood risk to infrastructure at sites where flood risk is known, is suspected and in all areas within the tidal flood zone. Use the outputs of such studies to undertake resilience planning (including diversionary Route planning) for flood prone sites and to inform investment plans to manage increasing flood risk associated with climate change.
- mitigate the risk of climatic changes to all high-risk earthwork and drainage assets by undertaking suitable interventions.
- work with weather forecasters to establish a more robust adverse weather process whereby relevant mitigation measure are taken in preparation of an extreme weather event.
- increase the understanding of potential climate change impacts on LNE&EM Route
- engage with the environment agency and local authorities to understand the link between our respective plans.
- continue to develop Key Route Strategies with the train and freight operating companies that reflect the changing trends in weather.

LNE&EM Route has identified actions planned in CP5 that will increase weather and climate change resilience including:

- real-time monitoring of water levels in our drainage assets
- proactive campaign of drainage management at or near tunnel portals
- upgrade jointed track to increase temperature resilience
- increase knowledge of risk from third-party trees
- review effectiveness of adhesion solutions
- engage with the Environment Agency to improve understanding of impact from sea level rise
- develop schemes for highly complex, multi-discipline problem sites such as Browney Curve embankment

LNE&EM Route will deliver the WRCCA plan in a timely, cost-efficient and safe manner.

Introduction

Weather events can be a cause of significant disruption to the railway network. Recent prolonged periods of rainfall and extreme storm events demonstrated much of the network is resilient; however, asset failures such as the Dawlish sea wall, Cambrian sea defences, Unstone landslip, and the widespread tree fall following the St. Jude storm, reveal the vulnerability of the rail network and the severe impact these weaknesses in resilience have on train services and our resources.

The impact of weather on the rail network is monitored using performance data. Schedule 8 costs; the compensation payments to train and freight operators for network disruption, are used as a proxy for weather impacts due to greater granularity of root cause reporting. Weather-related costs can also be captured within Schedule 4 payments; compensation to train and freight operators for Network Rail's possession of the network, and capital expenditure required to reinstate the asset.

Over the past eight years (2006/07 to 2013/14) the average annual Schedule 8 cost attributed to weather for the whole network was over £50m. The data clearly includes the impacts on train performance from the severe weather events during 2007, 2012 and 2013 from rainfall, and 2009 and 2010 from snowfall, Figure 2. In terms of the proportion of delay minutes, weather and seasonal events on average caused 12 per cent of all delays experienced during this eight-year period.

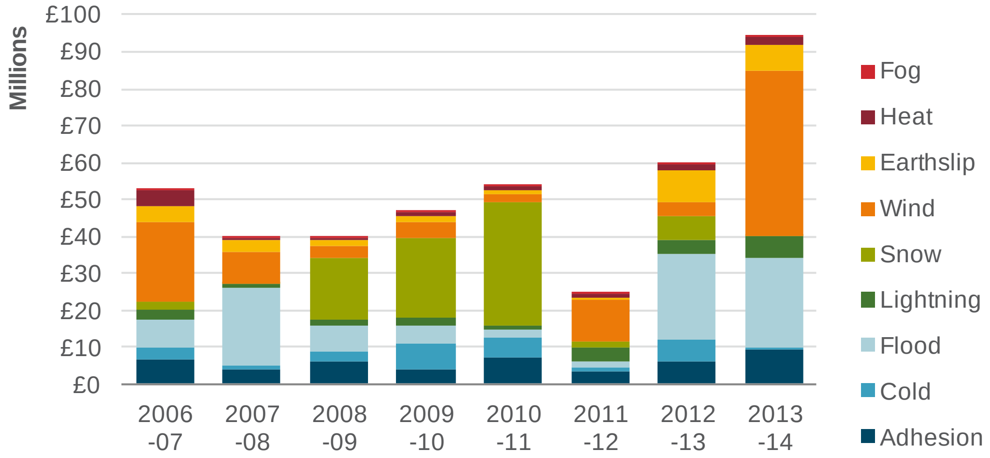

Figure 2 Whole network weather attributed Schedule 8 delay costs, 2006/07 to 2013/14

Following the recent increase in the rate of Schedule 8 compensation payments (by around 62 per cent), the equivalent payments in future years would be over £80m per annum.

These levels of performance cost, consequential costs of repairing the rail infrastructure, and wider socio-economic impacts in the UK, justify Network Rail's enhanced investments to increase weather resilience. The interdependencies within transport and infrastructure systems similarly justifies Network Rails' efforts to improve collaborative understanding of the wider impacts of weather-related events and our role in supporting regional and national resilience.

Historical temperature records indicate that a significant relatively recent shift in climate has occurred. The Hadley Centre Central England Temperature (HadCET) dataset is the longest instrumental record of temperature in the world, Figure 3, and clearly shows a rising trend in temperature over the past century[1].

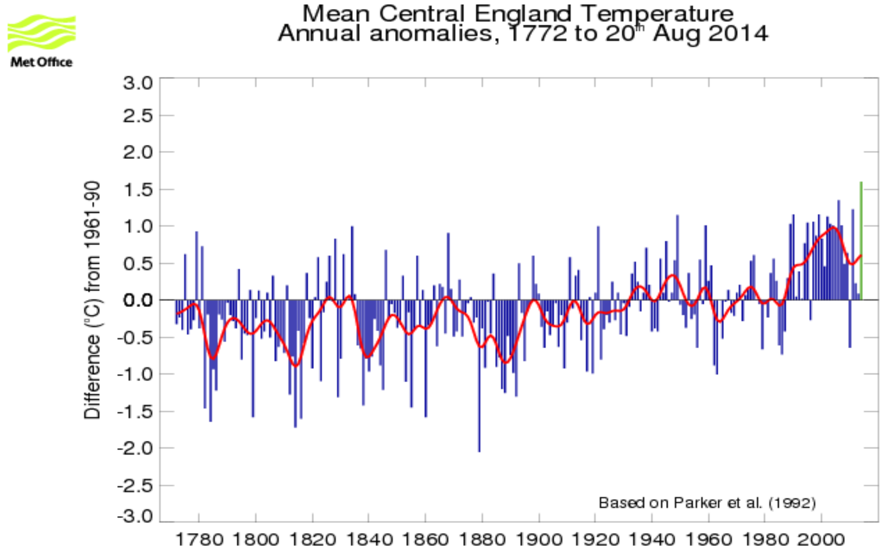

Figure 3 Mean Central England temperature record

[1] Parker, D.E., T.P. Legg, and C.K. Folland. 1992. A new daily Central England Temperature Series, *1772-1991. Int. J. Clim.*, ***Vol 12***, *pp 317-342*

Future climate change projections for the UK have been developed by the Met Office Hadley Centre, UK Climate Projections 2009 (UKCP09). UKCP09 provides probabilistic sets of projections based on low, medium or high greenhouse gas emission scenarios, for climate periods of 30 years to the end of this century. For Network Rail, as a safety critical focused organisation and major UK infrastructure manager, the high emissions scenario is an appropriate benchmark on which to base evaluations and decisions.

UKCP09 projects an overall shift towards warmer climates with drier summers and wetter winters, Figure 4 and Figure 5, with regional variations .

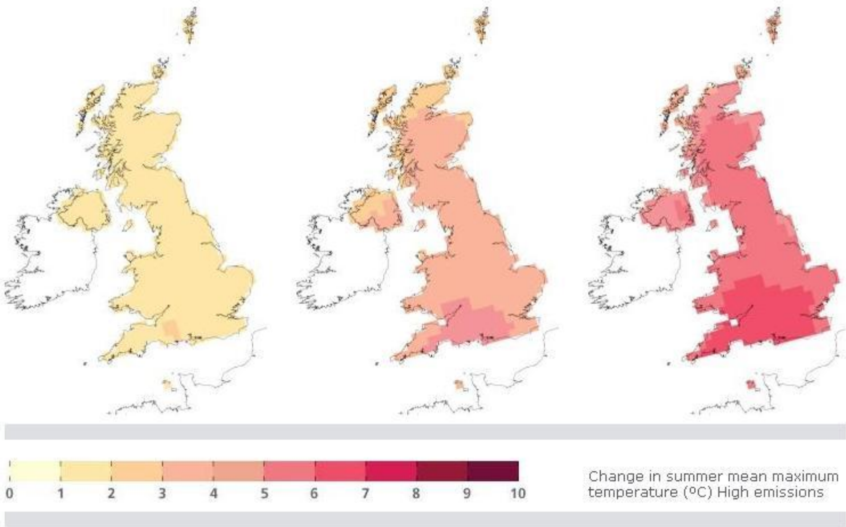

Figure 4 Change in summer mean maximum temperature (left 2020s, middle 2050s, right 2080s) (© UK Climate Projections, 2009)

It must be noted that climate change projections include inherent uncertainties, associated with natural climate variability, climate modelling and future emissions, and these uncertainties increase with downscaling to local levels. However, the projections can be used by Network Rail to provide a direction of where the UK climate is heading, and this Route WRCCA plan uses the projections to support the prioritisation of weather resilience actions.

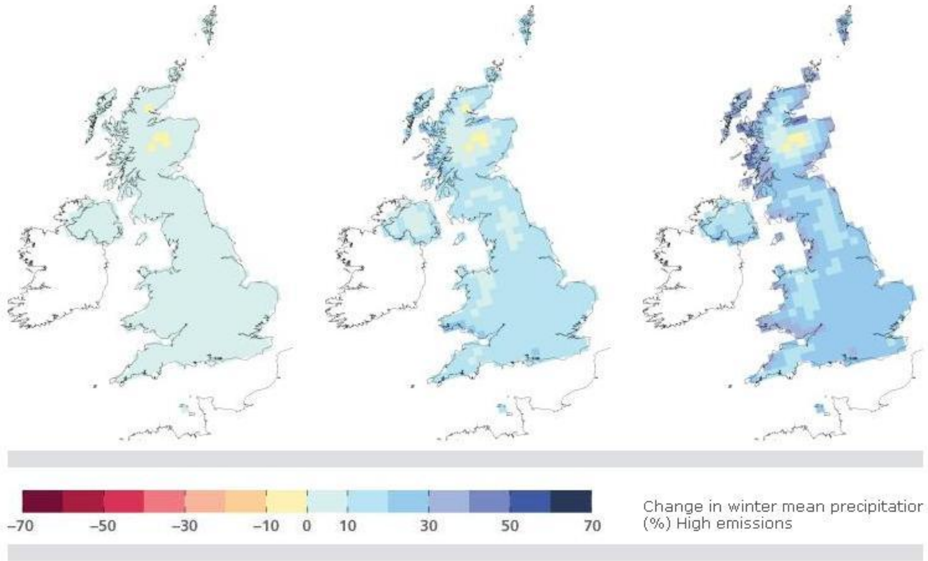

Figure 5 Change in winter mean precipitation (left 2020s, middle 2050s, right 2080s) (© UK Climate Projections, 2009)

To ensure weather resilience and climate change adaptation is approached consistently across Network Rail, an iterative framework provides key management stages: set strategy, assess vulnerability and impact, identify actions, and review, Figure 6. This framework has been applied to develop the LNE&EM Route WRCCA plan.

Figure 6 Weather resilience and climate change adaptation framework

Network Rail weather resilience and climate change adaptation actions will include a range of measures appropriate to the strength of evidence and level of risk:

- soft – changes to processes, standards and specifications, increasing knowledge and skill base
- hard – engineered solutions to increase resilience; e.g. raising of sea walls and increasing drainage capacity
- 'do nothing/minimum' – the option to 'do nothing' or 'do minimum' should be evaluated
- 'no regrets' – measures that increase the resilience of the assets to current and future impacts
- precautionary – investment into adaptation measures today in anticipation of risk in the future
- managed adaptive – a staged approach incorporating uncertainties in future risk and current investment funds, allowing assets to be retrofitted cost-effectively in the future.

The following sections provide findings from the LNE&EM Route vulnerability and impact assessments, and details of the actions, both completed and planned for Control Period 5, which will increase weather and climate change resilience.

