2019 – 2024

London North East and East Midlands

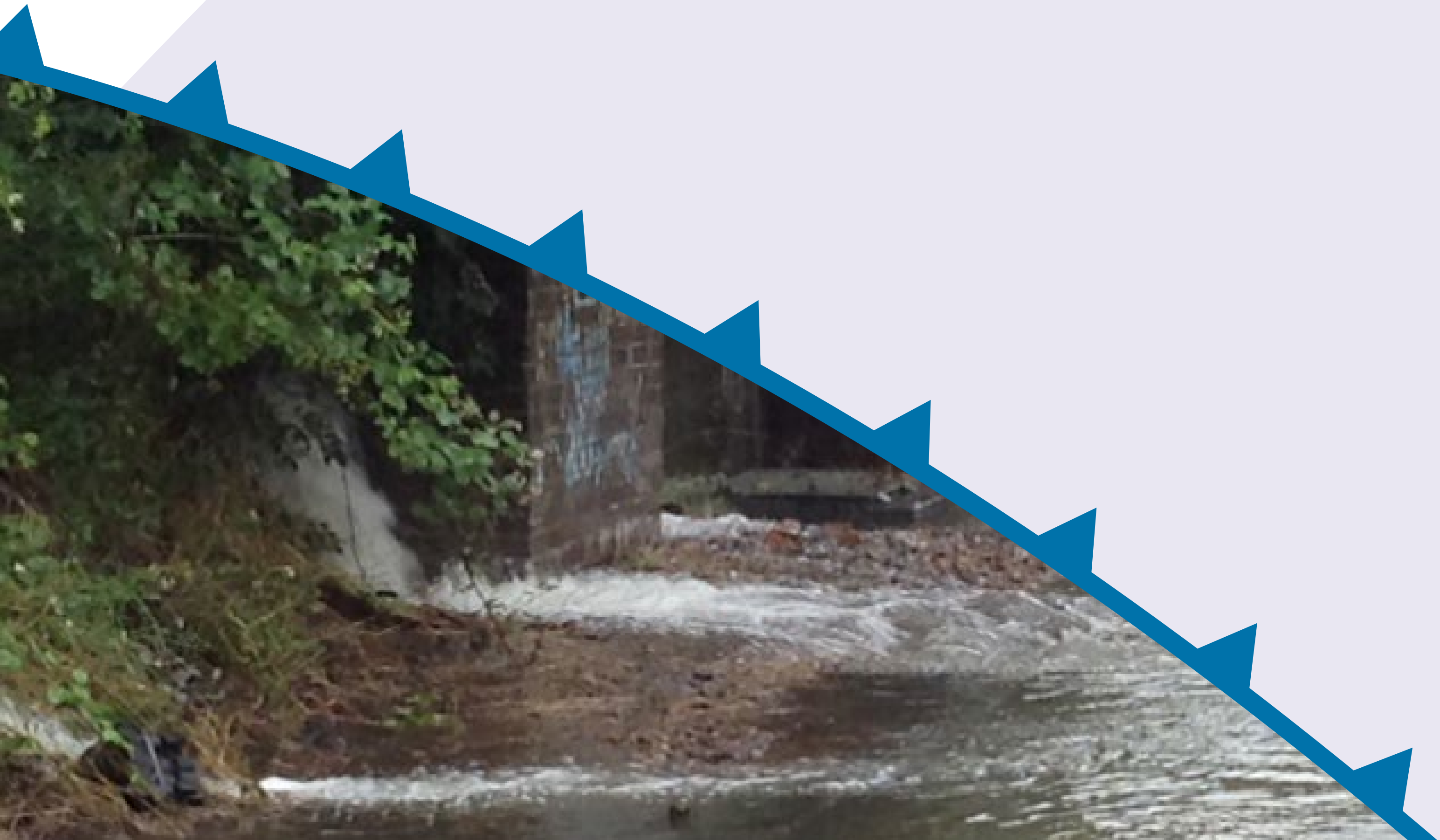
Route CP6 Weather Resilience and Climate Change Adaptation Plans

Contents

Purpose of this document

This document; defines the LNE&EM Route Weather Resilience and Climate Change Adaptation (WRCCA) Plan for CP6 and reviews progress against the WRCCA Plan published for CP5. This 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 rolling stock operating within the Route is not specifically assessed.

LNE&EM Region Weather Resilience and Climate Change Adaptation Plan – Version 1 – October 2020.



Director of Route Asset Management Statement

The railway network has been significantly affected by severe weather conditions including wind, snow, rainfall, lightning, heat and cold.

Figure 1
Kirkstall Flooding

Climate change projections suggest we will be entering a period with increasing average and maximum daily temperatures, drier Summers, wetter Winters, sea level rises and increased storminess. Increased storminess and Winter rainfall will increase the risk of flooding, subsidence and coastal storm surges, heat causes soil desiccation and track buckling, high winds result in debris falling on to the track, and snow and cold weather result in frozen points and blocked routes.

In CP5 LNE&EM Route made significant progress in improving the resilience of our most vulnerable assets. This included a targeted approach to drainage at specific sites that had previously experienced the highest delays and improved resilience to high winds by converting our most exposed areas of overhead line from head-spans to portals. We also upgraded a significant volume of light weight jointed track to Continuously Welded Rail (CWR) and timber Switches and Crossings (S&C) to concrete layouts to improve lateral resistance during hot weather.

In CP6 weather resilience continues to form an integral part of our asset management strategy, recognising the significant impact that the weather can have on the performance of the railway. A core aspect of our strategy is based around managing our drainage assets with a systems approach to provide greater resilience for the track and earthworks assets. We are also focussed on improving resilience in high winds through an extensive programme of lineside vegetation management. Our programme of scour mitigation also continues.

In addition to physical interventions, we are also keen to enhance our asset intelligence through remote monitoring to drive better responses and management in adverse weather. We also look to develop enhanced modelling techniques to better predict future weather impact at specific sites to assist with optimising renewal design with appropriate consideration for climate change.

Andrew Murray
Director of Route Asset Management
(London North Eastern & East Midlands)

Executive summary

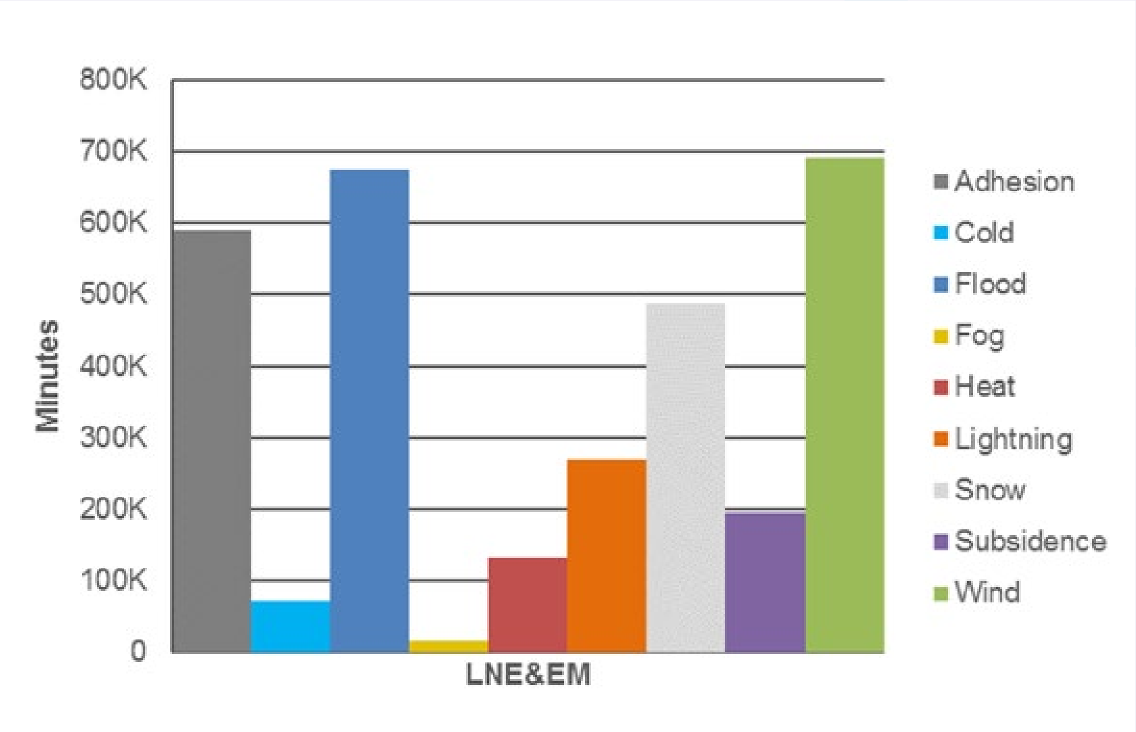
Current weather events can cause significant disruption to the operation of train services and damage to rail infrastructure.

The UK Climate Change Projections 2018 (UKCP18) indicate that there will be a shift to a warmer climate with significant changes in sea level and the pattern and intensity of precipitation across the year. Changes in the frequency and intensity of extreme weather events and seasonal patterns as a result of this could alter the likelihood and severity of weather event impacts. 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 is committed to supporting the improvement of weather and climate change resilience through the delivery of the route-specific objectives. We have developed an understanding of our risks by; assessing our weather-related vulnerabilities (for example Figure 2), identifying root causes of historical performance impacts and using UKCP09 regional climate change projections.

Our 2014 Route WRCCA Plan set out our Route WRCCA Strategy, summarised the findings of our Route vulnerability and impact assessments, detailed the CP5 investments and mitigating actions and highlighted future considerations.

Figure 2
LNE&EM Route weather attributed delay minutes – 2006/07 to 2018/19



This updated plan reports our CP5 progress, sets out our plan for CP6 and beyond and updates our vulnerability and impact assessments to account for changes in the Network Rail WRCCA Strategy and guidance.

In 2017 the Network Rail guidance on the climate change projections to be used for impact assessment and planning was reviewed. This recommended using the UKCP09 medium scenario, 90th percentile probability[1]. With the release of the UKCP18 data this has been updated to the UKCP18 Representative Concentration Pathway (RCP) 6.0 90th percentile.

In CP5 we were able to complete the majority of our planned schemes and initivations. Notable successes have been our drainage resilience programme, driving a significant reduction in train delay attributable to flooding events. We have also considerably reduced our scour risk at under-bridges through successful delivery of our mitigation programme. The trial site at Wood Green converting thirty Overhead Line head-spans to portals on the East Coast Mainline proved the technology and demonstrated the benefits of independent registration mitigating the risk to the asset in high winds. The on-going programme of jointed track removal and upgrading of timber S&C layouts has substantially reduced the risk of track buckling in high temperatures.

Although the actions taken in CP5 improved aspects of our resilience, weather events continue to impact our operations. LNE&EM Route is committed to addressing the risks through the timely, cost efficient and safe delivery of this Route WRCCA Plan.

[1]Previous recommendation used in the 2014 Route WRCCA Plans was UKCP09 high scenario, 50th percentile probability

Introduction

The railway routinely operates in a wide range of weather conditions, however, adverse and extreme weather can still cause significant disruption to our network.

Current weather events such as extreme rainfall, snow (and the resultant melt water) and high temperatures can cause delays, raise operating costs and increase safety risks. Recent examples of vulnerability in LNE&EM Route include; Farnley Haugh landslip, Springs Tunnel landslip, Corby landslip and Kirkstall flooding.

We monitor the impact of weather events on the performance of our network by using delay minutes and Schedule 8 delay compensation costs[2]. Incidents are recorded under 9 categories as follows;

- Adhesion – line contamination leading to traction loss, e.g. leaf fall, moisture, oils,
- Cold – e.g. ice accumulations on conductor rails, points and in tunnels,
- Flooding – standing or flowing water leading to asset damage or preventing trains from accessing the track,
- Fog – reduced visibility obscuring signals,
- Heat – high temperature impacts e.g. rail buckles, Temporary Speed Restrictions (TSRs), overheated electrical components,
- Lightning strike – e.g. track circuit and signalling damage or power system failure,
- Snow – e.g. blocked lines and points failures,
- Subsidence – the impacts of landslips, rockfalls and sinkholes, and
- Wind – e.g. trees and other items blown onto the track and into the overhead line equipment (OLE) or TSRs.

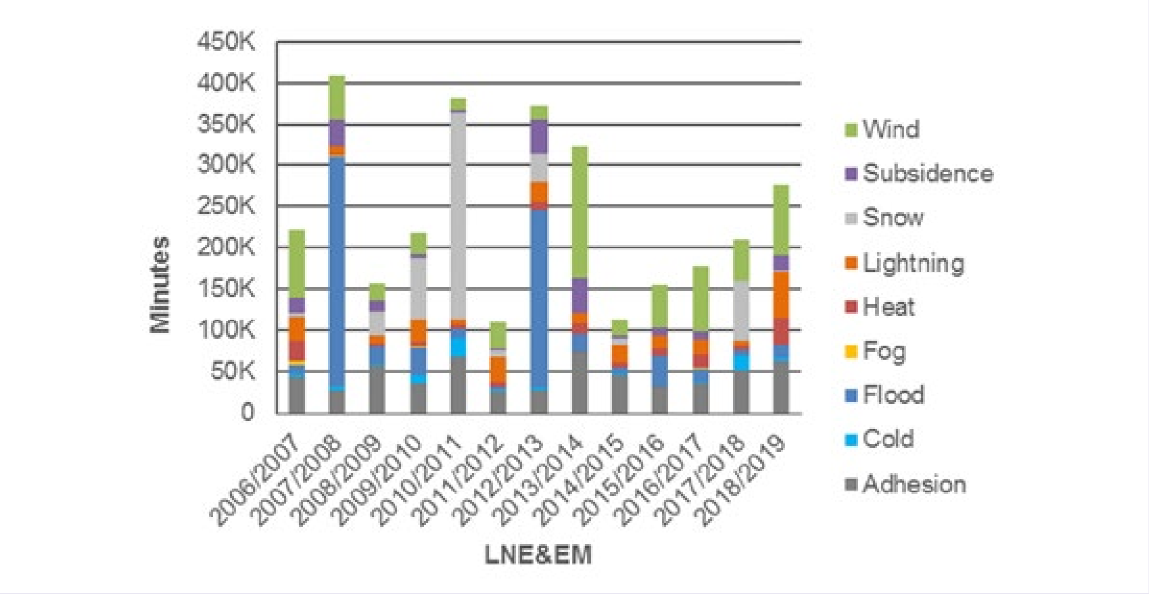
As this data includes the duration and location of each disruption, and attribute cause, they give a high degree of granularity for use in analysing weather impacts and trends.