LNE&EM Route WRCCA strategy

The Network Rail Sustainable Development Strategy outlines corporate weather resilience and climate change adaptation objectives, and commits the business to:

- understand our current weather resilience, and seek to optimise resilience and enhance adaptation capability
- develop a thorough understanding of the potential impacts of climate change in terms of infrastructure performance, safety risks and costs
- embed climate change adaptation within our asset policies and investment decisions
- communicate the role that the rail network plays in supporting weather and climate resilience across Great Britain, and support efforts to increase national resilience.

These objectives will support the long-term management of a weather resilient railway and are fundamental steps towards achieving Network Rail's sustainable development vision of *a railway fit for the future*.

LNE&EM Route strategy

LNE&EM Route is committed to supporting the delivery of this strategy through Route-specific weather resilience and climate change adaptation objectives:

- undertake quantitative studies to understand the flood risk to infrastructure at sites where flood risk is known, is suspected and in all areas within the tidal flood zone. Use the outputs of such studies to undertake resilience planning (including diversionary Route planning) for flood prone sites and to inform investment plans to manage increasing flood risk associated with climate change
- mitigate the risk of climatic changes to all high-risk earthwork and drainage assets by undertaking suitable interventions
- work with weather forecasters to establish a more robust adverse weather process whereby relevant mitigation measure are taken in preparation of an extreme weather event
- increase the understanding of potential climate change impacts on LNE&EM Route
- engage with the environment agency and local authorities to understand the link between our respective plans
- continue to develop Key Route Strategies with the train and freight operating companies that reflect the changing trends in weather.

Through these objectives, Network Rail's corporate commitments are applied in the context of LNE&EM Route, supported by the opportunities to deal locally with challenges from a changing regional climate. Meeting these objectives will contribute to the long-term resilience and sustainability of LNE&EM Route and the whole railway network.

LNE&EM Route vulnerability assessment

This section provides the details of the general vulnerability of the rail network in Great Britain and LNE&EM Route's specific vulnerabilities to weather impacts, and regional climate change projections.

Network-wide weather vulnerability

The challenge for Network Rail is to manage a complex and extensive portfolio of assets, with variations in geographic location, age, deterioration rates and vulnerability to weather impacts.

Continual analysis of the vulnerability of rail assets to weather, and identification of trends and characteristics of weather-triggered failures, improves our knowledge of the resilience of the rail network. An understanding of current weather impacts is an essential platform to implement cost-effective investments to adapt the network to future changes in climate.

The whole rail network is sensitive and exposed in some way to many primary climate drivers and secondary impacts, including:

- temperature
- rainfall
- wind gusts
- flooding
- landslips
- soil moisture
- sea level rise
- coastal erosion.

Network Rail has moved from subjective and expert review-based knowledge of weather and climate change risks to more detailed internal analysis of asset failure and weather data to understand thresholds at which failure rates significantly change. Figure 7provides an illustrative example of the analysis identifying assets with higher sensitivity to weather impacts. The horizontal lines are thresholds where there is 'no significant' (green), 'significant' (amber) or 'very significant' change in incident rates (red). This deeper dive analysis is critical to understanding the resilience of operational assets today and potentially in future climates.

From this analysis it has been established that high temperatures have wider impacts across assets, earthworks are the predominant asset sensitive to rainfall and overhead line equipment (OLE) to wind gusts.

Rail asset and weather impact relationships are complex, as demonstrated in the case of OLE where many wind-related failures are a result of vegetation incursion and not direct wind gusts as the primary impact. Therefore any analysis of rail assets and weather vulnerability requires deeper understanding of root causes to identify cost effective resilience actions.

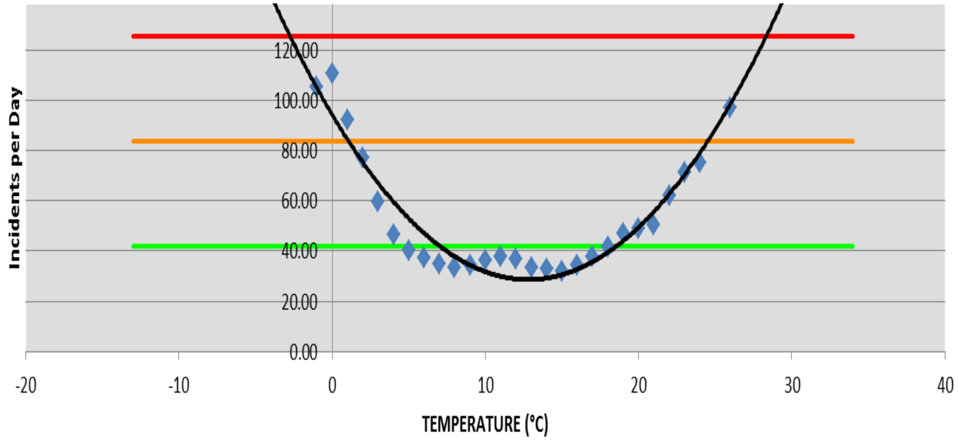

Figure 7 Example of asset failure and weather analysis

Managing operational response to weather vulnerability

Network Rail manages risks from weather-related impacts through a range of asset management tools, operational response standards and alert systems. Higher risk assets are prioritised for investment within asset policies and proactively managed through risk-based maintenance.

Defining 'normal', 'adverse' and 'extreme' weather conditions is fundamental to ensuring effective coordination across the rail-industry. Network Rail and the National Task Force (a senior rail cross-industry representative group) are currently reviewing weather thresholds and definitions to improve the Extreme Weather Action Team (EWAT) process which manages train services during extreme weather alerts.

Control rooms monitor and respond to real-time weather alerts through a range of action plans. Operational response to the risks posed by weather events includes: temporary speed restrictions (TSRs), deployment of staff to monitor the asset at risk, proactive management of the asset, i.e. use of ice maiden trains to remove ice from OLE or protection of assets from flood water, and in some cases where the risk dictates, full closure of the line. Increasing the resilience of the infrastructure reduces the need for operational response however the range of weather events experienced today, potential changes in the future, and the prohibitive scale of investments required to mitigate all weather risks, means that operational response will always be a critical process for Routes to manage safety risks.

Network Rail seeks continuous improvement of weather-based decision support tools, including flood, temperature, wind speed and rainfall alerts. A trial aiming to significantly improve real-time weather forecasting has installed approximately 100 weather stations on the Scotland rail network, Figure 8. The pilot study is currently being evaluated to support a potential wider roll-out of this level of weather service.

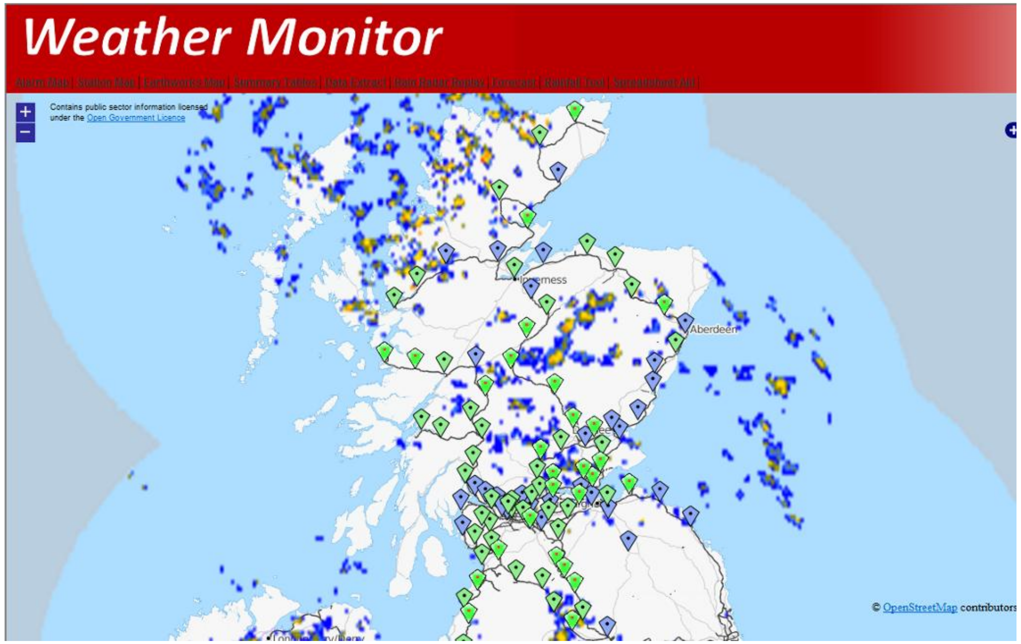

Figure 8 Scotland Route real-time weather monitor

For the management of operational flooding risk, Network Rail receives alerts through our Flood Warning Database based on warnings issued by the Environment Agency and the risk is translated to rail assets. In locations where no national flood warnings are available, Network Rail can arrange to receive alerts from bespoke river level monitoring equipment.

Longer-term flood risk management of rail assets is provided through geographic information system (GIS) decision support tools including flood datasets, such as Network Rail's Washout and Earthflow Risk Mapping tool (WERM). Transformative asset information programmes are currently aiming to improve weather-related hazard mapping in decision support tools.

Improving our network wide resilience

A Weather Resilience and Climate Change (WRCC) programme is at the centre of Network Rail's delivery plans. Its importance is underlined by the fact that it is one of the Company's top 15 business change projects. The programme was first identified in April 2013, but its priority and profile were heightened as a result of the extreme weather that was experienced between October 2013 and March 2014. The programme board and stakeholders include representatives from across the rail industry.

The WRCC programme is founded on a bow tie risk assessment of weather-related disruption, Figure 9 – this risk assessment methodology is used widely across Network Rail. The bow tie assessment provides a detailed understanding of the adequacy of the controls that are in place to reduce the causes of disruption and consequences and highlights those controls that need to be enhanced.

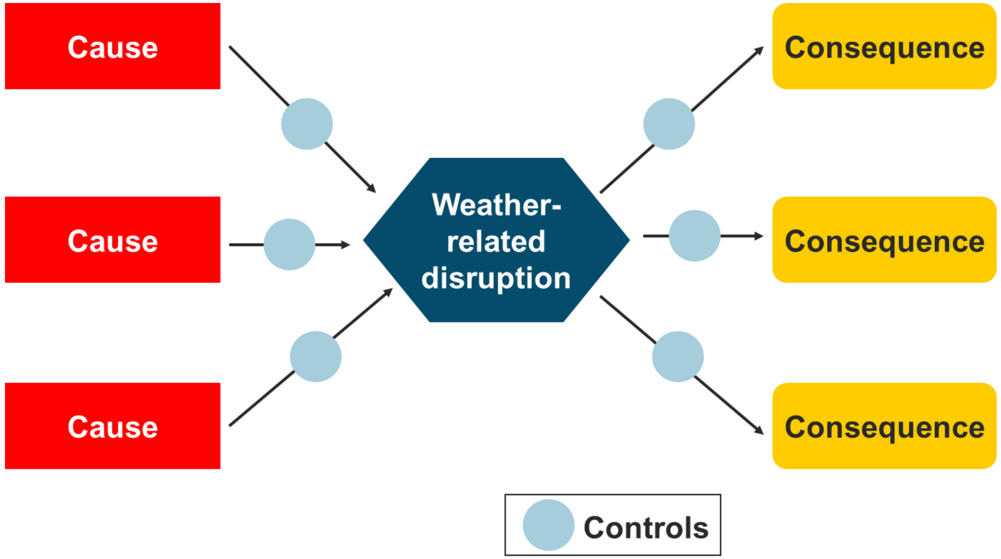

Figure 9 Bow tie risk assessment

The programme consists of six sub-programmes and their 23 constituent projects; these are described in Figure 10 below. Although the bulk of the outcomes that are currently defined expect to be delivered within the next 18 months, the programme is expected to extend throughout CP5.

It is important to emphasise the national-level programme supplements the work Routes are completing under their CP5 business plans.