In the past 13 years (2006/07 to 2018/19) the average annual number of Schedule 8 delay minutes attributed to weather for the LNE&EM network was 237k. This represents 10.6 % of the total number of Schedule 8 delay minutes for all causes over that period equating to an average annual cost of £9.1m.

The impacts of severe weather events on the LNE&EM Route can be clearly seen in Figure 3, for example:

- Rainfall during 2007/08 and 2012/13,
- Snowfalls of 2009 through to 2011 and 2017/18,
- Wind in most years, particularly 2006/07, 2013/14 and 2016/17, and
- Extreme heat in 2018/19.

Figure 3
LNE&EM Route weather attributed delay minutes by year – 2006/07 to 2018/19



[2]The compensation payments to passenger and freight train operators for network disruption

The costs of weather attributed Schedule 8 and 4 payments and the wider socio-economic impacts of rail disruption on the UK justify continued investments to increase current weather resilience. Network Rail's collaborative approach to understanding weather impacts in the increasingly interdependent infrastructure, societal and environmental systems is key to identifying appropriate resilience response that support our role in developing regional and national resilience.

Trends in the UK climate, and the UKCP18 data, indicate that there has, and will continue to be, a shift to a warmer climate. Figure 4 illustrates the changes in frequency and severity of Atlantic Winter storms and Figure 5 shows observed increases in the Central England Temperature record.

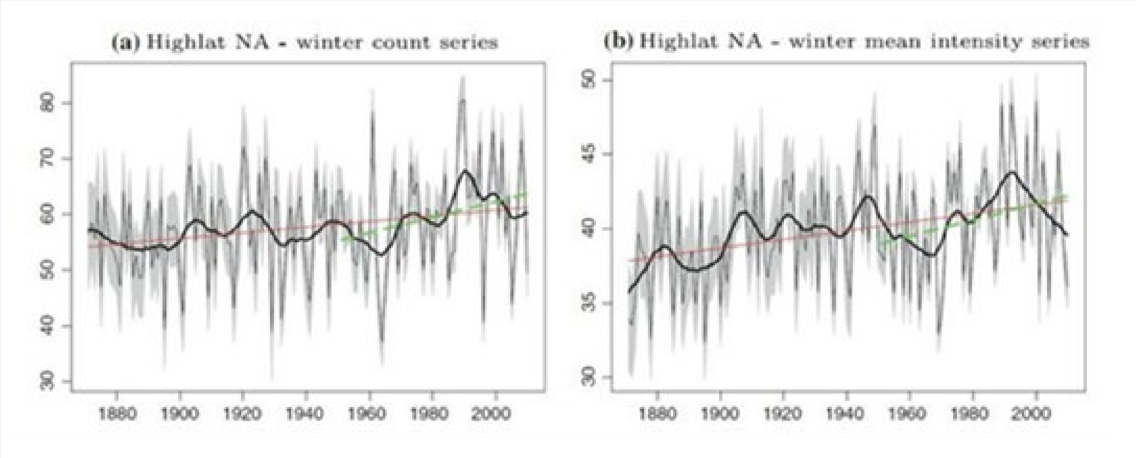


Figure 4
Intensity and frequency of high latitude Atlantic Winter storms[3]

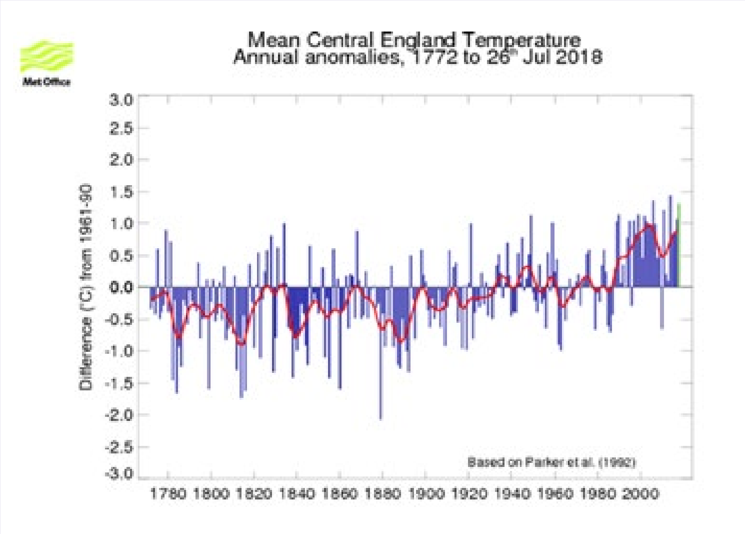


Figure 5
Mean Central England Temperature Record[4]

[3]Xiaolan L. Wang, Y. Feng, G.P. Compo, V.R. Swail, F.W. Zwiers, R.J. Allan, P.D. Sardeshmukh. 2012. Trends and low frequency variability of extra-tropical cyclone activity in the ensemble of twentieth century reanalysis

[4]Parker, D.E., T.P. Legg and C.K. Folland. 1992. A new daily Central England Temperature Series, 1772-1992. Int. J. Clim., Vol12, pp 317-342

Introduction continued

UKCP18 projects an overall shift towards warmer climates with drier Summers and wetter Winters for the whole of the UK, although the level of change will vary across the regions.

Examples of the changes are shown in Figure 6 for the mean maximum Summer temperature and Figure 7 for Winter precipitation.

Figure 6
Change in mean daily maximum Summer temperature (˚C) (left to right; 2030s, 2050s and 2070s) based on a 1981-2000 baseline[5]

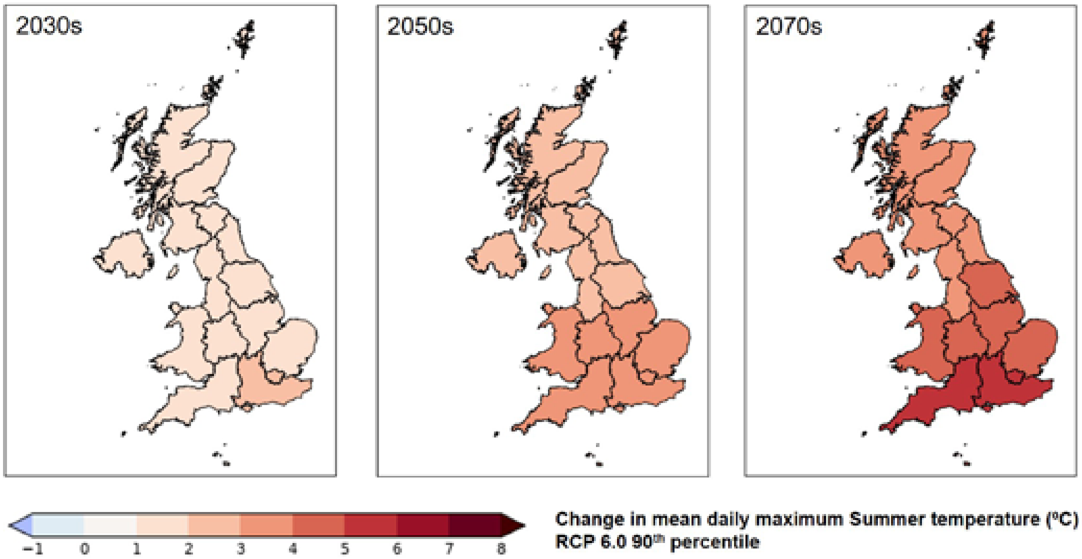
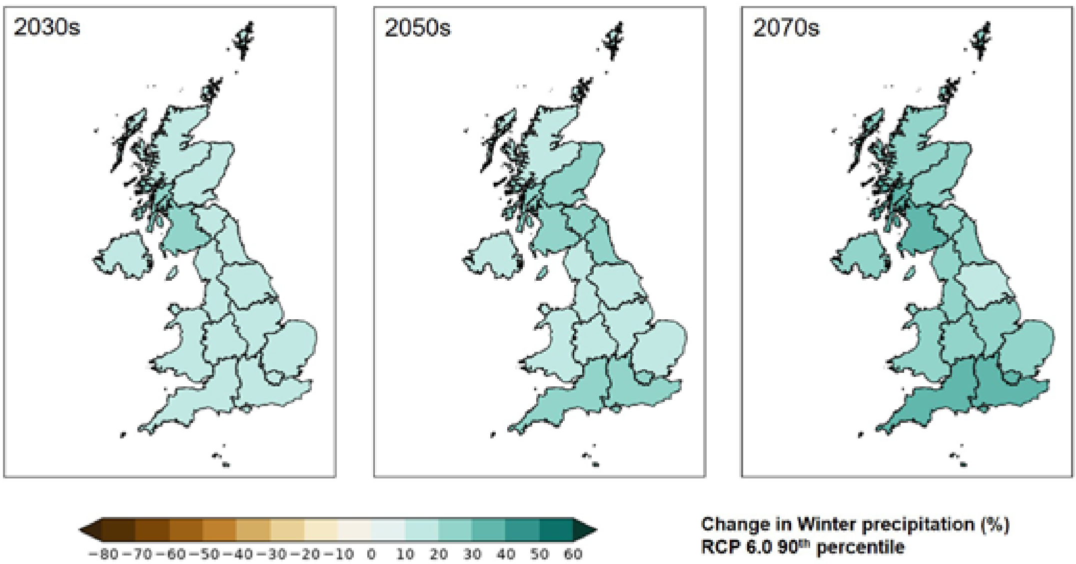


Figure 7
Change in Winter precipitation (%) (left to right: 2030s, 2050s and 2070s) based on a 1981-2000 baseline[6]



[5]© UK Climate Projections, 2018
[6]© UK Climate Projections, 2018

The potential increases in weather impacts due to climate change support the business case for enhancing weather resilience action and identifying actions that will deliver a railway that is safe and more resilient to the effects of weather, now and in the future.

The 2015 Paris Agreement unites nearly every nation in a common cause to undertake ambitious efforts to combat climate change and adapt to its effects. The central aim is for a strong global response to the threat that keeps the global temperature rise this century to well below 2˚C above pre-industrial levels and to pursue efforts to limit it to 1.5˚C.

The Department for the Environment, Food and Rural Affairs (Defra) provides national climate change guidance in a number of ways to enable the assessment of future climate risks and the planning of adaptation actions to maintain and improve resilience. Most important to Network Rail and the LNE&EM Route are:

- The UK Climate Projection data sets which are produced by the Met Office Hadley Centre, and
- The National Adaptation Programme (NAP).

The UK Climate Projection data sets are produced for use in assessing the future risk and impacts of the possible climate projections for the UK. They are used by government to conduct the 5 yearly UK Climate Change Risk Assessments (UKCCRA) and by individual organisations to understanding and planning for their specific risks.

For the 2014 Route WRCCA Plans Network Rail's national guidance was to use the UKCP09 high scenario, 50th percentile probability projections as an appropriate benchmark on which to base evaluations and decisions. In 2017 Network rail commissioned a review of its guidance taking into account the Paris Agreement, advances in climate science and additional years of climate observations and the then pending release of the UKCP18 dataset.

The conclusions of the review[7] were that as a safety critical focused organisation and major UK infrastructure manager the most appropriate UKCP projections to use are:

- UKCP18 – RCP6.9, 90th percentile probability as the baseline scenario for evaluations and decisions, and
- RCP8.5 90th percentile as the sensitivity test on assets with a lifespan beyond 2050.

Analysis in this report has been updated using the UKCP18 projections where available. It should be noted that some UKCP09 parameters have not been updated in UKCP18. Where this is the case, the UKCP09 data has been used and this is clearly indicated in the report.

[7]Identifying a climate change planning scenario, JBA Consulting 22/02/18

Introduction continued

The NAP is based upon the UKCCRA and is published by Defra every 5 years. It contains a summary of the impacts expected for each sector of the UK economy and tables detailing adaptation actions that the UK Government requires those sectors to undertake to ensure the continuing resilience of the UK economy.

The sectorial actions are apportioned to key stakeholders such as regulators and national infrastructure operators. Details of the Transport Sector actions in the NAP 2018 that are apportioned to Network Rail and hence the LNE&EM Route are included in Table 6 in the LNE&EM Route WRCCA Actions section of this Plan.

Although climate change projections include uncertainties, associated with natural climate variability, climate modelling and future emissions, they and the actions from the NAP can be used to provide guidance on the direction that the UK climate may take. LNE&EM Route has therefore used the projections in the creation of this WRCCA Plan.

To ensure a consistent approach to WRCCA consideration and action across Network Rail an iterative framework of key management stages is used (see Figure 8). The same framework has been applied to develop this Route WRCCA Plan.

Figure 8
Weather resilience and climate change adaptation framework

Network Rail will take a range of soft (changes to processes, standards, specifications and knowledge and skill base) and hard (engineered solutions to increase resilience) WRCCA actions tailored to the level of risk and the strength of evidence for it. Examples include:

- Do nothing/minimum – the option to do nothing/minimum and the risks should be evaluated,
- No regrets – increasing current and future resilience without compromising future flexibility,
- Precautionary – investment in adaptation now in anticipation of future risk, and
- Adaptation pathways – staged adaptation balancing future risk and current investment funds through phased investment enabling assets to be retrofitted cost-effectively in the future.

The following sections provide findings from the updated LNE&EM Route vulnerability and impact assessments, and detail progress on the CP5 resilience actions, actions planned for CP6 and additional actions for future consideration.

Figure 9
Farnley Haugh Landslip – 2017

LNE&EM Route WRCCA Plan

Network Rail's WRCCA Policy sets out the approach to achieving our company's vision of 'A better railway for a better Britain' by creating a railway that is safer and more resilient to weather impacts now and in the future.

It commits the business to seeking to apply the following key principles:

- Including current and future weather impacts in our risk analysis and investment decision making and embedding climate change specifications into policies, procedures and standards,
- Adapting at construction and at asset renewal, designing schemes to be resilient in the most cost-effective manner to and/or with passive provision for future weather conditions,
- In the event of catastrophic asset failure replacing on a like for better basis rather than like for like, considering the whole life cost and the best strategy for managing the railway,
- Identifying high priority locations for proactive resilience interventions and working to identify funding sources for projects not included within agreed Control Period funding, and
- Working with stakeholders to identify opportunities to enhance our preparation for, response to and recovery from adverse/extreme weather events.

LNE&EM Route Plan

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

- Reduce the risk of climatic changes to all high-risk earthwork and drainage assets by either undertaking suitable physical interventions or implementing appropriate monitoring regimes to safely manage the potential impact of adverse weather events,
- Proactive drainage management applying a system approach including used of RCM and detailed condition-based inspections,
- Establish a sustainable lineside environment which minimises performance and safety risk and maintenance intervention by removal of problem vegetation and dangerous trees utilizing specialist inspection and aerial and infrared photography captured by the RINM project,
- Work with lineside neighbours to establish an environment beyond the boundary that does not negatively affect safety of the line or performance including the management of trees and surface water run-off,

- Improve the resilience of our overhead line system in high winds, including head-span to portal conversions,
- Review effectiveness of adhesion solutions through effective vegetation management as well as fixed traction equipment,
- Upgrade jointed track and timber S&C layouts to increase temperature resilience,
- Improve the resilience of our track assets to high temperatures through continued upgrade of track components,
- Physical mitigation works at high risk scour sites,
- Work with weather forecasters to establish a more robust adverse weather process whereby relevant mitigation measures are taken in preparation of an extreme weather event,
- Engage with the Environment Agency (EA) and local authorities to align plans and optimise opportunities for joint schemes,
- Continue to develop Key Route Strategies with the train and freight operating companies that reflect the changing trends in weather, and
- Develop schemes for highly complex, multi-discipline problem sites such as Browney Curve embankment.

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.

Figure 10
Fanley Haugh landslip repair – 2017

LNE&EM Route vulnerability assessment

In the 2014 Route WRCCA Plan this section provided details of the general vulnerability of the national rail network and LNE&EM Route's specific vulnerabilities to current weather impacts, and regional climate change projections.

This Plan updates the vulnerability assessment taking account of:

- Advances in climate science,
- Improvements in our understanding of the impacts of weather and future climate, and
- Changes in Network Rail's climate change policy and guidance since the last plan was published.

Network-wide weather vulnerability

The rail network and its component assets are sensitive to the effects of a number of weather types. These manifest as either primary events (one weather type) or secondary events which are the result of these and/or a combination of weather types. It should be noted that these are the mechanisms by which impacts are felt, not the actual impacts themselves. Figure 11 illustrates the primary event types and their related secondary event types.

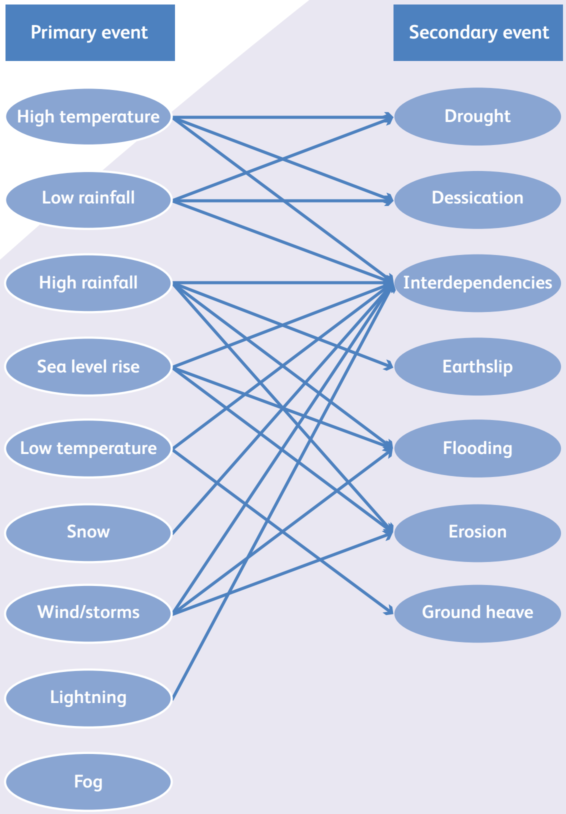


Figure 11
Examples of primary and secondary events

Managing a complex array of assets with varying ages, condition and weather vulnerabilities across a wide range of bio-geographic regions in a variety of climates is a complex challenge. Interdependencies with other sectors of the economy, for example power, telecoms and water infrastructure add to this.

Understanding current weather impacts is essential for assessing the probable effects of climate change and for the planning and implementation of appropriate cost-effective resilience investments to adapt the network to the future impacts.

The 2014 Plan outlined how we monitor the impact of weather on the performance of our network by using Schedule 8 delay compensation costs and the process we used to carry out a detailed analysis of this data to understand;

- The characteristics of weather-events that trigger failures,
- The thresholds at which failure rates change, and
- Trends in the failures of assets and the performance of the network.

The key findings of this work were that earthworks were the asset most affected by rainfall, overhead line equipment was most sensitive to wind and that temperature impacted the widest range of assets. These and the detailed outputs behind them have been disseminated to Network Rail's national asset function teams and the Routes for use in asset maintenance and investment planning.

As the above work was based upon current data the changes to Network Rail's national guidance for the climate change planning projections have not changed the conclusions.

We continue to monitor and analyse this data and we now have a 13-year series increasing our capacity to discern trends in failures and performance. We have now made the raw data available and we are continuing to look at how we can improve its use including through trend and performance reporting on a period, quarter an annual basis.

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 ECML and West Coast Main Line. It serves an important commuter route from North London into 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 12 below.

Figure 12
LNE&EM Route

The LNE Route has a number of coastal lines of variable criticality which will be vulnerable to future climatic change. The ECML (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.

LNE&EM Route vulnerability assessment continued

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 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 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 which can remain in place for prolonged periods of time. This can render the railway earthworks assets vulnerable to softening and weakening of the clays leading to 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 strata. This includes coal measures around Yorkshire, Derbyshire, Nottinghamshire and Leicestershire and further north the Yorkshire Dales, North Yorkshire Moors and the 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 %,
- Coal measures – 10 %,
- Chalk – 1 %,
- Cohesive till – 1 %,
- Alluvium – 32 %,
- Granular till – 25 %,
- Peat – 1 %,
- Interbedded limestone – 6 %,
- Over-consolidated clay – 2 %,
- Uncemented sands – 5 %, and
- Combination of above – 13 %.

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.

Figure 13
Springs Tunnel earthslip

Future climate change vulnerability

The complexity of the relationship between weather events and climate means that the UKCP18 data set cannot forecast future weather events. It projects modelled probabilistic trends that can be used to understand the potential future risks associated with certain climates and the likely changes in weather events/parameters. Network Rail therefore uses projections from the UKCP18 data set as a future baseline to understand potential risks and for making informed strategic decisions to increase future weather resilience.

Figure 14
Map of UK administration regions used in UKCP18[8]

UKCP18 provides regional projections across 13 administrative regions in Great Britain (see Figure 14). The LNE&EM Route spans several of these regions with the majority of it falling within the East Midlands, Yorkshire and Humber and North East England regions. These regions are therefore considered as representative of the Route for the purposes of analysing future climate projections.

In the 2014 Plan charts were generated using the UKCP09 High emission 50th percentile probability scenario for the three regions to show the projected changes in temperature and precipitation from the 2020s to the 2080s relative to the baseline climate of the 1970s (1961-1990).

For this report the charts and associated narrative have been updated in line with the current Network Rail climate change guidance which uses the current UKCP18 climate projections where available. Replacing the UKCP09 emissions scenario used in the 2014 report with the UKCP18 emissions scenarios noted in the introduction has involved a number of changes to the data used. These include:

- Using a new baseline period of 1981-2000,
- Moving from projection time periods of 30 years (2020, 2050, 2080) to shorter 20-year periods (2030, 2050, 2070), and
- The use of UKCP18 RCP 4.5 95th percentile data for sea level rise as a proxy for RCP 6.0 data (UKCP18 did not model RCP 6.0 for sea level rise).

[8]Met Office © Crown Copyright 2019 [available from UKCP18 Guidance: Data availability, access and formats: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance-data-availability-access-and-formats.pdf

LNE&EM Route vulnerability assessment continued

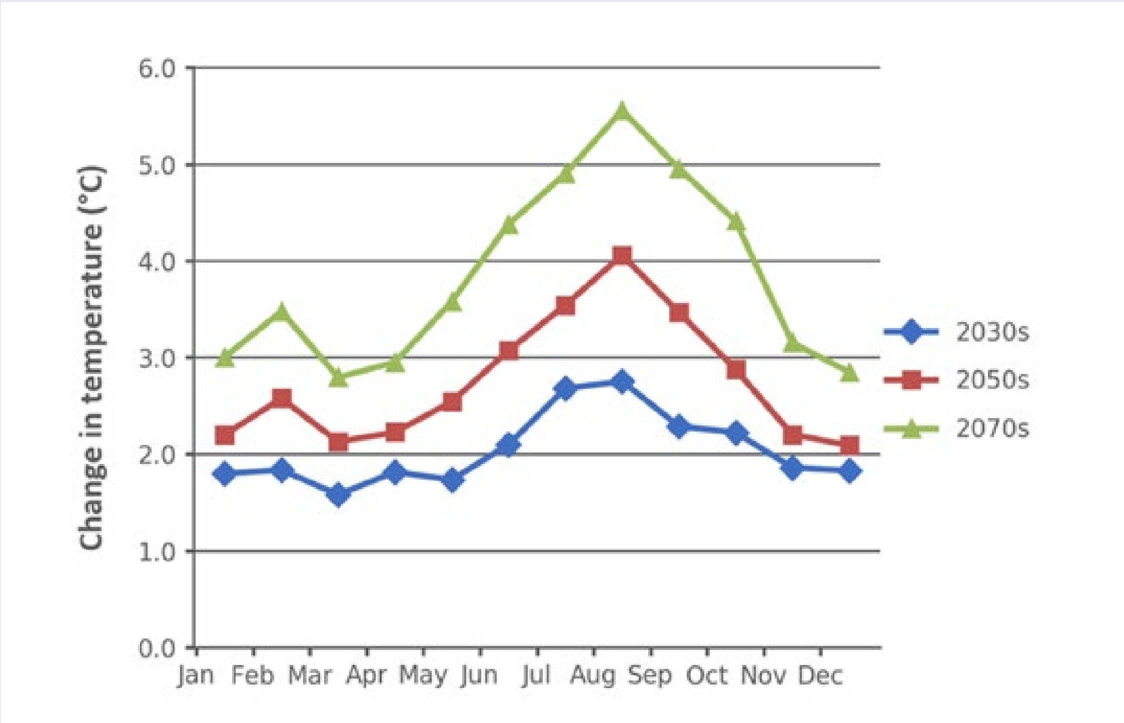
Mean Daily Maximum Temperature change

The mean daily maximum temperature for all three regions is projected to increase in every month of the year, with greatest increases expected in the summer months. This increase becomes larger across the century.

East Midlands

The highest mean Summer temperatures are expected to be in August for both the 2050s and 2070s with increases of 4.1˚C to 25.2˚C and 5.6˚C to 26.7˚C respectively. In Winter the highest mean temperatures will be seen in February for both periods with increases of 2.6˚C to 9.5˚C by the 2050s and 3.4˚C to 10.4˚C by the 2070s.

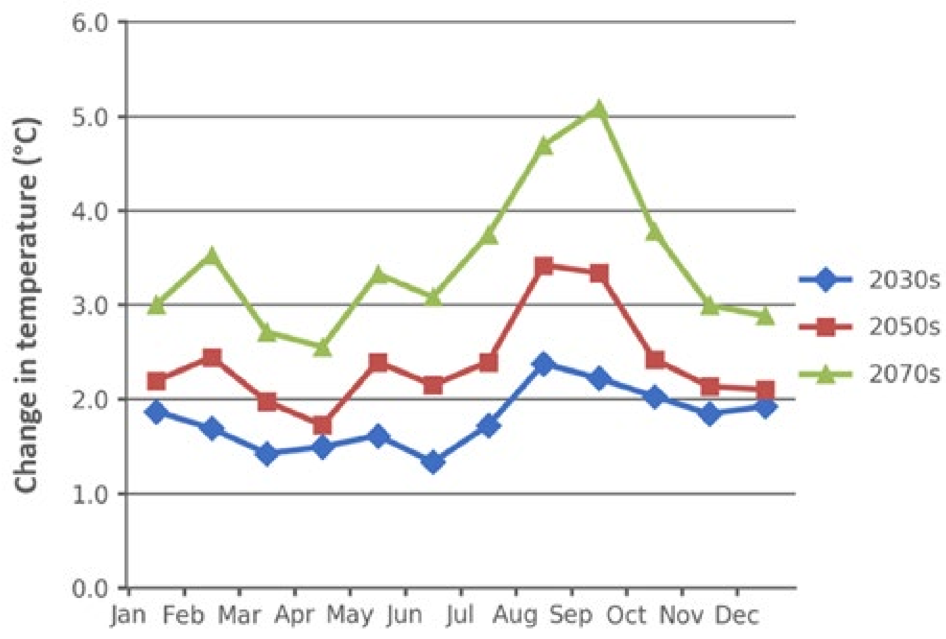
Figure 15
East Midlands, mean daily maximum temperature change (˚C) (RCP6.0 90th percentile)



Yorkshire and Humber

The highest mean Summer temperatures are expected to be in August for both the 2050s and 2070s with increases of 3.7°C to 23.3°C and 5.0°C to 24.7°C respectively. In Winter the highest mean temperatures will be seen in February for both the 2050s and 2070s with increases of 2.6°C to 9.0°C and 3.5°C to 9.9°C respectively.