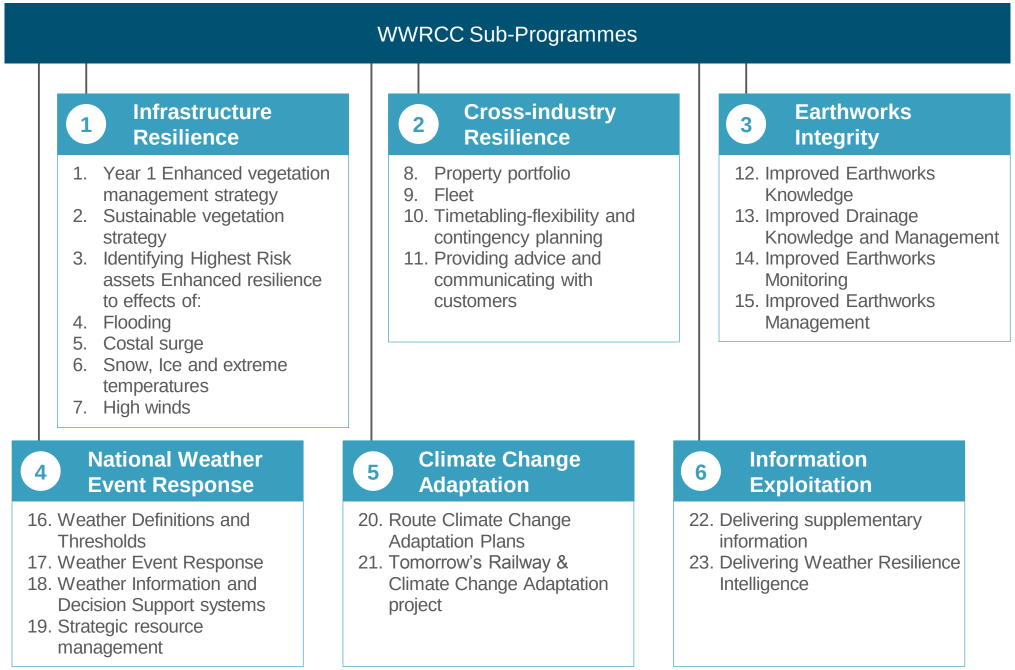

Figure 10 The constituent components of Network Rail's WRCC programme

The WRCC programme is currently supporting the delivery of:

- an enhanced vegetation management project: £10m of accelerated funding to address high-risk trees and mitigate the impact of both extreme winds and adhesion issues
- points enhancements: installation of up to 7,000 points heat insulation and covers in support of Key Route Strategy
- forensic investigation of earthworks failures in 2012/13 and 2013/14: the 261 failures that occurred during this two year period have been investigated with Deep Dive analysis being undertaken on 89 of them
- earthworks remote condition monitoring pilot: involving 250 high-risk sites across four Routes (Scotland, LNE, Wessex and Western) starting in December 2014
- improved drainage management: mobile works tools and drainage competency improvements by December 2014
- agreed weather thresholds and definitions
- an enhanced extreme weather action team process: this will be reviewed and the improved processes implemented into the first Route by end November 2014
- aerial surveys of infrastructure using the Light Detecting and Ranging (LIDAR) technique; This will be complete by December 2014
- enhanced weather forecast service which will be in use from April 2015.

Route weather vulnerability

The LNE&EM Route stretches from the Scottish borders to London King's Cross, following the East Coast Main Line (ECML). It also covers the North East, Yorkshire, Humberside, and Lincolnshire. The East Midlands Route covers the Midland Main Line (MML) from St Pancras to Chesterfield, along the East Midlands local routes radiating from Derby, Nottingham and Leicester as far as the East Coast Main Line and West Coast Main Line. It serves an important commuter route from North London into the St Pancras. LNE and EM joined in August 2013 to create one route combining two of the busiest routes in and out of London. Combined the LNE&EM Route covers 2,000 miles of track and is presented in Figure 11below.

Figure 11 LNE&EM Route

The LNE Route has a number of coastal lines of variable criticality which will be vulnerable to future climatic change. The east coast mainline (criticality 2) between Newcastle and Berwick-upon-Tweed is at risk from coastal erosion. While other Routes such as along the Humber estuary (HUL1) are at risk from storm surges.

The LNE&EM Route includes a very diverse range of rail track classification, topography and geology from very high tonnage on 125mph multiple track electrified railway to single track freight or passenger rural routes, and from low-lying and level coastal plains to steep terrain. The very diverse range of topography, from typically low-lying and gently undulating land in the south to the higher ground further north significantly influences the weather conditions experienced. The nature of the topography, its height and steepness, is linked to the geology of the areas, and this plays an important role in determining in what way the weather ultimately impacts the railway assets.

For the most part, clay geologies dominate the south of the Route, providing a gently undulating and low-lying topography. The impermeable ground and shallow gradients can encourage standing water and flood waters can remain in place for prolonged periods of time as a consequence, rendering the railway earthworks assets vulnerable to softening and weakening of the clays and, as a consequence, an increased number of relatively slow moving failures in embankments and cuttings.

Heading north from London the topography becomes more variable passing through the Jurassic, Permian and Triassic aged strata including Coal Measures around Yorkshire, Derbyshire, Nottinghamshire and Leicestershire and further north the Yorkshire Dales, North Yorkshire Moors and coalfields of Northumberland and Durham. The extremely variable nature of geology towards the north of the Route (cohesive and granular tills, coal measures, peat and alluvium) means the earthwork assets are vulnerable to various types of failures. A breakdown of the underlying geology of the Route, based on location of every five-chain length is demonstrated below:

- made ground – 4 per cent
- coal measures – 10 per cent
- chalk – 1 per cent
- cohesive till – 1 per cent
- alluvium – 32 per cent
- granular till – 25 per cent
- peat – 1 per cent
- interbedded limestone – 6 per cent
- over-consolidated clay – 2 per cent
- uncemented sands – 5 per cent
- combination of above – 13 per cent.

The Route can suffer from very high temperatures in the summer and very low temperatures in the winter. High summer temperatures encourage impacts such as desiccation shrinkage of clay geologies as trees extract moisture from the ground. Conversely, the extreme cold weather promotes freeze-thaw processes in rock fractures causing increased weathering and rock falls.

LNE&EM Route specific vulnerability to weather impacts includes several sites that suffered significant, repeated flooding during 2012 such as Eryholme, Peascliffe Tunnel, Potters Bar Tunnel, Ardsley Tunnel and Pelaw. The re-occurrence of flooding at specific sites not only highlights the need for drainage intervention to fix the issue but also identifies the need for regular maintenance of drainage assets in CP5 and into CP6.

At Barrow upon Soar on the SPC5 line, the railway embankment is located on the floodplain at the confluence of the Grand Union Canal and the River Soar at Pillings Lock. Following exceptional rainfall and from river/local land flooding the embankment softened and lost strength causing a rotational landslip and derailment of a freight train.

Significant earthslips have also occurred on outside party land, notably Unstone and Hatfield colliery, Figure 12. Both events were initiated by prolonged heavy rainfall events, and the occurrence of these potentially catastrophic failures highlights the significant efforts that need to be made in CP5 to identify vulnerable third-party assets as well as our own.

Figure 12 Hatfield colliery landslip

Future climate change vulnerability

The relationship between weather events and climate is complex; therefore it is understandable that climate change projections do not forecast future weather events. However, Network Rail can use the climate projections to understand potential risks and make informed strategic decisions to increase future weather resilience.

The UK Climate Change Projections (UKCP09) provides regional climate change projections across 13 administrative regions in Great Britain, Figure 13. LNE&EM Route spans across several of these regions with a large majority of the Route falling within the East Midlands, Yorkshire and Humber and North East England regions. Projections for these are considered to be representative of the future climate changes within the Route.

Figure 13 UKCP09 administrative regions

The following derived charts from UKCP09 data show the projected changes in temperature and precipitation for the high emissions scenario, 50th percentile (10th and 90th percentile data has been obtained). The projected changes are shown for future climate periods up to the 2080s (2070-2099) and are relative to the baseline climate of 1970s (1961-1990).

Mean daily maximum temperature change

Mean daily maximum temperatures for all three administrative regions, East Midlands, Yorkshire and Humber and North East England, are projected to increase throughout the year, with greater increases expected in the summer months.

In the East Midlands the average maximum daily temperature in July is expected to increase by over 2.8°C, reaching 23.2°C by the 2050s, and by over 4.6°C, reaching 25°C by the 2080s. Average maximum daily temperature in January is expected to increase by 2.2°C, reaching 8°C by the 2050s, and by 3.2°C, reaching 9°C by the 2080s, Figure 14.

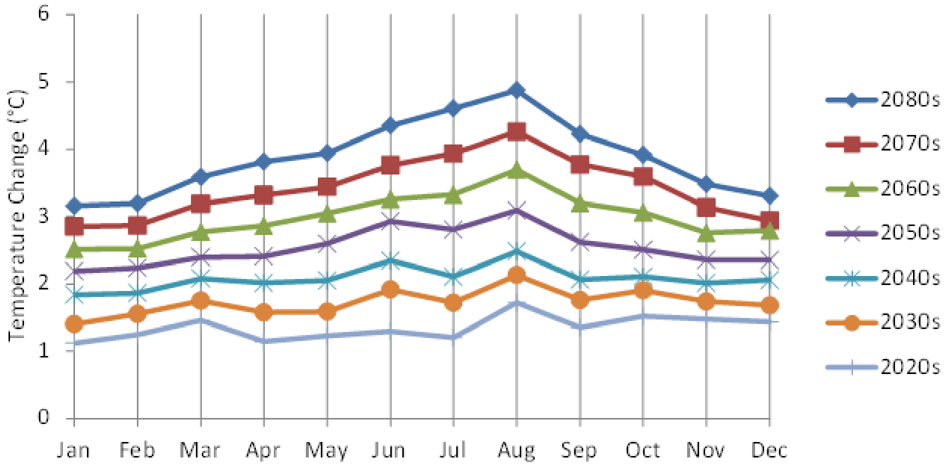

Figure 14 East Midlands, mean max temperature change (50th percentile)

The average maximum daily temperature in Yorkshire and Humber in July is expected to increase by 2.6°C, reaching 21.7°C by the 2050s, and by over 4.2°C, reaching 23.3°C by the 2080s. Average maximum daily temperature in January is expected to increase by 2.2°C, reaching 7.6°C by the 2050s, and by 3.2°C, reaching 8.6°C by the 2080s, Figure 15.

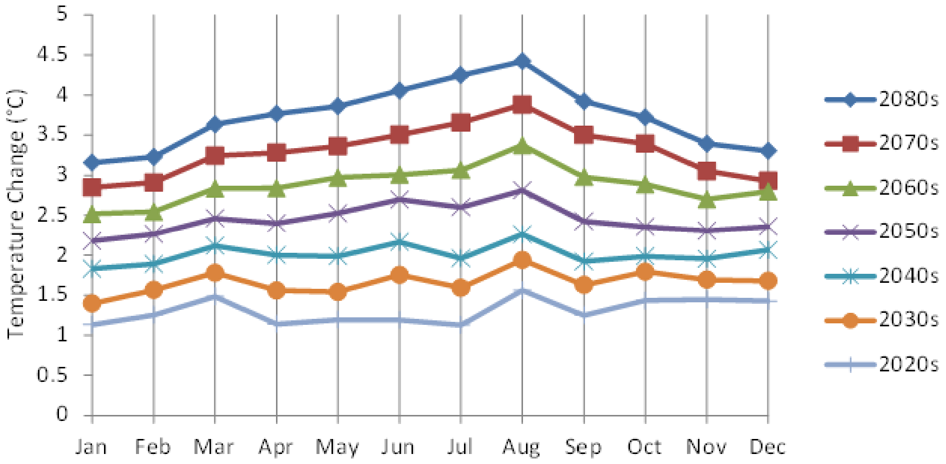

Figure 15 Yorkshire and Humber, mean max temperature change (50th percentile)

Projections for North East England reflect the UK's overall increasing trend in the mean daily maximum temperatures. The average maximum daily temperature in July is expected to increase by 2.5°C, reaching 20.3°C by the 2050s, and by over 4°C, reaching 21.9°C by the 2080s. Average maximum daily temperature in January is expected to increase by 2°C, reaching 7°C by the 2050s, and by 3°C, reaching 8°C by the 2080s, Figure 16.