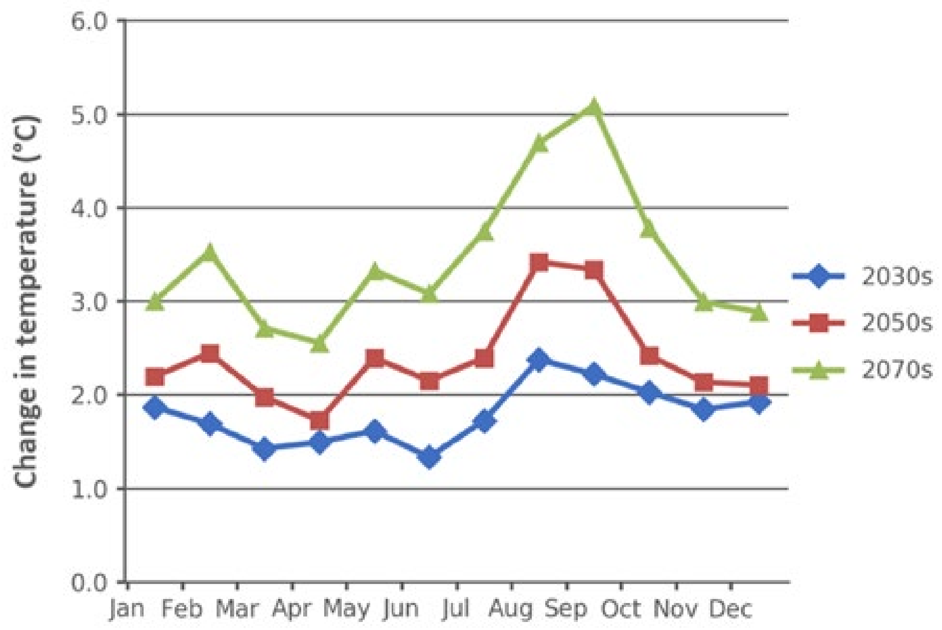
Figure 16
Yorkshire and Humber, mean daily maximum temperature change (°C) (RCP6.0 90th percentile)



North East England

The highest mean Summer temperatures are expected to be in August for both the 2050s and 2070s with increases of 3.4°C to 21.7°C and 4.7°C to 23.0°C respectively. In Winter the highest mean temperatures will be seen in February for both the 2050s and 2070s with increases of 2.4°C to 8.3°C and 3.5°C to 9.4°C respectively.

Figure 17
North East England, mean daily maximum temperature change (°C) (RCP6.0 90th percentile)



LNE&EM Route vulnerability assessment continued

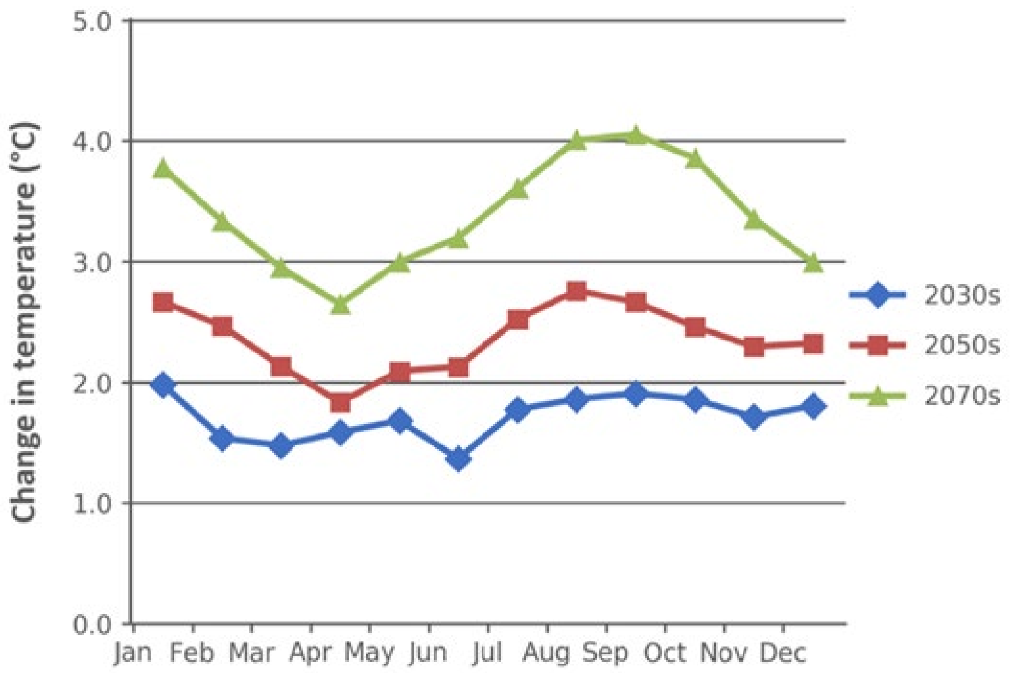
Mean Daily Minimum Temperature change

The mean daily minimum temperature for all three regions is also projected to show increases throughout the year with the highest in Winter and Summer. The level of increase is expected to become higher across the century.

East Midlands

The highest mean minimum temperatures for Summer are expected to be in August, with increases of 2.8˚C to 13.9˚C by the 2050s and 4.0˚C to 15.1˚C by the 2070s. The lowest mean minimum temperatures will still occur in February with expected increases being 2.5˚C by the 2050s to 3.1˚C, and by 3.3˚C by the 2070s to 3.9˚C.

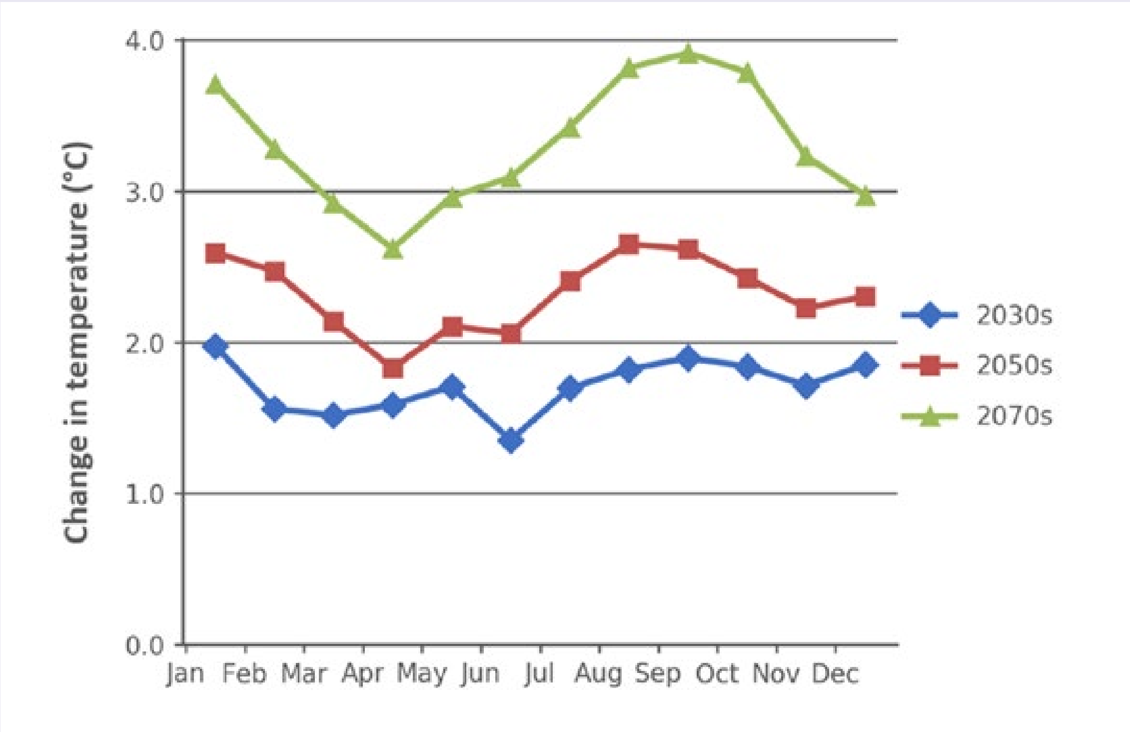
Figure 18
East Midlands, mean daily minimum temperature change (˚C) (RCP6.0 90th percentile)



Yorkshire and Humber

The highest mean minimum temperatures for Summer are expected to be in July and August, with increases of 2.4˚C and 2.6˚C to 13.4˚C by the 2050s. By the 2070s the highest minimum temperatures will be in August with an increase of 3.8˚C to 14.6˚C. The lowest mean minimum temperatures in the 2050s will occur in January and February with expected increases of 2.6˚C 3.1˚C. By the 2070s the lowest mean minimum temperatures will still be in February with an expected increase of 3.3˚C to 3.9˚C.

Figure 19
Yorkshire and Humberside, mean daily minimum temperature change (˚C) (RCP6.0 90th percentile)

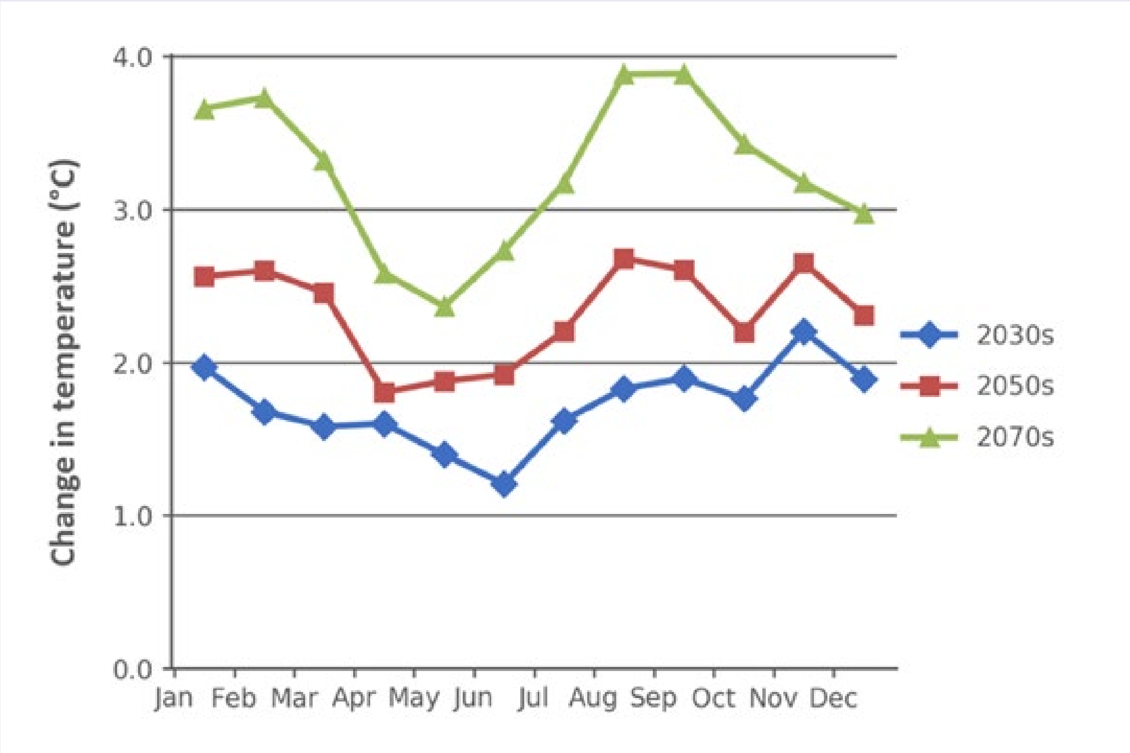


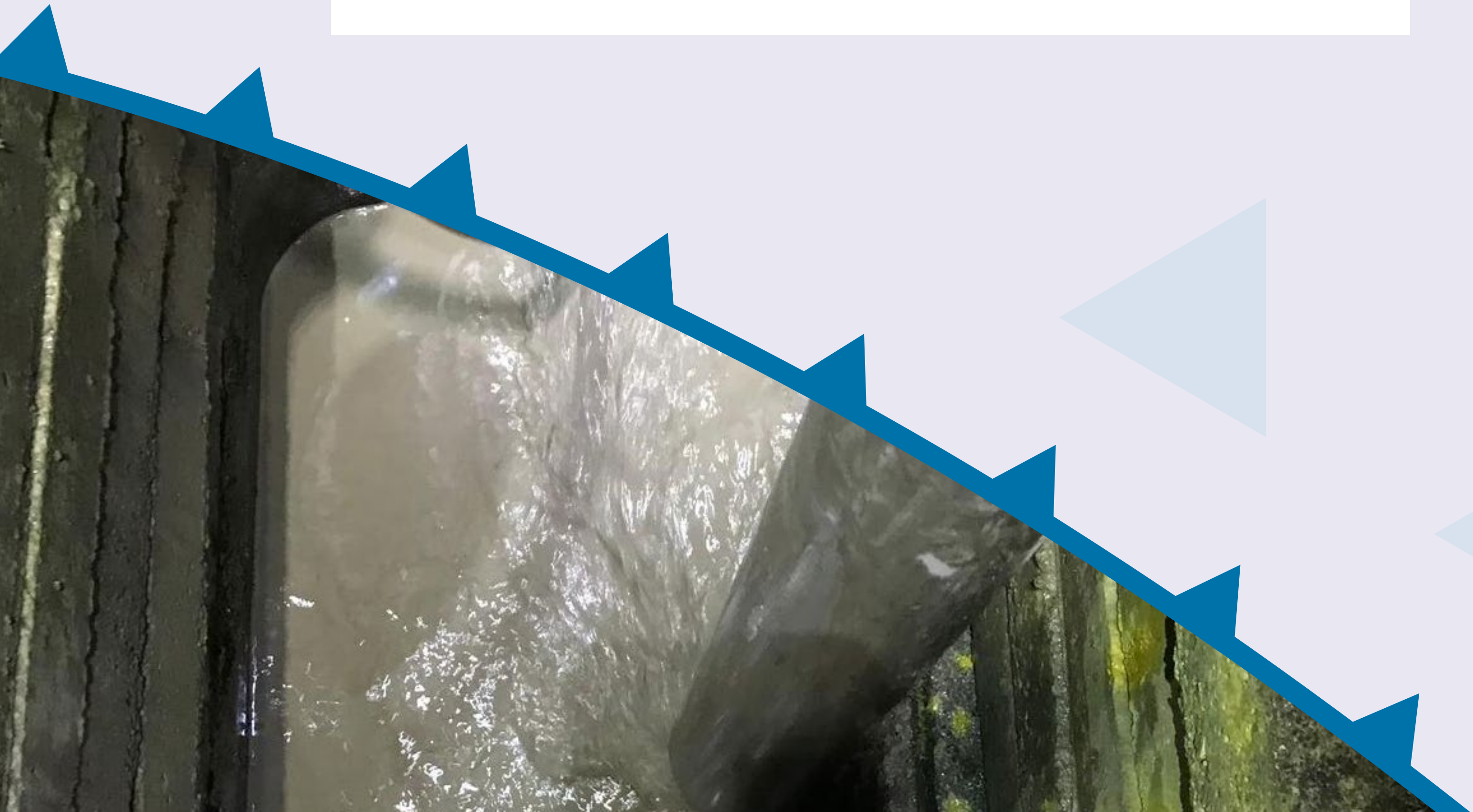
LNE&EM Route vulnerability assessment continued

North East England

The highest mean minimum temperatures for Summer are expected to be in August with increases of 2.7˚C to 12.6˚C by the 2050s and 3.9˚C to 13.8˚C by the 2070s. The lowest mean minimum temperatures in the 2050s will occur in January with an expected increase being 2.6˚C to 2.7˚C. In the 2070s they will be in December with an increase of, 3.0˚C to 3.6˚C.

Figure 20
North East England, mean daily minimum temperature change (˚C) (RCP6.0 90th percentile)





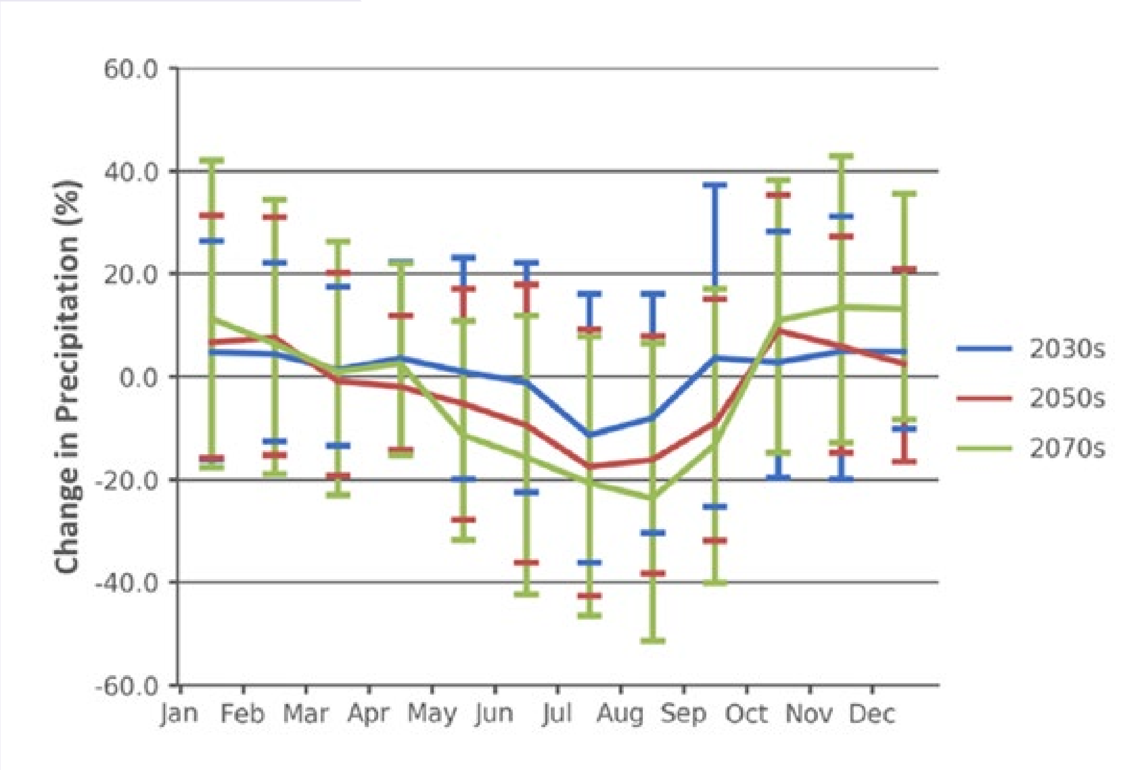
Mean daily precipitation

The UKCP18 narrative for mean daily precipitation in the three regions is for significantly wetter Winters and drier Summers. Network Rail's chosen climate change planning scenario (RCP6.0 90th percentile) shows the upper range of Winter rainfall increases, but it does not illustrate the highest potential Summer rainfall reductions. These are best represented by the RCP6.0 10th percentile projections. Figures 21, 22 and 23, therefore plot the RCP6.0 50th percentile projections with error bars that indicate the wider range of change associated with the 10th and 90th percentiles.

East Midlands

In the 2050s January, November and December will be the wettest months with mean daily rainfall increases of 31.3 %, 27.2 % and 21.0 % to 2.7mm/day and 42.7 % to 2.9mm/day respectively. By the 2070s November will be the wettest month with an increase of 42.0 % to 3.1mm/day. The driest month will be July showing decreases of 42.6 % to 0.9mm/day by the 2050s and 46.4 % to 0.8mm/day by the 2070s.

Figure 21
East Midlands, change in mean daily precipitation (%) (RCP6.0 50th percentile with the wider range showing the 10th and 90th percentiles)



LNE&EM Route vulnerability assessment continued

Yorkshire and Humber

In the 2050s and 2070s December will be the wettest month with mean daily rainfall increases of 19.5 % to 3.6mm/day and 34.7 % to 4.1mm/day respectively. The driest month will be July showing decreases of 40.7 % to 1.0mm/day by the 2050s and 44.5 % to 1.0mm/day by the 2070s.

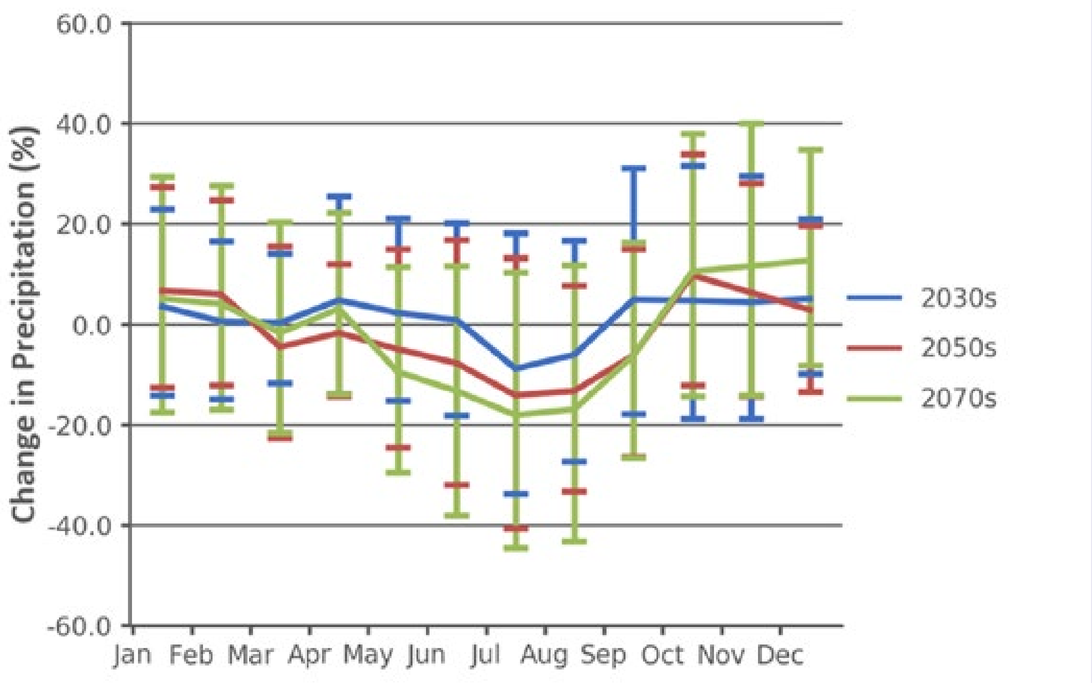
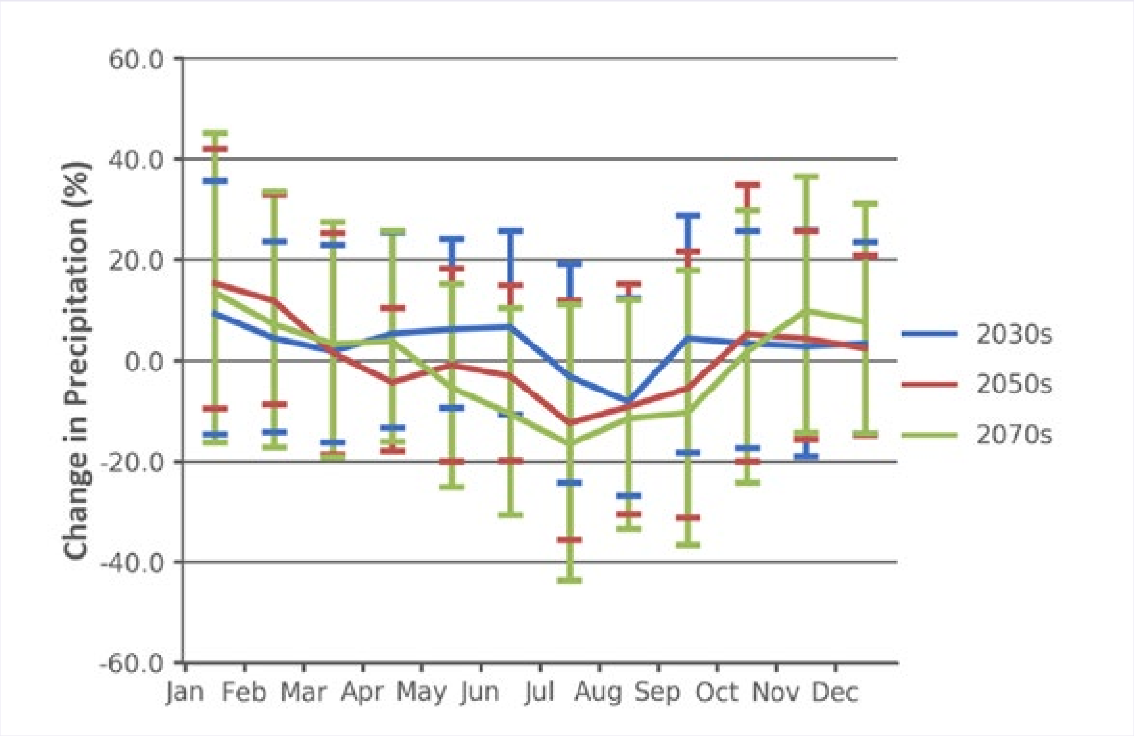


Figure 22
Yorkshire and Humber, change in mean daily precipitation (%) (RCP6.0 50th percentile with the wider range showing the 10th and 90th percentiles)

North East England

In the 2050s January will be the wettest month with mean daily rainfall increases of 42.1 % to 3.8mm/day. By the 2070s November will be the wettest month with an increase of 36.5 % to 4.1mm/day. The driest month will be July in the 2050s and 2070s with decreases of 35.7 % to 1.2mm/day and 43.7 % to 1.1mm/day respectively.

Figure 23
North East England, change in mean daily precipitation (%) (RCP6.0 50th percentile with the wider range showing the 10th and 90th percentiles)



LNE&EM Route vulnerability assessment continued

Storm intensity and river flows

In addition to changes in total rainfall, climate change is also expected to increase the frequency and severity of river flooding events and individual rainstorm events, Summer rainstorms show the largest increases.

The EA produces guidance on the rainstorm intensity and river flow uplifts that should be used to account for climate change. This guidance is being reviewed due to the release of UKCP18 climate change data, however, at the time of publishing this plan the guidance is still based on the UKCP09 Medium Emissions scenario. This recommends that rainstorm intensities for the LNE&EM Route regions should be increased by 10 % for the 2050s and 20 % for the 2080s. Climate uplifts[9] for river flows are provided by river basin and those relevant to the LNE&EM Route regions are shown in Table 1.