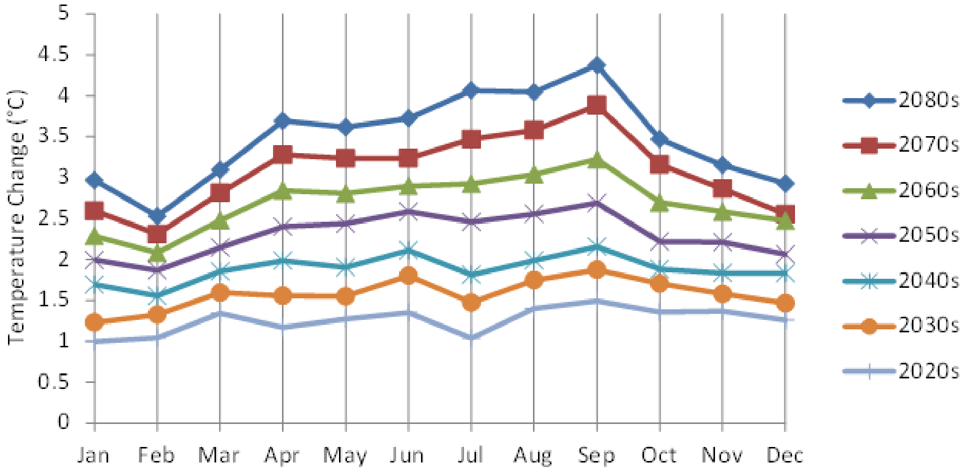

Figure 16 North East England, mean max temperature change (50th percentile)

Mean daily minimum temperature change

The mean daily minimum temperatures for all three administrative regions, East Midlands, Yorkshire and Humber and North East England, are also projected to increase throughout the year.

In the East Midlands the average minimum daily temperature in July is projected to increase by 2.7°C, reaching 13.8°C by 2050s, and by 4.3°C reaching 15.4°C by the 2080s. Average minimum daily temperature in January is projected to increase by 2.8°C, reaching 3.5°C by 2050s, and by 4°C, reaching 4.7°C by 2080s, Figure 17.

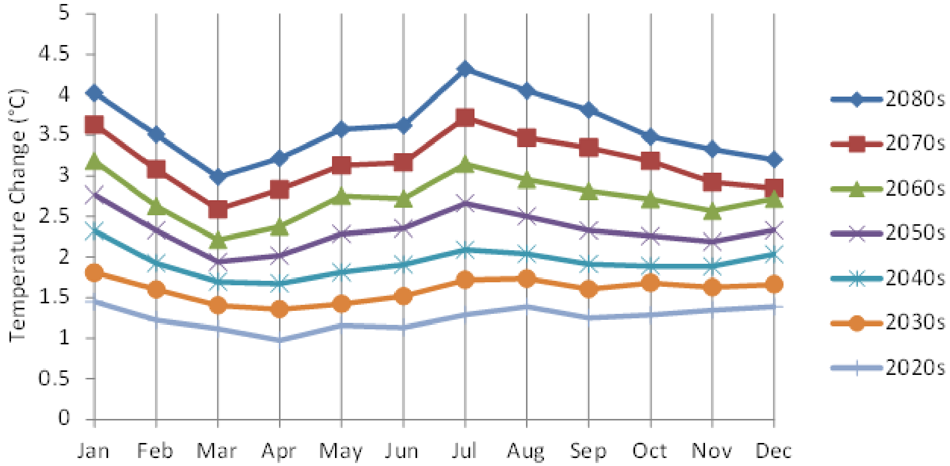

Figure 17 East Midlands, mean min temperature change (50th percentile)

In Yorkshire and Humber the average minimum daily temperature in July is projected to increase by 2.6°C, reaching 13.4°C by 2050s, and by 4.2°C reaching 15°C by the 2080s. Average minimum daily temperature in January is projected to increase by 2.7°C, reaching 3.2°C by 2050s, and by 4°C, reaching 4.5°C by 2080s, Figure 18.

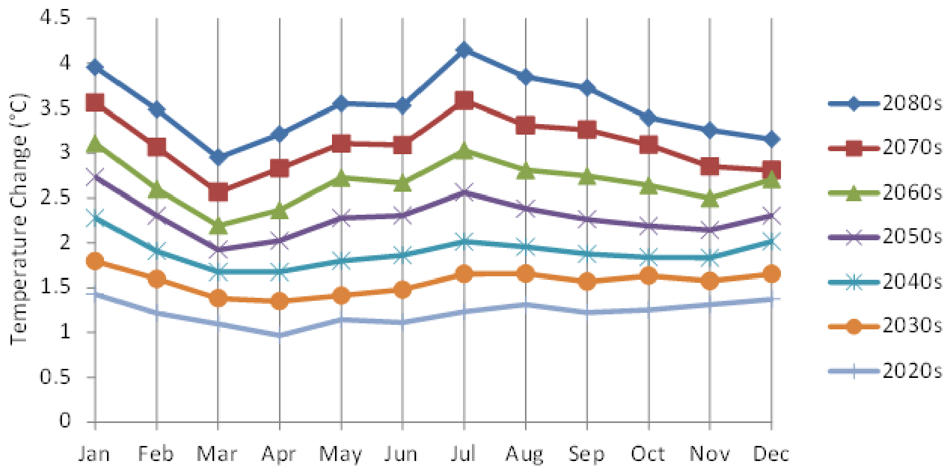

Figure 18 Yorkshire and Humber, mean min temperature change (50th percentile)

In North East England the average minimum daily temperature in July is projected to increase by 2.5°C, reaching 12.4°C by 2050s, and by 4°C reaching 13.9°C by the 2080s. Average minimum daily temperature in January is projected to increase by 2.3°C, reaching 2.3°C by 2050s, and by 3.5°C, reaching 3.5°C by 2080s, Figure 19.

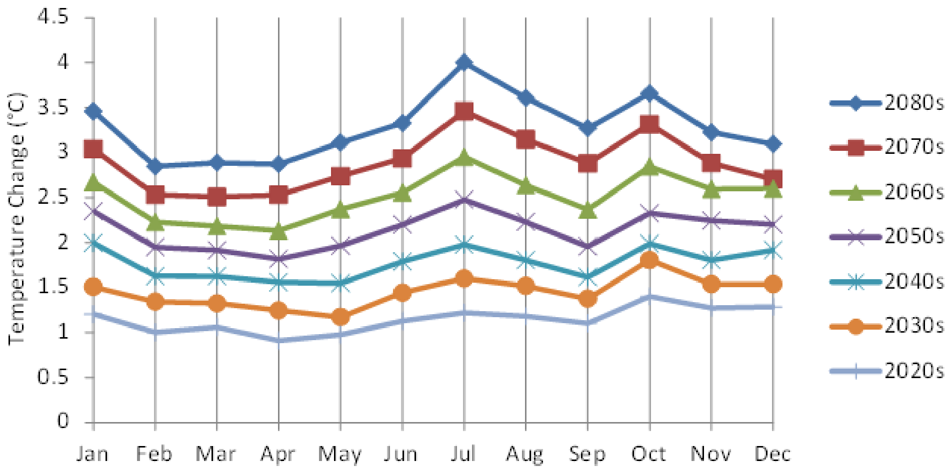

Figure 19 North East England, mean min temperature change (50th percentile)

Mean daily precipitation

Projections for mean daily precipitation for all three administrative regions, East Midlands, Yorkshire and Humber and North East England, show a significant increase in the winter months and a decrease in summer months. Generally, the greatest is projected to occur in February, while the greatest decrease is expected in August.

In the East Midlands the increase in daily precipitation in February is projected to be 19 per cent, reaching 1.9mm per day by the 2050s, and 32 per cent, reaching 2.1mm per day by the 2080s. The mean daily precipitation in August is projected to decrease by 17 per cent by the 2050s, to 1.5mm per day, and by 27 per cent, to 1.3mm per day by the 2080s, Figure 20.

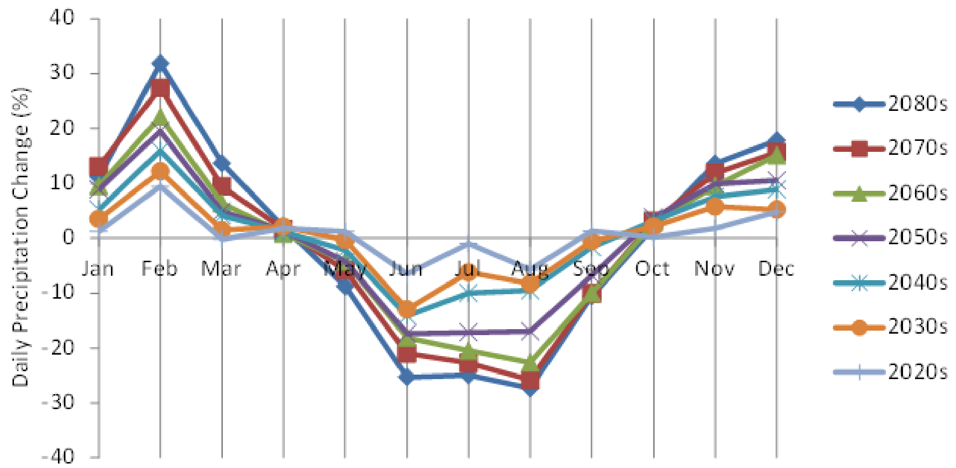

Figure 20 East Midlands, mean daily precipitation change (50th percentile)

In Yorkshire and Humber the mean daily precipitation in February is projected to increase by 14 per cent, reaching 2.3mm per day by the 2050s, and by 23 per cent, reaching 2.5mm per day by the 2080s. Mean daily precipitation in August is projected to decrease by 20 per cent by the 2050s, to 1.7mm per day, and by 32 per cent, to 1.5mm per day by the 2080s, Figure 21.

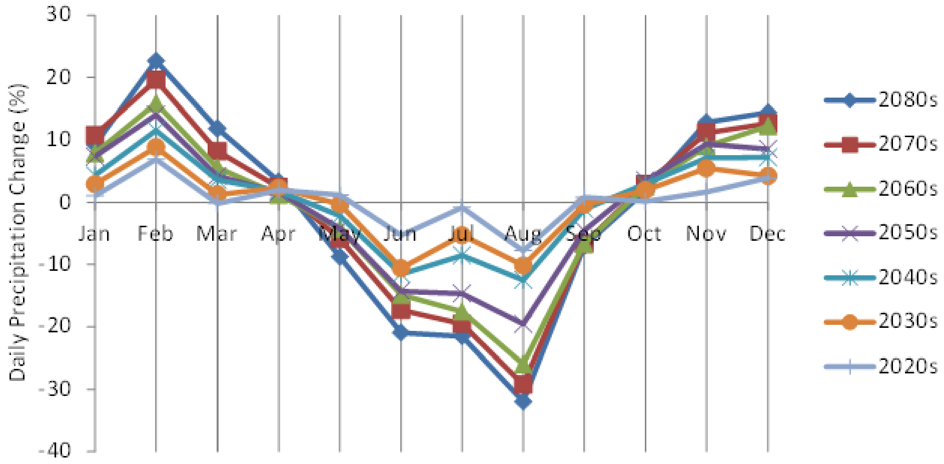

Figure 21 Yorkshire and Humber, mean daily precipitation change (50th percentile)

Projections for North East England are similar. The mean daily precipitation in February is projected to increase by 13 per cent, reaching 2.3mm per day by the 2050s, and by 21 per cent, reaching 2.5mm per day by the 2080s. Mean daily precipitation in August is projected to decrease by 16 per cent by the 2050s, to 1.9mm per day, and by 26 per cent, to 1.7mm per day by the 2080s, Figure 22.