Table 1
River flow uplifts

River basin	2050s uplift	2080s uplift
Anglian	20 %	35 %
Humber	20 %	30 %
Northumbria	20 %	25 %

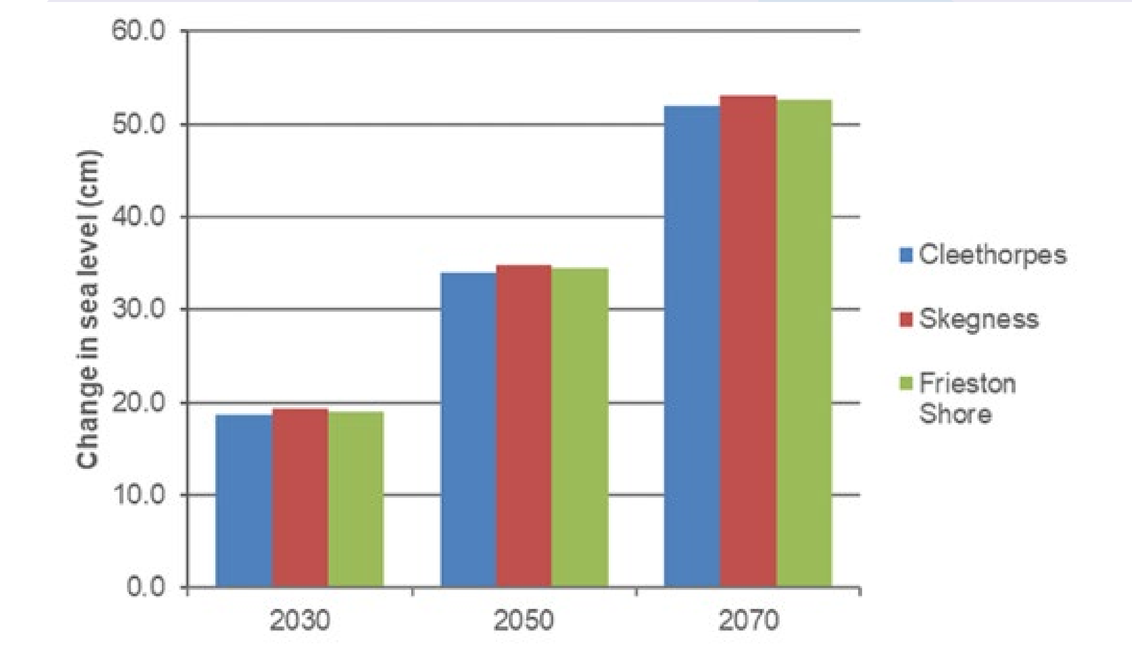
Sea level rise

Sea level varies around the coast due to differences in coastal morphology and isostatic rebound since the last ice age. As this also affects the degree of sea level rise, projections have been obtained for 3 coastal locations in each of the 3 administrative regions covered by the LNE&EM Route.

East Midlands

Skegness will see the highest rises by the 2050s and 2070s of 34.9cm and 53.1cm respectively and Cleethorpes will see the lowest at 34cm and 51.9cm.

Figure 24
Sea level rise projections for the East Midlands (cm), RCP4.5 95th percentile

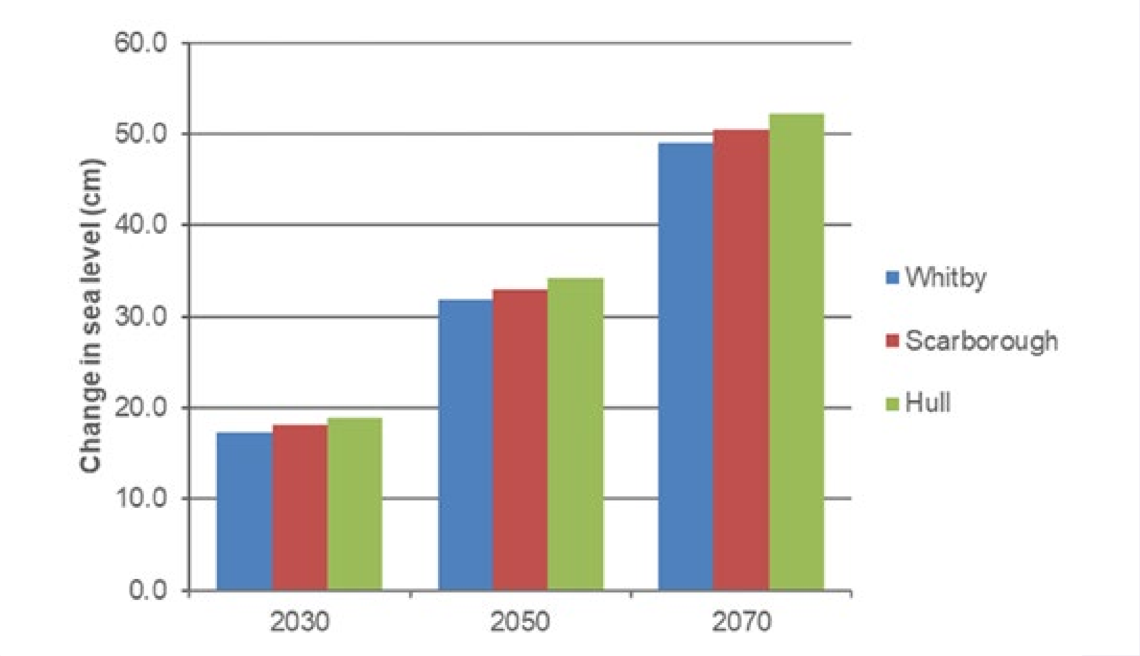


[9]EA higher central climate change estimate as the most comparable to Network Rail's climate change planning scenario.

Yorkshire and Humber

Hull will see the highest rises by the 2050s and 2070s of 34.2cm and 52.2cm respectively and Whitby will see the lowest at 31.8cm and 49cm.

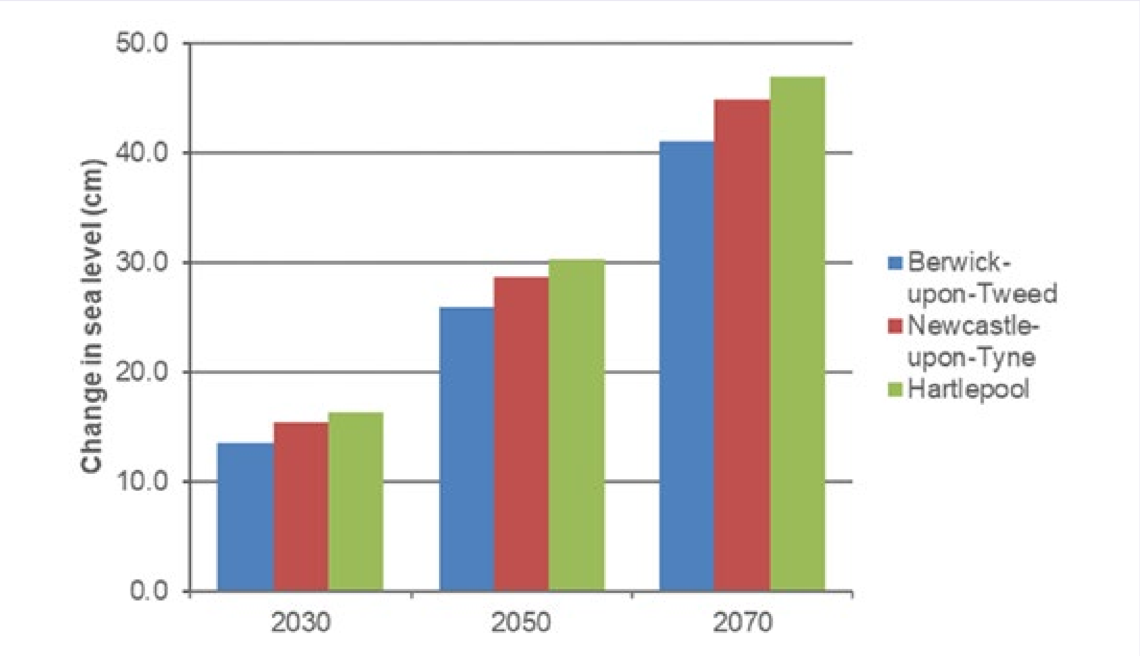
Figure 25
Sea level rise projections for Yorkshire and Humberside (cm) RCP4.5 95th percentile



North East England

Hartlepool will see the highest rises by the 2050s and 2070s of 30.2cm and 46.9cm respectively and Berwick-upon-Tweed will see the lowest at 25.9cm and 41cm.

Figure 26
Sea level rise projections for North East England (cm) RCP4.5 95th percentile



LNE&EM Route Impact Assessment

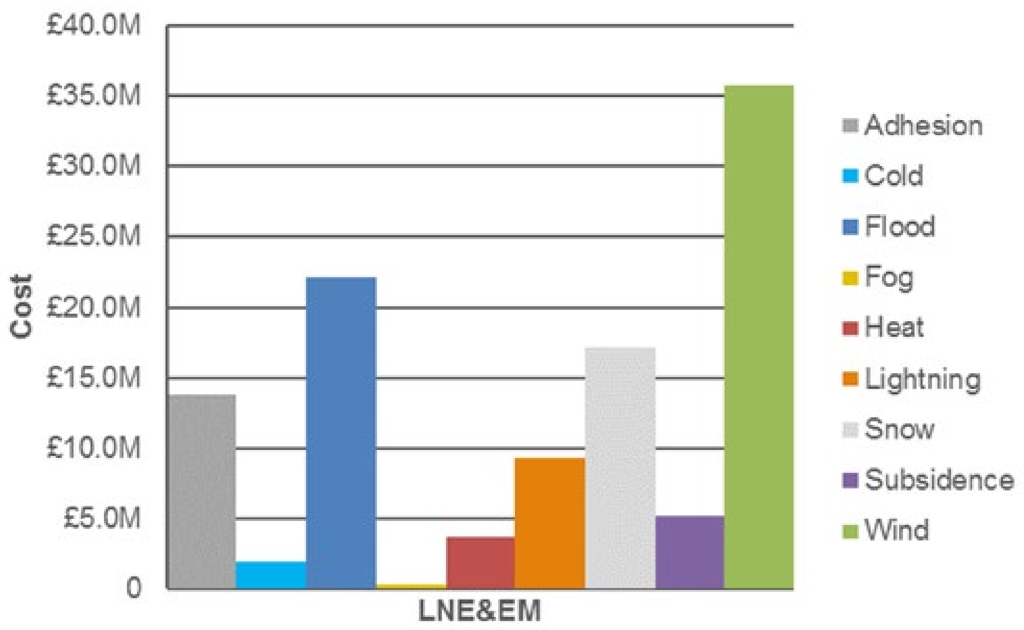
This section provides an update of the LNE&EM Route weather impact assessment findings published in the 2014 LNE&EM Route WRCCA Plan, including annual performance impacts and identification of higher impact locations on the Route.

Performance impacts

The impact of weather events on our network's performance is monitored using delay minutes and Schedule 8 delay compensation costs as proxies. As these data include the duration and location of each disruption, and attribute cause, they give a high degree of granularity for use in analysing weather impacts and trends.

In the 2014 plan eight financial years of Schedule 8 data were analysed to give an assessment of the weather impacts for the LNE&EM Route. This Plan updates that assessment using additional data from the past 5 years, see Figure 27.

Figure 27
LNE&EM Route weather attributed Schedule 8 costs – 2006/07 to 2018/19



The updated analysis shows that whilst both wind and flooding continue to be more significant weather impacts than snow and adhesion, wind has become significantly costlier. Schedule 8 costs for wind related events were £42.8m in the last 13 years, 47.6 % more than the cost of flooding related incidents (£29m) over the same period.

Climate modelling cannot provide future weather forecasts, but it does give us projections for the trends in future weather patterns. Combining these trends with our analysis of current weather impacts allows us to understand the future vulnerability and possible impacts upon the LNE&EM Route.

There is a high degree of confidence in the UKCP18 projections for temperature, rainfall and sea level rise, but lower levels for wind, lightning and snow fall. Planning for the latter parameters should still be undertaken, but outputs should be more flexible to acknowledge the higher possibility of alternative climate outcomes.

The findings from the combined analysis of current weather impacts and UKCP data (UKCP09 for wind, lightning and snow and UKCP18 for temperature, precipitation and sea level rise) will be used in the prioritisation of resilience actions as summarised in Table 2 below.

Table 2
Prioritisation of weather-related impacts on LNE&EM Route

Impact	Schedule 8 Cost per year[10]	Climate projections[11]	Prioritisation
Wind	Average £3.57m Highest £11.90m	Changes difficult to project, however generally expected to increase	High
Adhesion	Average £1.04m Highest £1.72m	Complex relationship between multiple causes and their climate projections	Medium
Snow	Average £1.47m Highest £4.10m	Changes difficult to project, but increases in Autumn, Winter and Spring minimum temperatures suggest reduced snow days	Medium
Lightning	Average £0.34m Highest £1.63m	Changes in storms difficult to project, however generally expected to increase	Medium
Cold	Average £0.34m Highest £0.58m	Increases in mean minimum daily temperatures across the regions in Autumn, Winter and Spring range from 1.8°C in April to 2.7°C in January and September for the 2050s and 2.4°C in May to 4°C in September for the 2080s	Low
Subsidence	Average £0.99m Highest £1.44m	Increases in mean daily rainfall across the regions for late Autumn, Winter and early Spring months, for example; 15.5 % in March and 42.1 % in January by the 2050s becoming 20.3 % in March and 45.1 % in January by the 2080s Decreases in mean daily rainfall for late Spring through to early Autumn, for example; -20.1 % in May and -42.6 % in July by the 2050s becoming -25.2 % in May and -51.3 % in August by the 2080s Increased frequency and intensity of Winter and Summer storms	High
Heat	Average £0.75m Highest £1.53m	Increases in mean maximum daily temperatures across the regions range from 2.1°C to 2.6°C (Winter) and 2.1°C to 4.1°C (Summer) by the 2050s. In the 2080s this becomes 2.8°C to 3.5°C and 3.1°C to 5.6°C respectively	Medium
Flooding	Average £2.42m Highest £8.19m	Increases in mean daily rainfall for late Autumn through to early Spring and increased intensity and frequency of Winter and Summer storms (see subsidence)	High
Fog	Average £0.03m Highest £0.10m	This is a complex picture with low confidence[12], however possible seasonal changes across the regions for the 2080s have been indicated as: Winter +2 % to -34 %, Spring -34 % to -37 %, Summer -56 % to -66 % and Autumn -20 % to -27 %	Low

It should be noted that the rate charged for Schedule 8 delays increased in 2015 and that this will have been responsible for some of the increase in delay costs. However, this affected all weather related delays equally and does not affect their relative impact rankings.

[10] Based on the range of Schedule 8 costs over the 13 years from 2006/07 to 2018/19
[11] UKCP09 2050s Medium emissions scenario 90th percentile; UKCP18 2050s RCP6.0 90th percentile except sea level rise
[12] Probabilistic data is not available from the UKCP09 data sets, this has been sourced from a supplementary UKCP09 report and represents the average of 11 models run using the Medium Emissions Scenario

LNE&EM Route Impact Assessment continued

Identification of higher risk locations

Since the publication of the last Plan the LNE&EM Route network has continued to experience extreme weather events that have challenged weaknesses in our assets and operations. Climate change projects more frequent and intense extreme weather events, so understanding the impacts of current and future events is critical to investment decision making.