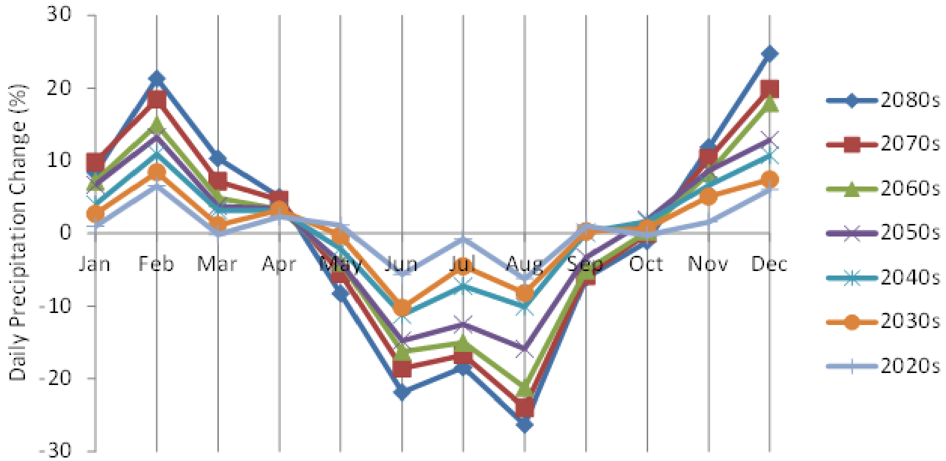

Figure 22 North East England, mean daily precipitation change (50th percentile)

Sea level rise

Sea level rise for LNE&EM Route coastal and estuarine assets can be represented by the projections for North East Lincolnshire, near Grimsby. For the high emissions scenario, the projections for the 50th percentile for 2050 is 0.263m and 0.572m by the end of century (the rise is unlikely to be higher than 0.406m and 0.895m respectively), Figure 23.

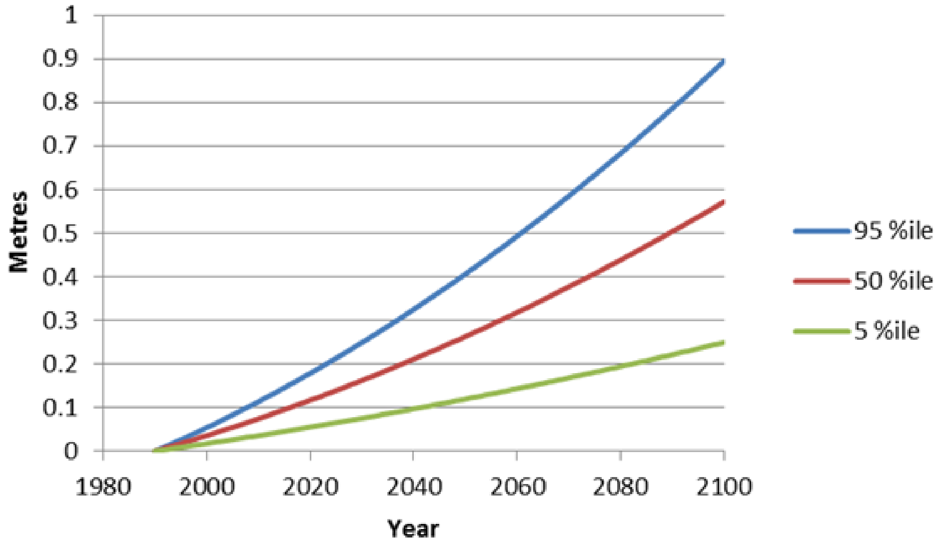

Figure 23 UKCP09 sea level rise projections for Grimsby area

The understanding of the vulnerability of LNE&EM Route rail assets to current weather and potential risks from future climate change is an important stage in developing WRCCA actions

LNE&EM Route impact assessment

This section provides the findings from the LNE&EM Route weather impact assessment, including annual performance impacts and identification of higher impact locations on the Route.

Performance impacts

The impact of weather on the rail network can be monitored within rail performance data. Schedule 8 costs; the compensation payments to train and freight operators for network disruption, are used as a proxy for weather impacts due to greater granularity of root cause reporting.

Schedule 8 costs, for the past eight financial years for the two areas LNE and East Midlands have been analysed, Figure 24,to provide an assessment of weather impacts:

- ‘flooding’ costs include delays due to a range of fluvial, pluvial, groundwater and tidal flooding of assets
- ‘earthslip’ delays have been included due to internal analysis indicating primary triggers of earthworks failures are weather-related
- ‘heat’ and ‘wind’ include direct impacts on assets and impacts on delay due to speed restrictions implemented as part of Network Rail’s operational response during weather events.

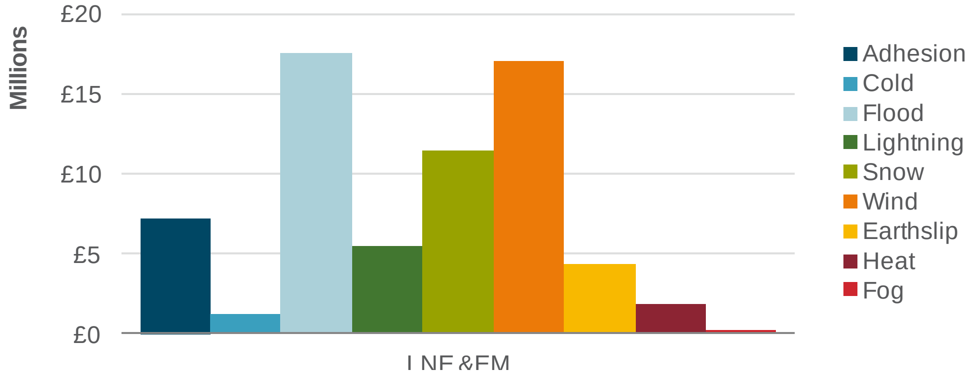

Figure 24 LNE&EM Route weather attributed Schedule 8 costs 2006/07-2013/14

The analysis clearly shows that flooding and wind has been the most significant weather impacts for the Route, with total Schedule 8 costs of over £17m per impact during the period 2006/07-2013/14.

The impacts of changes in winter and summer precipitation on flooding patterns are complex; however, it is expected that flooding events will increase in frequency and intensity, and presents increased risk to LNE&EM Route over the coming decades.

Climate modelling cannot provide strong projections for future changes to wind speeds, though, increased storminess is generally projected and may increase the risk of wind-related incidents on the Route. The risk of lightning strikes is also likely to be affected by increased storminess.

Snow-related delays have been significant but are projected to decrease in the future. However, extreme cold-related events are projected to continue to occur and actions to ensure resilience to cold-related weather impacts should continue to be factored in future seasonal preparedness and investment decisions.

A combination of the assessment of historical weather impacts on the LNE&EM Route and regional climate change vulnerability from UKCP09 can be used to prioritise weather resilience actions.

Table 1 Prioritisation of weather-related impacts on LNE&EM Route

Weather-related impact	Schedule 8 costs[1]	Projected future impacts	Prioritisation
Flooding	£2.20m	Up to 19 per cent increase in February mean daily precipitation[2]	High
Wind	£2.13m	Wind changes difficult to project however generally projected to increase	High
Earthslips	£0.54m	Up to 19 per cent increase in February mean daily precipitation[2]	High
Snow	£1.44m	Up to 2.8oC increase in January mean daily minimum temperature[2]	Med
Adhesion	£0.91m	Complex relationship between adhesion issues and future climate change.	Med
Lightning	£0.69m	Storm changes difficult to project however generally projected to increase	Med
Heat	£0.23m	Up to 2.8oC increase in July mean daily maximum temperature[2]	Med
Sea level rise	Not recorded	0.26m increase in sea level rise[3]	Med
Cold	£0.15m	Up to 2.8oC increase in January mean daily minimum temperature[2]	Low
Fog	£0.03m	Complex relationship, however research suggests fog events may decrease	Low

1 Annual average 2006/07 to 2013/14,
2 UKCP09 projection, 2050s High emissions scenario, 50th percentile, against 1970s baseline
3 UKCP09 projection, 2050s High emissions scenario, 50th percentile, against 1990 baseline

It is also worth noting the Schedule 8 cost per delay minute in CP5 will be on average 60 per cent higher, further reinforcing the importance of effective WRCCA actions.

Identification of higher risk locations

A geographic information system (GIS) based decision support tool, METEX, has been developed to analyse gridded observed weather data and rail data, including the past eight years of delays attributed to weather.

Over recent years our network has experienced some of the most extreme weather on record and weaknesses in existing assets will be captured in performance impacts. Climate change is projected to impact the UK with more intense and frequent extreme weather events, so taking actions on our current weaknesses, and proactively managing future risks are important steps to increasing our future resilience.

Higher-risk locations have been identified by assessing METEX outputs for high-frequency/ high-cost sites across the whole Route, and detailed assessment of key sections of the rail network. These locations have been assessed to determine:

- validity of the delay attribution to a weather impact
- root cause of the delay
- resilience actions that have been undertaken
- resilience actions that are currently planned
- identification and prioritisation of additional resilience actions.

In addition, Routes have identified potential future risks and resilience actions based on climate change projections and Route knowledge.

Flooding impact assessment

LNE&EM Route has experienced flooding at 167 separate sites since April 2009. 354 individual incidents have caused 163,000 minutes delay.

The level of delay and disruption at our flood risk sites varies widely, as do the nature of the root causes of flooding and scope of the countermeasures required to manage risk. At Eryholme on the northern East Coast Main Line, for example, three inverted siphons became blocked and overwhelmed in September 2012 and contributed to a sustained episode of track flooding that caused 23,858 minutes of delay, Figure 25.

Figure 25 Eryholme flooding September 2012

In 2012/13, a significant number of intense rainfall events led to many incidents of flash flooding and flood-related incidents in LNE&EM Route.

In approximately half of the flooding incidents experienced in poor drainage condition has been identified as the root cause of flooding. Many drainage systems were overwhelmed by sheer volume of water during periods of heavy rain and significant flows from adjoining land were recorded.

Flooding remains a constant and significant risk to the reliability of the railway, and with climate change projections indicating an increase in winter rainfall and potential changes in the duration and intensity, our approach to drainage and flood risk mitigation must be one of constant vigilance, innovation and improvement.

To reduce flood risk, a programme of interventions and projects has been developed. Several initiatives have been launched, as follows:

- the Route has established a **Water Management Group** (WMG) to identify root causes of flooding, drive delivery of countermeasures, increase resilience, improve behaviours and maintain focus on drainage as a discipline and key contributor to the success of the business. Our WMG focuses primarily on the ‘Top 21’ flooding sites; those that have caused the most delay to our customers and risk to our business. 74 per cent of agreed actions have been completed. A further 146 known flood sites have been assessed. Root causes of flooding have been identified and work to increase resilience has been programmed in the remainder of CP5
- **Drainage Management Plans** (DMPs) have been written for all lines of railway within the Route. The DMPs, which have been written to correspond with the track maintenance engineer’s areas, offer strategies for managing flood risk and parent asset condition through a structured programme of inspection, evaluation, intervention and risk assessment. A key component of each DMP is the parent asset risk assessment. Fact-based evidence of asset condition, such as current earthwork and track quality condition scores, is merged with quantified water-related risks including fluvial and pluvial risk, permeability of subjacent strata, cutting crest washout risk and estimated flood volumes/theoretical flow paths intersecting with the railway corridor. The resulting array of data is ‘scored’ and ‘sliced’ to yield a magnitude of risk for each eighth, mile and 5-mile section, thus giving an opportunity to prioritise interventions quantitatively and efficiently. Each DMP is a ‘live’ document and forms the basis for a structured, strategic approach to managing water-related risk and mitigating impact of water on parent assets and train performance
- **Remote Condition Monitoring** (RCM) has been employed at three locations to monitor flood risk. A programme of installation of bespoke RCM at a further 29 critical sites has been developed and is being considered for investment. Sites being considered include:
  - Ardsley Tunnel Portals
    - ECML (Doncaster to Leeds spur)
    - 4025 delay minutes due to flooding in CP4
    - cess chamber and off-track watercourse water level sensors proposed
  - Kirk Sandall
    - DOW (Doncaster to Wrawby)
    - 6565 delay minutes due to flooding in CP4
    - cess chamber and outfall water level sensors proposed
  - Eryholme
    - ECML (York to Newcastle)
    - 25949 delay minutes due to flooding in CP4
    - inverted siphon water level sensors proposed
  - Clay Cross
    - Midland Main Line (Derby to Chesterfield)
    - 4078 delay minutes due to flooding in CP4
    - cess and off-track water level sensors proposed
- a **major programme of interventions** to reduce risk of water-related train delay and asset degradation has been developed. In addition to flood prevention schemes, tunnel portal drainage improvements, a number of large multi-disciplinary projects are also being considered to solve persistent water-related challenges and reduce risk. Projects include:
  - Tunnel portal risk management projects
    - Ardsley Tunnel crest and portal drainage (Doncaster to Leeds ECML spur)
    - Elstree Tunnel crest and portal drainage (Midland Main Line south)
    - Amptill Tunnel slope and portal drainage (Midland Main Line south)
    - Hertford Loop tunnels track degradation prevention project
    - Bradford to Halifax tunnel approach crest drainage
  - Corby Tunnel risk management
    - work to reduce water ingress, flood risk and track degradation in conjunction with track and structures teams
  - Luton DU track quality improvement project
    - culvert and sub 450mm ID underline asset restoration to reduce wetbeds and risk of speed restrictions
  - Goole subway flood prevention project
    - work in conjunction with Electrification and Plant and Structures teams to improve performance of drainage within a subway in Goole to reduce risk to members of the public
  - flood prevention schemes
    - 130 projects to address root causes of flooding and train delay
  - track quality improvements
    - focused effort to improve track quality through refurbishment of lineside ditches and culverts.