The impacts of weather on our Route are captured via the delay minute and Schedule 8 cost data and input into our METEX GIS system along with gridded observed weather data. The outputs of this allow high impact frequency/cost sites to be identified and targeted for detailed assessment to:

- Verify the attribution of the delay(s) to a weather impact(s),
- Determine the root cause of the delay,
- Identify if resilience action has been taken in the past or is already planned, and
- Generate and prioritise appropriate resilience actions.

In addition to the above assessments LNE&EM Route has also identified potential future risks and resilience actions based on climate change projections and Route knowledge.

Combining these findings allows us to proactively identify potential investments that would address current weaknesses and mitigate and/or enable the mitigation of future risks. This approach is critical to creating a railway that is safer and more resilient to weather impacts now and in the future.

Schedule 8 impacts of WRCCA risks

Heat impact assessment

Between 2006/07 and 2018/19 heat related incidents accounted for an average of 16,357 delay minutes and £0.75m in Schedule 8 costs per year. This is 5.2% of LNE&EM's annual average weather-related delay minutes and 6.9% of the annual average cost.

It is predicted that the year will become hotter on average in all seasons. Spring will move earlier, and autumn will move later. Winter will be shorter. Average and daily maximum temperatures will increase, and heatwaves will become more frequent, longer and more severe (see climate data). Growing seasons will lengthen, droughts will become more common.

Track Asset

The track assets are particularly susceptible to heat, as the air temperature rises the steel rails expand and the risk of track buckle increases. Track disturbance increases the risk and buckles can often occur due to the movement of the track under the train vehicles increasing the risk of derailment. To mitigate this risk the track maintenance team undertake considerable preparation for the onset of summer installing rail anchors and lateral end restraint plates (LERPs) as well as painting rails white to reflect the heat. Track maintenance activity, especially that which affects the ballast, can also increase the risk making the track unstable until full consolidation is achieved. Work of this nature tends to be restricted in Spring and Summer for this reason, and any emergency work is mitigated by speed restrictions. With Spring expected to start earlier, and Summer's duration to be longer, the restricted period for maintenance will increase shortening the maintenance window and increasing the risk of speed restrictions.

Buckles are far more likely to occur on jointed track (especially on lighter timber sleepers) or in S&C (especially on lighter wooden bearers). LNE & EM's strategy is therefore to replace these vulnerable assets through the renewal and enhancement programme. Jointed, plain line track being replaced with continuously welded rail (CWR) on much heavier concrete sleepers and S&C replaced with a heavier rail section on concrete bearers.

Removal of jointed track, however, removes all the designed expansion gaps. When CWR is installed the rails are hydraulically stretched to create room for expansion. The amount of stretch depends on the temperature of the rail during installation but is always to the same Stress Free Temperature (SFT) of 27˚C. This means if the rail is cut into below this temperature the rail ends will jump apart. The SFT allows the rail and track to be far more resilient in hot weather. With the predicted increase in peak temperatures the SFT may need to be reviewed particularly on the southern end of the Route. This is unlikely to occur in CP6 so will need to be mitigated with speed restrictions during the hotter periods of the day.

Even within CWR Insulated Block Joints (IBJ) may remain which are also susceptible to the heat. They are designed to create 'sections' of track to facilitate the signalling system. When an IBJ deteriorates, the track circuits fail and the signals turn red stopping trains. The increase in temperatures and the earlier Spring and longer duration Summer will impact on the signalling performance over an increased period of time.

Rail creep (the rails moving longitudinally through sleeper housing) can also result in buckling where the rail moves towards a fixed asset. Certain rail fastenings increase this risk as well as locations with significant track gradients and repeated braking of trains. Through the track renewal and enhancement programme, known locations susceptible to rail creep will specify the reduction in sleeper spacing by increasing the number of sleepers and increasing the overall weight of the track and number of fastenings holding the rail in position. Track renewals also target the removal of obsolete rail fastenings for more resistant modern equivalents.

Vegetation

As stated above it is anticipated that increased temperatures will lengthen the growing season, the duration of safety and performance risks will therefore increase. More frequent and more robust vegetation management will be required to mitigate any risks. Particularly the risks associated with sighting distances at foot and user worked crossings (UWC) and sighting for signals both of which can be compromised by the growth of vegetation.

For CP6 LNE&EM Route has embarked on an ambitious campaign to not only achieve full compliance to the vegetation standard but also become far more environmentally responsible adopting the recommendations of the Varley Review completed in CP5. The first stage was to undertake a full hazardous tree survey and remove all category 4 – 7 trees. All category 1 – 3 trees were subject to routine reinspection cycle. The expected higher temperatures may begin to affect the health of certain species and the reinspection frequency may need to increase.

LNE&EM Route Impact Assessment continued

Buildings

These assets are the most resistant to weather and climate change the only exception being heat. As temperatures increase more consideration will be needed to mitigate including installation of cooling equipment and better ventilation. This will affect all manned buildings not only for the welfare of Network Rail staff but also passengers in station buildings. Numerous unoccupied buildings house critical equipment (mainly signalling assets see below) such as relay rooms and location cases which will also require cooling equipment, ventilation and/or heat deflection equipment.

Structures

LNE&EM Route has several swing bridges and the only draw bridge on the network, all of which are subject to thermal forces which negatively impact on their performance. As temperatures increase the operation of these structures may need to be restricted to the cooler parts of the day.

Signalling

As stated above, signalling assets do not perform well in the heat and start to fail when the buildings they are housed in begin to overheat. Increased temperatures in early Spring and longer duration Summers increases the risk of asset failure and impact on train performance.

There is an impact on both lineside and relay room equipment if high temperatures are present, which have an adverse effect of the operation of the asset.

The following is a summary of where notable improvements have been made in previous years:

- There has been a significant amount of work carried out with our colleagues in the building teams in the area of relay rooms. Appropriate air conditioning installations have been deployed and maintained such that currently events are rare of failure in this area, and
- Again, in the area of lineside equipment housings a number of interventions have been made as follows:
  - Sun hoods to deflect direct heat from the equipment housings,
  - Heat reflective paint,
  - Localised installations of coolant devices i.e. fans, and
  - Other coolant technologies i.e. coolant packs and coolant fins to the outside of the location.

Our knowledge of how to protect against high temperatures has significantly improved in last few years and in addition to the improvements above we now include extreme temperature interventions alongside any planned signalling renewals where this is applicable.

OLE

The majority of the ECML and MML is auto tension (AT) Mk3B OLE using balance weights which correctly installed and maintained have a temperature range of around 56˚C which is -18˚C up to 38˚C. When installed there should be an additional 100mm travel added to the balance weights so in effect there is an additional 4˚C taking the temperature range to 60˚C. This means that the current AT system should be adequate for the temperatures expected by 2050 and improvements to this will be sought via the long term OLE strategy as a matter of course.

Cold and snow impact assessment

Between 2006/07 and 2018/19 cold related incidents accounted for an average of 12,182 delay minutes and £0.34m in Schedule 8 costs per year. This is 3.9 % of LNE&EM's annual average weather-related delay minutes and 3.1 % of the annual average cost. Over the same period snow-related delays averaged 47,409 delay minutes and £1.47m in Schedule 8 costs per year. This is 15 % of the annual average weather-related delay minutes and 13.4 % of the annual average cost.

It is predicted that the year will become hotter on average in all seasons. Spring will move earlier, and Autumn will move later. Summer will be longer, and Winter will be shorter. Average and daily maximum temperatures will increase (see climate data). Frost and snow days will reduce. The likelihood of severe Winters will decrease, but current levels of severity will remain possible.

The impact of cold temperatures and snow accumulations affect different assets in different ways. The action of repeated freeze/thaw can cause stresses in certain assets particularly structures and geotechnics. The accumulation of large quantities of snow can cause issues with buildings, vegetation and level crossings but when it melts can cause issues with drainage assets. The predicted reduction in severe Winters will also vary across LNE&EM. Severe cold temperatures and heavy accumulation will become rarer across the Route, but will still be risks in the northern end.

Structures

The biggest issue is the formation of icicles from bridges/tunnels touching OLE causing section trippings of the electrification equipment. This is mitigated by additional patrols known in wet over bridges and tunnels. There have also been incidents of bricks and masonry becoming dislodges by the freeze/thaw action and falling on to the track and even on top of trains. This is also mitigated by increased structures examination in cold weather.

Earthworks & Drainage

Earthworks are also susceptible in cold weather and the freeze/thaw action in rock cuttings can result in large pieces of material becoming dislodged. This is also mitigated with additional inspections. The greater risk is when large accumulations of snow melt and the risk of flooding and washout/bankslip increases. Again, this is mitigated with increased inspections which are combined, at historic locations, with remote condition monitoring and/or CCTV monitoring of water levels.

LNE&EM Route Impact Assessment continued

Buildings

Buildings are also susceptible to the mass weight of large accumulations of snow on building roofs but also on canopy and shelters within buildings compounds and stations.

Track

Plain line track has to also consider the opposite affects to hot weather as rails contract in cold temperatures increasing the risk of broken rails. This is mitigated with frequent ultrasonic testing of the rails looking for any defects in the rails. The LNE&EM strategy is also to remove all rails older than 1976 where, due to differing manufacturing techniques at the time, the likelihood of defects developing is increased.

On very tight radius curves the risk increases where contraction of the rails can cause the track to be pulled in towards the inside of the curve'. At these locations ballast profiles are particularly monitored and maintained.

The biggest cold weather performance risk for track is of frozen points resulting in points failures. LNE&EM has the vast majority of points fitted with points heating to prevent this. This is then further mitigated with the fitment of the largest points heating remote condition monitoring system of any of the routes in the network.

Off Track

Level crossings are particularly vulnerable to large accumulations of snow in a number of ways. The flangeways within the deck are particularly shallow and prone to the build up of ice which can lead to the risk of train wheels riding up over the ice. This is mitigated by regular checks and removal of any build up throughout the extreme weather.

Highway management also has implications on the railway infrastructure, snow ploughing can cause a build up of snow piles across level crossing decks preventing barriers with skirts from lowering fully and causing their failure. Also, highway gritting can also cause a build up of salts on the rails at level crossings and result in track circuit failures which affect performance. This is mitigated with regular checks and flushing of rails through the Winter.

Flooding and sea level rise impact assessment

Between 2006/07 and 2018/19 inland and coastal flood related incidents accounted for an average of 69,150 delay minutes and £2.42m in Schedule 8 costs per year. In combination these represent 21.8% of LNE&EM's annual average weather-related delay minutes and 22.2% of the annual average cost.

It is expected that sea level will rise along the LNE&EM Route coast with small variations depending on the location (see climate data). Storm intensity and frequency will increase. The risk of coastal erosion and defence overtopping will increase. Discharges to estuaries and the coast will become more difficult.

Flooding

Winters are expected to become significantly wetter on average and the frequency and intensity of Winter storms will increase. Summers will become significantly drier, but the intensity and frequency of Summer storms is expected to increase markedly. Summer storm rainfall will be more severe than in Winter. Intense Summer rainfall after droughts/dry periods will increase the surface/flash flood risk and peak river flows will increase (see climate data). Drainage renewals and a targeted jetting programme and proactive maintenance regime are focal parts of our CP6 plan to further improve and sustain our drainage resilience to prevent track flooding and reduce the likelihood of earthwork failures.

Figure 28
Examples of drainage work

Drainage Assets will see significant investment in CP6, both trackside and off track, to protect track and earthworks assets by mitigating the effects of expected changes in precipitation. Year 1 of CP6 tested the railway severely through several storm events in Autumn and Winter especially around the East Midlands and the central belt of LNE around Sheffield, Leeds and Doncaster. Investment in drainage assets in these areas will reduce both the number of times that our assets are impacted and the severity of the remaining impacts. This investment will also help to reduce the incident and impact of scour of both Structures and Earthworks assets too.

Greater engagement with external bodies such as the EA, Lead Local Flood Authorities, Internal Drainage Boards and third party landowners must occur if there is to be any meaningful impact of train performance. We need to understand their weather resilience and climate change plans to ensure we can align ours. This is already planned with Network Rail contributing to wider flood mitigation schemes around Leeds and Rotherham which will result in much greater protection of the railway.

The signalling asset is vulnerable to the effects of flooding across the whole signalling asset base. Whilst the largest risk is to specific lineside assets i.e. track circuits, point machines and equipment housings there remains a risk around some of our larger interlocking sites.

There have been incidents of unexpected flooding across all routes with varying degrees of operational impact commensurate again with the location of where the incident happens.

In recent times flooding has become the biggest extreme weather problem for signalling assets with a number of incidents due to localised events occurring where there have been no historic issues. Our risk mitigation methodology in such events is to 'sign out' the signalling system until an assessment has been made to confirm it is safe to revert back to 'normal signalling'.

LNE&EM Route Impact Assessment continued

The following is a summary of remedial work has been undertaken following flooding events:

- All signalling assets that were impacted by water damage have been replaced, typically this would be the equipment housings and the associated equipment for each site within them,
- When these assets are renewed they are either moved to a location clear of any possible future flooding events or, as a minimum, placed 1 meter above ground level, and
- All point machines and track circuit connections have been renewed.

Figure 29
Flooded damage to signalling assets

Earthworks especially are prone to deterioration and failure due to poor drainage and flooding. In CP5 the bank slip that occurred at Watford (LNW Route) was due to the failed drainage and resulted in a derailment. A further bank slip in CP6 year 1 at Corby Penn Green in the East Midlands was due to third party owned attenuation ponds which over topped. Water from these cascaded over the cutting edge taking the bank side with it. Whilst it didn't cause a derailment it did engulf a standing passenger service significantly impacting the large number of passengers on board. Much of the earthworks job bank for CP6 includes significant packages of work to mitigate this risk at similar locations.