Impact of flooding on structures
Structures over watercourses are at risk from floodwater in a number of ways. The most immediate risk stems from scour, which is the erosion of sediment from around a structure's foundations. During flood events Network Rail monitors flood alerts and flood warnings from the Environment Agency around structures assessed as high risk. If water levels reach specific thresholds, speed restrictions or closures are considered to manage safety of train services.

The significant level of flood warnings in 2007, 2008 and 2012 saw structures assets subject to monitoring on a large scale.

Figure 26 Skip Bridge over the River Nidd

Other risks include hydraulic uplift/buoyancy and hydrostatic risks, where water-saturated material places higher than expected pressure on a part of the structure. The risk of hydraulic uplift has not been fully quantified, but an initial 2014 study showed that out of 2122 structures in the Route, 650 are at possible risk from some form of hydraulic uplift or lateral movement, Figure 27.

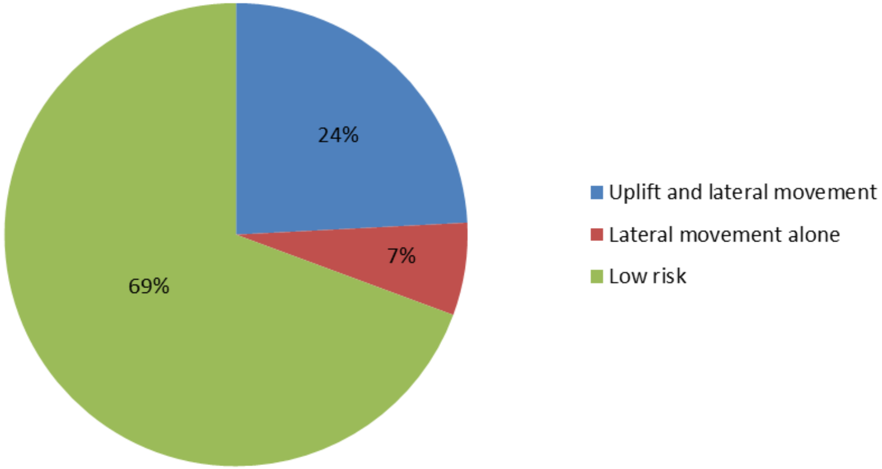

Figure 27 LNE&EM Route hydraulic risk to structures

To combat both the safety and performance impact of flooding at structures, Network Rail has conducted scour assessments at many of the structures viewed as being at risk. These assessments form the backbone of our response, giving us a detailed report on the level of risk at any given structure. Where flooding is seen as a risk, flood markers are placed to allow for monitoring of the structure from a safe position during a flood event.

As part of Network Rail's safety response, all structures that suffer speed restrictions or closures are examined before re-opening. Due to concerns for diver safety these cannot always be conducted within timescales conducive with good performance. To increase the speed of re-opening, Network Rail have been exploring the use of sonar through a trial at Scarborough Bridge, Figure 28.

Figure 28 Scarborough Bridge sonar trial site

Figure 29 MBW3/47 fully scour protected with rock armour in 2013

At the end of CP4 and continuing into early CP5, Network Rail has delivered a number of measures to reduce flood risk of structures assets, including scour protection Figure 29.

Wind impact assessment

The two key impacts to LNE&EM assets during high winds are the susceptibility of the overhead line equipment to sway and the risk of falling trees.

The overhead line equipment is a concern in the open rural areas and Northumberland coast where the infrastructure is more exposed. Blanket speed restrictions are imposed to manage risk, supported by weather data from lineside wind monitoring devices to minimise disruption to train services.

When sustained periods of heavy winds are forecast then a thinning out of the train service is planned in conjunction with the train operating companies (TOCs) to allow a sustainable train service to operate through the period of reduced speed.

LNE&EM have trialled head-span to portal conversions in susceptible areas of overhead line equipment to strengthen the section in times of high winds, Figure 30.

Figure 30 Potters Bar Head-span to Portal Conversion Trial

Head-spans can cause complete Route closure after a single overhead line failure and has been the cause of some significant delays on the Route in 2013/14. The introduction of a portal isolates the damage to one line which can significantly reduce performance impact.

Falling trees, especially from third-party land, has caused issues in times of high winds. A proactive regime of tree felling and vegetation management has been undertaken throughout the Route. All high-risk trees identified through the national lineside tree survey have been removed. An extensive programme of vegetation clearance work, Figure 31, is planned over the coming two years to further reduce the likelihood of wind-related vegetation issues affecting the infrastructure.

In some secondary routes boom gated crossings still exist. In times of high winds these are prone to failure and staff are deployed to push the gates to aid their closure. There is a campaign throughout the Route to replace these with automatic barriers.

Figure 31 Vegetation clearance

Earthslips impact assessment

Earthwork failures are often triggered by water. This can be by direct rainfall and saturation of the earthwork, a failure of a drainage system at the crest or toe of the earthwork, third-party inflows, or groundwater level changes.

The Route carried out various reactive works in response to weather induced earthwork failures in CP4. Looking through CP5, a more proactive asset management approach aims to reduce delay costs and failures occurring. We have implemented increased use of remote monitoring equipment at numerous sites to determine how our assets react to weather events

LNE&EM Route METEX data analysis reveals that there were 94 incidents with over £1000 Schedule 8 costs that were coded to ‘Earthslip’ in the eight-year period 2006/07 to 2013/14.

Analysis of the METEX top 20 (10 each for LNE and EM) revealed that 12 of these were identified as being the result of weather. Of these 12 incidents, four were as a result of poor drainage on third-party land. All but one of the sites has had mitigation action undertaken in Control Period 3 or Control Period 4 as emergency reactive works, and works are planned for CP6 for the remaining site.

Adverse weather process

The Route has developed an adverse weather response process to help reduce the risk to the railway from earthslips during extreme weather conditions. The LNE&EM adverse weather earthworks list contains 189 sites, some of which have intervention works planned for CP5. All sites on the adverse weather list are monitored by the Meteo Hydrocast tool, Figure 32, for local weather conditions, forecasts and real time alerts.

The Route Earthworks team has worked closely with Route Control in York and Derby to ensure that the correct mitigation response is initiated when a specified amount of rainfall is forecast. Mitigation measures include sending out watchmen and carrying out cab rides to review the sites. In more extreme circumstances, speed restrictions and line closures can be implemented.

The adverse weather list and adverse weather response process is currently under review for further development. It is anticipated that sites will be added and removed throughout CP5 and improvements to the response processes made.

	Recent radar				Warning					Predictive radar			UKMO 24 hours		ECMWF 2 to 5 days			
	Last 24h	12-13h	13-14h	14-15h	T	2	3	4	5	14-15h	15-16h	16-17h	17-04h	04-16h	Wed	Thu	Fri	Sat
Aldwarke Flood Risk Site	6.4	0	0	0						0	0	0	0	0	1.8	3.6	1.1	0.4
Appleby and Santon Flood Risk Site	2.7	0	0	0						0	0	0	0.2	0	0	3.5	2.4	0.4
Ardsley Tunnel Flood Risk Site	5.8	0	0	0						0	0	0	0	0	0.7	4.4	0.4	0.9

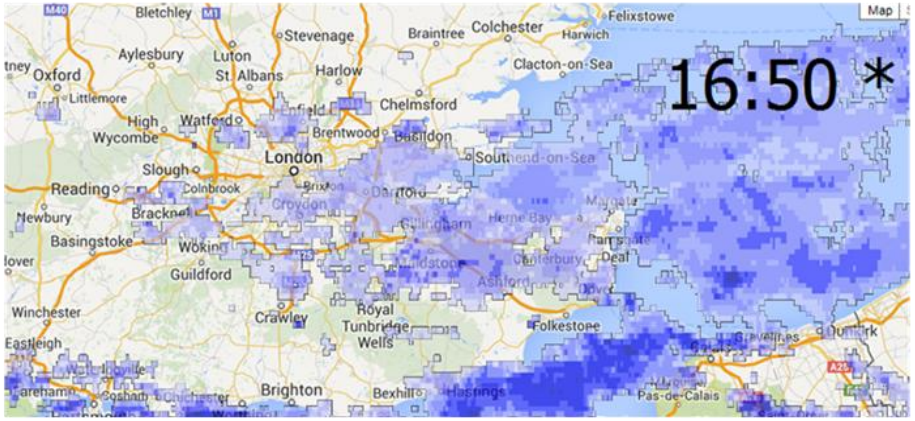

Figure 32 Example of Hydrocast imagery and predictive rainfall figures

Remote condition monitoring

The Route is increasing the use of monitoring and remote condition monitoring (RCM) equipment at numerous sites to determine how our assets react to weather events. Up to 50 cutting sites will trial the use of new remote condition monitoring at identified high-risk locations. The aims of RCM strategy are:

- provide a risk mitigation tool allowing for line speed to be maintained and to allow for remediation to be planned in advance
- to manage safety and performance risks posed by earthwork failures between identification and renewal
- improve staff safety by eliminating as much as possible manual monitoring and the use of watchmen
- to replace as far as practicable the current process of ‘Very High-Risk’ sites during extreme weather
- to be a reusable, mobile, resilient, robust cost-effective system.

Improving earthworks drainage

Earthflow and washout failures are caused by poor drainage whether it be Network Rail drainage assets or on third-party land. Controlling the flow of water on to and out of our land is an essential part of reducing failures. In 2010 following significant rainfall at Spittal on ECM7 line, Figure 33, a lake formed behind the embankment and flooding occurred, overtopping and flowing through the embankment which subsequently caused a washout. In collaboration with drainage teams in CP5 a proactive, risk-based programme of inflow management will be sought to minimise and control the quantity of water from adjoining land.

Figure 33 Spittal failure

The Clarborough tunnel derailment in April 2012 was caused by a combination of heavy rainfall and poor earthworks drainage with water overtopping a crest ditch resulting in a cutting slope failure at a tunnel Portal, Figure 34.

LNE&EM Route are identifying where further toe and crest drain interventions are required in CP5 and CP6 to prevent earthwork failures.

Figure 34 Clarborough tunnel failure

Earthworks in the Floodplain
At Barrow upon Soar the railway embankment, Figure 35, is located in the floodplain at the confluence of the Grand Union Canal and the River Soar at Pillings Lock. Following exceptional rainfall and river and surface water flooding, the embankment softened and lost strength causing a rotational landslip and derailment of a freight train. Research into the LNE&EM 'earthwork in the flood plain' list is under way with interventions and improved resilience planning at vulnerable locations.

Figure 35 Barrow Upon Soar earthwork regrade

Scour protection
With increased capacity to record scour during the examination and evaluation process, the LNE&EM Route are identifying vulnerable sites where scour could cause loss of support at high-risk earthworks. With projections indicating increased precipitation levels, earthworks will need to be more resilient to cope with increased river levels and higher flow rates. This is of particular concern along the Middlesbrough to Whitby line (MBW) which follows the River Esk valley down to Whitby. Works are planned at various locations along this Route for CP5.

Third-party slopes
Significant earthslips have occurred on third-party land, notably Unstone landslip,Figure 36, which affected the Midland mainline north of Chesterfield at the end of CP4. The failure was initiated by prolonged heavy rainfall on a unstable slope. The occurrence of these potentially failures highlights the significant efforts that need to be made in CP5 to identify vulnerable third-party assets as well as our own. LNE&EM are investigating ways in which all third-party slopes can be identified for special examinations to take place and any inherent risks managed.

Figure 36 Unstone landslip

Snow and cold impact assessment
Snow becomes a particular problem when it’s widespread across large parts of the Route. LNE&EM, because of the large geographical area it covers, can have issues with dispatching staff to affected areas due to road conditions and accessibility. In times of widespread disruption LNE&EM invokes a Key Route Strategy (KRS). This is documented before the onset of the winter period and is imposed in a staged approach depending on weather forecasts. The TOCs and FOCs (freight operating companies) are involved in the process through regular conferences. In strategic locations identified in the plan, teams are deployed in advance using the weather forecasting models to operate and clear critical points equipment.

Mechanical signalling is often problematic due to the number of moving parts that require frequent adjustment during periods of cold weather, and can also become inoperable when overwhelmed by heavy snow. Modular re-signalling is planned during CP5 on the Derby to Stoke, Nottingham to Grantham and Nottingham to Newark lines which will remove a large proportion of the mechanical signalling issues on the Route.

Over the past two years, remote condition monitoring has been installed at all points where switch heaters are present. This enables the equipment to be monitored and adjusted remotely throughout the year and enables engineers to quickly establish any appropriate repairs that may be required in advance of cold weather. It is also valuable to support an understanding of trends, and in the event of a points failure to understand if the operation of the heating equipment contributed to the failure.

A number of LNE&EM Route tunnels can be significantly impacted by periods of heavy rainfall and severe cold; this is due to groundwater ingress within the bores (internal surfaces) and shafts (ventilation access), Figure 37, or due to the discharge of catchment surface water at the portals (entrances),Figure 38. Commonly, tunnels which are located within rural environments, deeply constructed (often below the groundwater table and/or below rivers or other bodies of water) and inherently endure high levels of water ingress are at greater risk of disruptions due to severe cold weather.

Figure 37 Tunnel shaft with frozen groundwater

Figure 38 Tunnel portal with frozen surface water

The LNE&EM Route currently manages a total of 122 tunnel assets, 19 of which have tunnel bores with electrified Overhead Line Equipment (OHLE). The future CP5/CP6 Route enhancement schemes will result in further tunnel assets becoming electrified as part of the 'North TransPennine Electrification' and the 'Midland Mainline Electrification'. Investment into heated wires and bespoke drip shielding will provide protection to sensitive components.

Severe cold impacts upon the railway infrastructure equipment located within the tunnel, which in turn can result in impaired operational performance. Owing to the age of Network Rail's tunnel assets, water ingress is often a long-standing feature and from a structural maintenance perspective can generally be tolerated to a certain degree. Water ingress can also cause operational maintenance issues in track, signalling and overhead line equipment and these are exacerbated by heavy rain and severe cold.

The remedial actions for controlling or reducing water ingress into tunnels can be classified under two basic types:

Passive Control – Controlled diversion of water ingress that does not reduce the water flow but either partially contains and/or channels it along a specific route into a drainage system. Typical methods include catchment pans, localised corrugated drip sheeting, ventilation shaft drainage and portal crest drainage.

Figure 39 Tunnel portal crest drainage

Active Control – Major renewal works at high cost to either locally seal or divert water ingress by an appropriate method to reduce the flow to an acceptable rate. Typical methods include mass void grout injection, mass brickwork repointing, weep-hole coring, brickwork relining and spray applied structural concrete, Figure 40.

Figure 40 Spray applied structural concrete

Throughout CP4 and into CP5 the LNE&EM Structures asset management team have been committed in their maintenance efforts to improve the existing Passive Controls within all tunnels including:

- the renewal of age expired or defective ventilation Shaft 'Ring-Dam' drainage to control the varying influxes of groundwater before it reaches the railway infrastructure equipment (typical installation cost of £25k per ventilation shaft at non-electrified Tunnels)
- regular clearance and improvements to portal headwall drainage to reduce the risk of icicles forming above the OHLE and to reduce the risk of earthwork failures
- improved portal headwall stepped access to a number of high-risk sites to enable a safer and quicker response to the presence of icicles and to improve drainage maintenance
- the installation of catchment pans to resolve issues associated with groundwater under pressure discharging directly on to the railway infrastructure equipment.

Further investment and innovation is required to maintain optimum Route performance, including:

- Improved track drainage within tunnels with known severe groundwater ingress to better manage the known environment and maintain track quality
- The installation of 'weep-hole' cores along the bore lining to allow groundwater to run off at focal points rather than percolate through the brickwork and discharge intermittently throughout the bore and on to the railway infrastructure equipment
- The removal of encrusted soot and contaminants from the tunnel lining to allow full examination of the historic brickwork, removal of falling minor debris risk and reduce the contamination of railway infrastructure equipment within the tunnel
- The removal of widespread age expired corrugated drip sheeting which masks the historic brickwork

Adhesion impact assessment

In CP5 LNE&EM has an intensive vegetation programme to improve the railway corridor.

Each year a full review of historic rail head adhesion problem sites is undertaken and this in turn leads to a targeted programme of de-vegetation. Where there are areas of heavy contamination that the de-vegetation programme proves insufficient to manage, and if the contaminant is rail borne, then there is the option of the rail head treatment train (RHTT), Figure 41, to manage the issue and this runs throughout the autumn season.

Figure 41 Rail Head Treatment Train

The RHTT is supported by a number of dedicated teams that treat discrete sites with hand held traction gel applicators (TGAs). There is also mechanical traction gel applicators fitted in the sites most prone to adhesion issues causing wheel slippage. Following a review of the 2013 Autumn season, 16 new TGAs have been installed on the Route at strategic locations including Selby and Deepcar.

Lightning impact assessment

The Route followed the national initiative of installing varisters to protect vulnerable Signalling & Telecommunication equipment, and has continued to install FURSE lightning protection to an increased number of assets to further improve resilience,Figure 42. A targeted programme of protection will be employed to reduce lightning impact at any additional sites.

A programme of installing UPS (Uninterrupted Power Supply) and upgrades is under way on the Route in locations where lightning has caused historic problems.

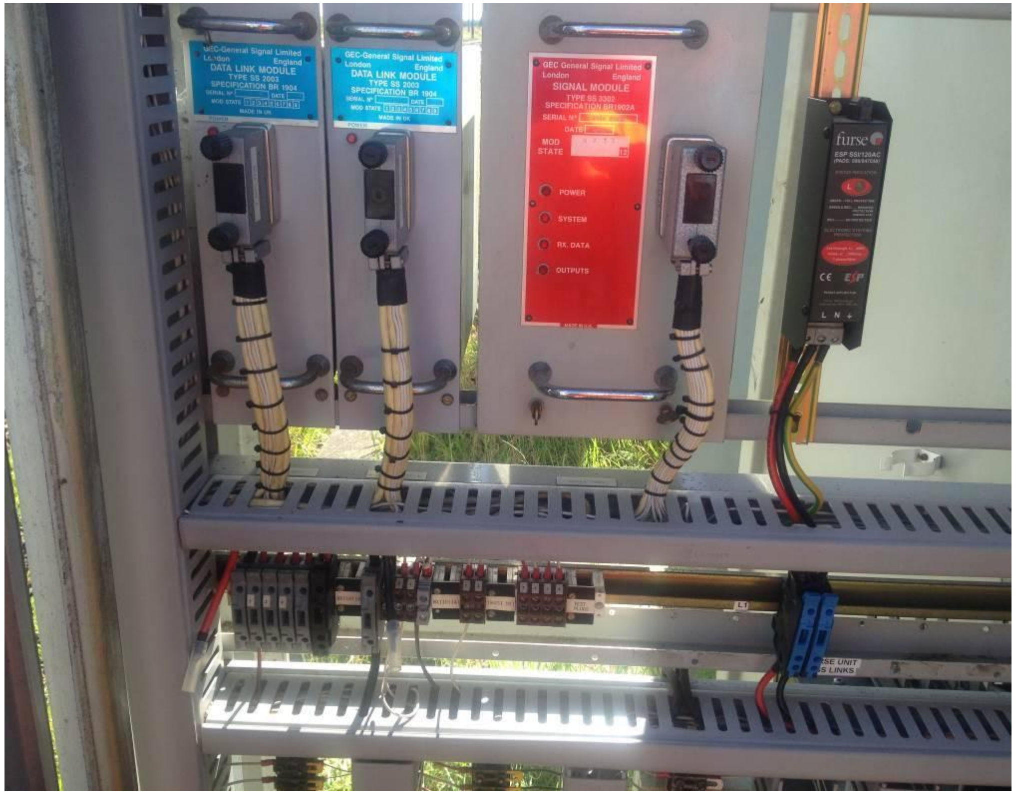

Figure 42 FURSE lightning protection installed in trackside signalling cabinet

Heat impact assessment

A proactive hot weather regime is in place throughout the Route for the management of critical rail temperatures and temporary speed restrictions (TSRs) for track. This monitors stressing records, fishplate oiling, rail adjusting, ballast profile conditions, wet bay sites, transient worksites and other sites at risk. A weekly conference is held with the Track Maintenance Engineers (TMEs) to discuss risks, post and pre works, current position and mitigating actions.

Traditionally, painting Switches & Crossings (S&C) white has been used to mitigate performance risks to switch diamonds in hot weather but has increasingly been used as a means to limit rail temperatures on S&C vulnerable to track buckles in hot weather. Painting rails white has been shown to keep rail temperatures up to 5ºC lower than unpainted rails in sunshine, Figure 43.

Figure 43 Temperature reduction from painting rails white

Fragile track infrastructure, particularly jointed track is being targeted for renewal in CP5 to improve performance of the track asset in hot weather as well as bringing other performance and whole life asset cost benefits.

To protect vulnerable Signalling and Telecommunications (S&T) equipment from heat, a campaign of fitting heat shield hoods, Figure 44, heat reflective paint and in extreme cases fan assisted ventilation systems to trackside cabinets throughout the Route has been undertaken. There has also been a programme of forced air cooling systems fitments to maintain temperature in the larger equipment rooms and re-locatable equipment buildings (REBs).

Figure 44 Heat Shield Protection Hoods for Trackside Signalling Equipment

Sea level rise impact assessment

In 2013 the highest ever recorded river levels were experienced at a number of locations across the Route following tidal surge conditions. The Humber River barrier was also breached.

The Route section affected by the surge was the Hull Station to Selby Line which carries passenger and freight traffic. Although there were no reports of track problems it was considered certain that with erosion of the foreshore and movement of the channel, if the ongoing slip was not remediated in the near future it would cause movements at track level requiring the line to be closed. Work was undertaken at Hessle Foreshore where the failure of an existing cantilever sheet pile wall river defence, Figure 45, was remediated by construction of a more robust bored pile wall option, Figure 46.

Figure 45 Hessle Foreshore sheet piled wall in October 2012

Figure 46 Hessle Foreshore bored piled wall in 2014

The projected rise in sea levels could put further sites on the network at risk if similar tidal surge events occur in the future. A review of known ‘at risk’ sites has been undertaken and is being linked with future asset management plans for earthworks and drainage schemes.

Fog impact assessment

Some sections of the LNE&EM Route are signalled using semaphore signalling systems, which were previously lit by filament lamps. Over the past few years there has been a change out to an LED equivalent which provides significantly improved visibility during fog conditions.

There are other examples where we have fitted surveillance cameras at crossings to improve the view of the signaller in times of poor visibility. This has proved to be effective at Flemingate and Driffield on the Hull to Bridlington line where fog has been a particular problem. When the fog is very severe, ‘Fog men’ are deployed at the level crossing to ensure the safe operation with the signaller of the crossing.

LNE&EM Route WRCCA actions

Network-wide weather and climate change resilience will be driven predominately by Network Rail's Central functions through revision to asset policies and design standards, technology adoption and root cause analysis. The location specific nature of weather impacts will require analysis and response at Route level.

This section is a concise summary of LNE&EM Route actions planned in CP5, Table 2 , beyond Business as Usual (BAU), and potential additional actions, Table 3, for consideration in CP5 and future Control Periods to increase weather and climate change resilience.

Table 2 Planned actions in CP5

Vulnerability	Action to be taken	By when
All Impacts		
Climatic conditions and specific weather-related risks are not clearly communicated to asset renewal and enhancement processes	Include clear requirements for climatic conditions and resilience levels in Route requirement documents.	Ongoing
Risk to staff from extreme weather conditions	Continue to develop and train staff in the use of the latest technology and equipment to minimise the need for our staff to be out in extreme weather.	Ongoing
Flooding		
Known flood sites	There are a number of sites in LNE&EM that are known flood risks to the railway. A plan to fix each one and reduce the risk of a further flood event to ALARP has been developed.	2014-19
Vulnerability of drainage assets around tunnel portals.	Risk-based, proactive campaign of drainage management at and near tunnel portals. A combination of heavy maintenance and refurbishment of existing systems, improvements to connectivity and installation of new drainage where required to reduce risk to ALARP.	2014-19
Asset knowledge	A risk-based programme of detailed, systematic drainage examination to comply with policy and standards, improve asset knowledge, understand risk and cost and develop a proactive annual maintenance regime to assure drainage performance.	2014-19
Third-party inflows	A proactive, risk-based programme of inflow management to minimise and control the quantity of water we inherit from adjoining land. Case-by-case analysis of our liabilities and obligations. Site-specific management regime for critical inflows	2014-19
Lack of real time monitoring	Real-time monitoring of water levels within our drainage assets to determine functionality of the systems in place and forecast potential drainage issues during extreme weather. Allowance for new research and monitoring equipment for emerging sites. Establishment of an accessible web-based platform for data review.	2014-19
Sub 450mm underline assets	A programme of research and countermeasures to manage risk of underline drainage assets with an internal diameter of less than 450mm. Risks to be mitigated include voiding of track, loss of line and level, flooding, ballast contamination and nuisance to third parties	2014-19
Water management issues relating to TSRs, L2 faults, VPEs and Super Red sites.	A proactive, risk-based programme of work to mitigate risk of Temporary Speed Restrictions, L2 faults, VPEs and Super Red sites where water management is the root cause of the problem. Off-track drainage systems that serve areas at risk will be assessed, surveyed and improved to reduce likelihood of safety and performance impact to ALARP.	2014-19
Shared critical asset flood prevention	Work to meet the reasonable expectations of Internal Drainage Boards and other statutory drainage undertakers, and to achieve compliance with Land Drainage Acts.	2014-19
Scour and other hydraulic risks that result in performance reduction and possible safety risk associated with structures during flood events	Engage in programme of scour assessments across Route with further investigations where required. Place scour protection (e.g. rock armour) to structures found to be high risk from scour	October 2016

Vulnerability	Action to be taken	By when
The condition and effectiveness (capacity) of drainage for Buildings' assets such as platforms, canopies and car park surfaces are a primary concern. The management of storm water is vital to prevent slips and trips and the freeze thaw action on platforms. From the passenger perspective rainwater over spilling from canopies, pools of water forming on platforms and car parks is unacceptable	The design of outfall drainage from these assets needs to consider the broader storm water management system, e.g. canopy outfall to track via a platform. Inadequate capacity can result in the wash out of fine materials and undermine foundations or track formations.	2014-19
Rainwater is a primary cause of the accelerated deterioration of structural components. Most affected by this are canopies and footbridges, especially when combined with dissolved rock salt put down as a means to address winter frost.	The Buildings' weather resilience programme plans to investigate the current state of drainage at stations and depots. This will allow us to understand the scope required to implement repairs and meet increasing demand.	2014-19
Earthworks		
Third-party slopes at risk from climatic changes and limited knowledge of the location and number of these third-party slopes.	Third-party slopes to be identified and investigated with works scoped to offer more protection to the railway from adverse weather events and climate change. The embankment at Browney Curve is an example of a large-scale issue that requires a detailed investigation to determine an appropriate scheme of works.	2014-19
Vulnerability of all sites on the adverse weather list.	Review adverse weather list and determine a fix for each site to improve resilience.	2014-19
Tunnel portal cutting slopes at risk from climatic changes.	High-risk tunnel portal slopes to be identified and schemes developed.	2014-19
Rock cutting slopes at risk from climatic changes including freeze thaw processes.	Carry out work on policy aligned sites which are not in the CP5 business plan. Utilise CP5 blockades to carry out rock cutting maintenance, refurbishment or renewal. Consider temperature remote monitoring at high-risk rock cuttings for freeze thaw monitoring.	2014-19

Vulnerability	Action to be taken	By when
Earthworks at risk of flooding	Research and initial interventions into our 'earthwork in the flood plain' list, interventions required to improve resilience at vulnerable locations. Include scour intervention and flooding of low-lying coastal areas. Details to be worked up in the next few months.	2014-19
Limited knowledge of precipitation 'trigger levels' during extreme weather events.	Carry out research and improve our site specific knowledge to determine site specific trigger levels.	2014-19
Impact of drier summers on earthworks shrinkage and moisture deficit	Study required to identify sites that will be at an increased risk of movement caused by drier ground conditions.	2014-16
High temperatures		
Failure of S&T and E&P equipment due to heat in lineside buildings	Target funding to enhance air conditioning equipment in vulnerable locations or fit where none currently exists.	2014-19
Failure of vulnerable track assets caused by increase in rail temperatures	Plan to upgrade jointed track at key locations to CWR as part of CP5 renewals strategy.	2014-19
CWR will need to withstand higher rail temperatures.	Review required to consider the benefits of increasing the Stress Free Temperatures on a site specific or geographical basis to increase the Critical Rail Temperatures.	2014-16
Coastal and estuarine		
Flooding of vulnerable S&T assets	Provide funding to renew and raise location cabinets in vulnerable areas.	2014-19
Risk of ballast wash-out	Further work is required in conjunction with the Environment Agency to better understand and model the impact of rising sea levels combined with tidal surge for specific locations. This will allow us to further develop our own asset management plans and also better understand the investment plans required by any third-parties to reduce the impact, e.g. improved river flood defences.	2014-19
Wind		
Dangerous trees on third-party land	Increase knowledge of key stakeholders of risk and potential consequences. Proactively provide funding to remove at risk trees using specialist subcontractors	2014-19

Vulnerability	Action to be taken	By when
Cold and Snow		
Failures in level crossings due to highway salting	Target funding to flush crossings susceptible to failure	2014-19
Susceptibility of MCB OD crossings due to radar/LIDAR issues	Target funding to provide deployment of staff to remove snow in times of high snowfalls	2014-19
Adhesion		
Identify all sites that suffer high level of rail adhesion problems	Undertake an annual review to identify all sites that have suffered high levels of rail adhesion problems in the previous Autumn season.	Mid 2014
High-risk veg removal programme	Undertake DDDT removal programme to remove risk.	Mid 2015- End 2015
Installation of traction gel applicators	Annually review sites currently fitted with traction gel applicators. Add additional as required based on risk.	Mid 2015
Lightning		
S&T equipment hit by lightning	Provide funding for enhanced lightning mitigation works.	2014-19

In addition to the above actions in CP5, the following actions have been identified as potential enhanced WRCCA actions which will require business case evaluation and funding submission.

Table 3 Potential additional WRCCA actions requiring further evaluation

Vulnerability	Action to be evaluated
All Impacts	
All assets	Continue to monitor reliability trends for all asset types and incorporate emerging issues into future asset strategies.
Flooding	
Drainage	Continued focus on enhanced drainage schemes through the LNE&EM water management review group.
Effects of flash floods	Culvert cleaning, jetting, CCTV inspection and re-lining on primary and main secondary routes and flood plain locations to improve culvert capacity and alleviate flooding risk
Management of Scour risk following flooding events can result in prolonged line closures	Undertake robust scour mitigation works to allow specific flood actions to be established.
Real time monitoring of water levels.	Continued development and implementation of flood level monitoring systems.
Earthworks	
Real time monitoring of earthworks	Further research required into Remote Condition Monitoring solutions for earthworks
Increased rainfall intensity and temperature variations will accelerate the natural weathering processes of weak rock material.	Further research required into areas susceptible to rapid deterioration. This may require an enhanced programme of remedial work.
Moisture deficit	Further investigation is required into embankments which are susceptible to moisture deficit issues and may require enhanced vegetation management plans to control the issue.
High temperatures	
Equipment overheating	Research required into new methods of keeping equipment cool.
Real time monitoring of track resistance to thermal forces	Research required into enhanced remote monitoring of track resistance
Wind	
Risk of trees on the OLE and/or track	Review of enhanced removal of all ‘taller than distance’ from track trees

Vulnerability	Action to be evaluated
Impact of over-head line failures	Develop a programme of OLE head-span to portal conversions to minimise the impact of failure.
Risk to third-party property from trees on Network Rail owned land	Review of enhanced removal of all ‘taller than distance’ from boundary trees
Imposition of blanket speed restriction during high wind speeds	Review of the requirement to impose a blanket speed restriction during periods of high wind speeds post completion of LNE&EM enhanced vegetation management scheme
Cold & Snow	
Ice formation and water ingress in tunnels	Install tunnel shaft cowells and undertake accelerated shaft lining renewal to reduce water ingress.
Corrosion of rail in level crossings	Further research is required into salt action in level crossings. Guided wave ultrasonic technology to be developed and implemented to enable rails in level crossings to be monitored without the need to lift the deck.
Lightning	
Signalling system lightning vulnerability	Research required into new lightning protection methods.

Management and review

Corporate management and review

Weather resilience and climate change adaptation will require long-term commitment to regular review and management across the business. The challenge for the industry, and for all organisations managing assets vulnerable to weather events, is to develop cost-effective strategies to accommodate climate change and implement these strategies in a timely manner to avoid an unacceptable increase in safety risk, reduction in system reliability or undeliverable downstream risk mitigation strategies.

Key actions being taken within corporate functions include:

- Safety, Technical and Engineering – Review of weather and climate change within asset policies and standards, and monitoring of WRCCA actions through the S&SD Integrated Plan
- Network Operations – Review of the Extreme Weather Action Team process and definition of 'normal', 'adverse' and 'extreme' weather
- Group Strategy – Delivery of future weather resilience in the Long-Term Planning Process
- Infrastructure Projects – Review of weather and climate change within the Governance for Railway Investment Projects (GRIP).

The progress on WRCCA actions is reported through Network Rail's governance process to the Executive Committee as part of regular Strategic Theme business management updates.

LNE &EM Route management and review

LNE&EM Route will be working closely with the Environment Agency, local authorities and other relevant bodies to ensure we have a joined up approach to managing the factors that impact on the railway and the surrounding environment. We will continue to review our actions as our understanding of climate change develops. We will incorporate this into the validation of our asset strategies to ensure our infrastructure is as resilient as possible.

LNE&EM Route will continue to invest in remote condition monitoring technology to obtain a real time picture of how our assets are performing. Specialist teams have been set up to focus on asset reliability, to quickly establish trends and target the right solutions to our emerging issues.

Review of Route WRCCA plan actions

The actions within all eight Route WRCCA plans will be monitored through internal Network Rail governance processes.

Route WRCCA plan progress will be reported every six months through the S&SD Integrated Plan. The plan monitors the actions being taken across Network Rail delivering safety and sustainable development objectives. The whole plan is monitored monthly by the cross-functional S&SD Integration Group.

Enhancement of assets will be included in Network Rail workbanks and monitored through our asset management processes.

Network Rail will also look to engage with the wider rail industry, specifically Train Operating Companies and Freight Operating Companies, to discuss the Route WRCCA actions to identify opportunities for collaboration to facilitate effective increase of rail system resilience. We will also update the Office of Rail Regulation (ORR) on progress through regular bilateral meetings.

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