Figure 30
Corby Penn Green bankslip and flood – 2019

For areas where there is a history of flooding we have previously implemented installations at a height that is clear of flooding levels and we now include flooding assessments within the project requirements for signalling renewals. Also, it is policy that any trackside cabling/terminations should be mounted at least 1 meter above ground level.

LNE&EM Route Impact Assessment continued

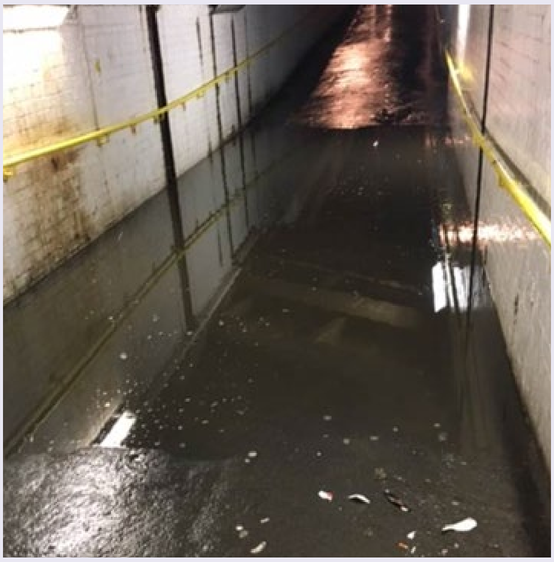
Sea level rise

We will continue to identify key sections of railway that are at risk from sea level rise and which will require long term planning and capital investment. This may be done by identifying and classifying key sections of railway as a Coastal, Estuarine or River Defenses (CERDs). Such sections are managed as a specific site and may include assets from different asset disciplines such as earthworks and structures. An example is the site on the Hull to Leeds line known as Hessle Foreshore. This has been subject to significant scour requiring emergency works in 2013 and 2019. By treating it as a CERD a long-term strategy for the site can be agreed with multiple asset owners to ensure no future loss of service on this line. This has allowed us to engage with the EA as it develops the 100 year strategy for the Humber Estuary.

The predicted increase in sea level will impact on coastal and low-lying estuarine areas of LNE & EM. The change in sea level alone is unlikely to severely impact on the railway but this, in conjunction with the predicted increase in storm events and storm surges, has the potential to impact on railway assets. Again, this reinforces the need to liaise with external bodies and neighbours to ensure our plans align.

It is not anticipated anything additional will be required in CP6, but in the longer-term, greater pumping arrangements may need to be considered to mitigate sea level rises. The only current item in the CP6 Business Plan is to improve the current pumping arrangements at Goole Station subway to prevent the repeated problem of flooding (see Figure 31).

Figure31
Goole Subway and fixed pump



Subsidence

Between 2006/07 and 2018/19 subsidence (earth slip, desiccation etc.) related incidents accounted for an average of 23,741 delay minutes and £0.99m in Schedule 8 costs per year. This is 7.5 % of LNE&EM's annual average weather-related delay minutes and 9 % of the annual average cost.

Geotech assets are most susceptible to subsidence and much of the CP6 job bank will mitigate risk of:

- Washouts,
- Cutting failure, and
- Embankment failure.

The root cause of a lot of these is down to ground water levels which can lead to failure of slopes. This is why many of the interventions are around drainage improvements and close liaison with the drainage team ensures a systems based solution is specified. Physical works to the asset can include changes to the slope gradient or the installation of additional support or stiffening activities. The biggest item planned in CP6 is at a location on the East Coast Mainline at 'Browney Curve' adjacent to the River Browney (see Figure 32).

Figure 32
River Browney, County Durham

LNE&EM Route Impact Assessment continued

There are a number of key risks at this location, most immediately a risk of poor track geometry, leading to rough ride reports from drivers (there have been numerous over the years) and a high potential for TSRs. Sudden deterioration in track quality or sudden/accelerated movement in the formation also carries a derailment risk.

The last TSR imposed in 2003 cost in excess of £1.7m in Schedule 8 penalties to the train operators, however due to the changes in the scheduled payments and the increase in traffic, it is expected that similar speeds imposed now would be vastly more disruptive and expensive. To limit this risk the maintenance team have to tamp both lines 3–4 times per year to manage deterioration.

At this location Network Rail undertook a joint Ground Investigation (GI) with the local Council in 2015–16 and we continue to collaborate. This joint GI alone saved Network Rail approximately £400k. In 2016 the Geotech team spent £0.7m on drainage repairs and embankment strengthening. They also replaced several hundred yards of Signalling and Telecom cabling which was slipping down the bank and causing disruptive damage.

There was an associated risk of dewirement at this location as the OLE masts were moving independently from the track. The tamping of the track allows the repair of top and alignment faults and corrects any errors in cross level and resulting twist, but both tracks are generally migrating 'down the bank' and towards the River Browney. Over the years this has required the OLE wires to be reregistered several times, but in 2018 five sets of individual masts were replaced with portals at a cost of approximately £1.53m. This has greatly mitigated this risk and can be seen in Figure 33 below.

Movement of the track and OLE, and the surrounding third-party slopes, has been monitored for many years to understand the rate and depth of movement. The resultant data analysis throughout CP4 and 5 has allowed the RAM (Geotech) to understand the problem and the optimum solutions for implementation in CP6.

Figure33
Browney Curve and CP5 installation of OLE portals

Wind impact assessment

Between 2006/07 and 2018/19 wind related incidents accounted for an average of 83,837 delay minutes and £3.6m in Schedule 8 costs per year. This is 26.5 % of LNE&EM's annual average weather-related delay minutes and 32.7 % of the annual average cost.

This is difficult to model into the future, so there are no projection figures, however the expected trend is for increased gust speeds and increases in the frequency and intensity of storms.

Vegetation

Management of lineside vegetation is a core part of our plan to reduce the likelihood of trees falling on the line. LNE&EM has a Vegetation Management Plan agreed with the Regulator and initiated in CP5. Starting in December 2017 and for the remainder of CP5 this focused on the 36 highest risk locations on the Route equating to over 56 miles of lineside, mainly on the electrified ECML and MML.

In CP6 and CP7 the plan moves away from targeted discrete locations toward lines of route. This will still prioritise our highest risk but also drive efficiency in cost and delivery. The first three years of CP6 will concentrate on electrified routes to remove the risk of section trippings, or even dewirements, caused by vegetation. This will leave only the lowest risk routes for CP8.

At the end of CP5 a Route wide Hazardous Tree Survey was completed where all large trees were assessed and scored. All of the highest risk trees were made safe and addressing the risk of them blowing down on to the track in high winds. A new survey will be undertaken at the end of CP6 in line with the Off Track standard.

OLE

The tension in the over headline electrified wires is maintained using balance weights but high winds, especially crosswinds, can shift the wires out of alignment causing the risks of de-wiring and wires blowing off train pantographs to increase. As a result, when high winds are recorded, a speed restriction is imposed on all electric traction. Where the OLE is of headspan construction, the implications of a dewirement increase significantly as it could affect multiple lines increasing the time and cost of repair. By converting headspans to portals the resistance to high winds increases. It also allows each line to be independently registered thus, in the unlikely event of a dewirement, is more likely that only one line will be affected. Figure 34 is a site on the south end of the East Coast Mainline that was completed in CP5.

Figure 34
OLE Headspan to Portal conversion

LNE&EM Route Impact Assessment continued

Lightning impact assessment

Between 2006/07 and 2018/19 lightning related incidents accounted for an average of 12,228 delay minutes and £0.34m in Schedule 8 costs per year. This is 3.9 % of LNE&EM's annual average weather-related delay minutes and 3.1 % of the annual average cost.

Lightning prediction is difficult to model into the future, so there are no projection figures. However, as the expected trend is for increased severity and frequency of Summer and Winter storms, increases in lightning frequency are possible.

Signalling assets are vulnerable to the effects of lightning strikes including both analogue & digital electronics systems, for example; axle counters, power supplies, interlocking line and remote-control systems. As technology has developed the resilience to lightning has improved and modern system designs provide far higher levels of protection than previous generations. It is very difficult to retrofit effective lightning protection to legacy signalling systems so, the options we have are very limited with campaign fitments being extremely costly. Our primary means of improving lightning protection is to renew the signalling system or parts thereof. Often, the most susceptible signalling assets are those installed on the lineside, where dependent on the geographic location, their failure can have varying degrees of cost and delay impacts, for example main line versus secondary lines of route.

The following is a summary of where notable improvements have been made in previous years:

- The installation of Solid State Interlocking (SSI) isolating transformers, improved surge protection to SSI and track circuits,
- Fitment of better surge protection and more isolating transformers in both lineside SSI and power supply systems,
- The work done for Special Instruction Notice 119 which improved earthing arrangements at lineside equipment housings,
- Automatic resetting of the Long Line SSI links by the resetting of the Long Distance Terminal (LDT) SSI modules via the SSI LDT reset units each year keeps proving its worth, and
- Identification of earthing deficiencies in relay rooms throughout the Route.

Our knowledge of how to protect against lightning has significantly improved in last few years and in addition to the improvements above we now include lightning mitigation interventions alongside any planned signalling renewals where relevant. The Signalling Asset Renewal Policy going forward is one of a life extension holding-pattern until the onset of the national Digital Railway European Train Control System (ETCS) programme, which has varying delivery timescales across each of the routes.

However, there remain concerns and work to be done in the following areas:

- Signalling remote control systems; we need to review the protection from our telecoms links on the connections between the central interlocking and remote sites,
- There are certain types of Electronic Signal Heads that have proved quite vulnerable and which, in the event of a localised strike, can result in the loss of a signal,
- A significant example where a very localised direct lightning strike can still have a catastrophic effect on the signalling asset, despite protection being installed, would be a direct strike on our infrastructure at York station. A couple of years ago a localised lightning strike caused the highest ever total equipment failure due to lightning in our known history. This resulted in a complete loss of signalling in the York Station area, and
- The fitting of surge protection in lineside power supplies.

Adhesion impact assessment

Between 2006/07 and 2018/19 adhesion related incidents accounted for an average of 51,658 delay minutes and £1.0m in Schedule 8 costs per year. This is 16.3 % of LNE&EM's annual average weather-related delay minutes and 9.6 % of the annual average cost.

Changes in the rainfall and temperature patterns will alter the growing season lengthening it, therefore changing the timing of Autumn. In addition, increases in storminess may remove leaves at additional times of year. Both of these may change the pattern of leaf fall.

Vegetation Management

The LNE&EM Vegetation Management Plan factors in where we have had reports from train and freight operators of issues of rail adhesion. This increases the priority of those sites especially if there is also a history of Station run-throughs, Wrong Side Track Circuit Failures (WSTCFs) and Signals Passed at Danger (SPAD). Many of the new types of rolling stock introduced onto the Route at the end of CP5 and beginning of CP6 are fitted with Wheel Slip Detection and GPS positioning equipment giving far more accurate and measurable data. The Hazardous Tree Survey completed at the end of CP5 also included a leaf fall assessment and identified the worst species for causing this issue and allowed:

- The Vegetation Management Plan to be rescored and reprioritised for CP6, 7 and 8,
- The Rail Head Treatment Plan to be reviewed and reprioritised, and
- The installation of fixed traction gel applicators at the worst sites especially where track gradients are steeper, on approaches to stations and high risk signals.

Fog impact assessment

Between 2006/07 and 2018/19 fog related incidents accounted for an average of 182 delay minutes and less than £0.03m in Schedule 8 costs per year. This is 0.06 % of LNE&EM's annual average weather-related delay minutes and 0.3 % of the annual average cost.

All seasons are projected to see reductions in fog days across both regions, with the exception being the East Midlands which will see a small increase in the Winter. However, these are low confidence projections (see climate data).

Figure 35
Vegetation management sites

The biggest issues with fog are that it can restrict the ability of drivers to see signals and signallers to view CCTV equipment. Over CP4 and 5 a major programme of replacing standard signal lamps with LEDs has been undertaken. These are far brighter and easier to view in foggy conditions. All resignalling schemes and signal renewals specify LED lamps in line with current standards.

CCTV at level crossings is used by signallers to ensure the crossing is clear. If it is too foggy, operational staff are required as 'eyes on the ground' to undertake this check. Across LNE&EM all level crossings have been assessed for potential closure. This is done by building bridges, new roadways etc. and it will continue into CP6.

LNE&EM Route WRCCA actions

As the impacts of weather events are location specific LNE&EM Route will be responsible for identifying and carrying out the WRCCA investments necessary to deliver the continued and improved resilience of their assets and operations.

Network Rail's central functions will assist and enable the LNE&EM Route in this by providing asset policies and design standards that have weather resilience and climate change considerations embedded within them, by carrying out root cause analysis of national weather and asset data and through the review and adoption of appropriate new technologies.

This section summarises the WRCCA actions undertaken by the LNE&EM Route in CP5 and those that we have planned for CP6. The first two tables in this section show the;

- Progress against the CP5 WRCCA actions identified in the 2014 Plan, and
- WRCCA actions planned for CP6 (Table 4).

The nature of the railway means there are always more renewals/enhancements required than there is budget for in any particular control period. The third table (Table 5) therefore contains potential additional actions that the LNE&EM Route has identified as desirable to deliver WRCCA resilience, but which are not funded in the current CP6 business plan.

These represent the next WRCCA interventions which would be undertaken in LNE&EM Route should further funding be identified in CP6. Where funding for delivery in CP6 is not forthcoming these interventions will be reassessed during CP7 planning.

The delivery of some of these actions may be planned for one or more Control Periods in the future and they will require further development and business case evaluation before making a funding submission in the appropriate Control Period.

The final table details actions that have been apportioned to Network Rail, and hence the LNE&EM Route, in the Defra NAP. Some of these will align with CP6 planned and funded actions (Table 4), some will align with the actions in Table 5 and others will require further consideration in CP6 and beyond.

Table 4 and Table 5 cross reference with 6 to indicate the relationship between the LNE&EM Route actions and the delivery of the NAP actions.

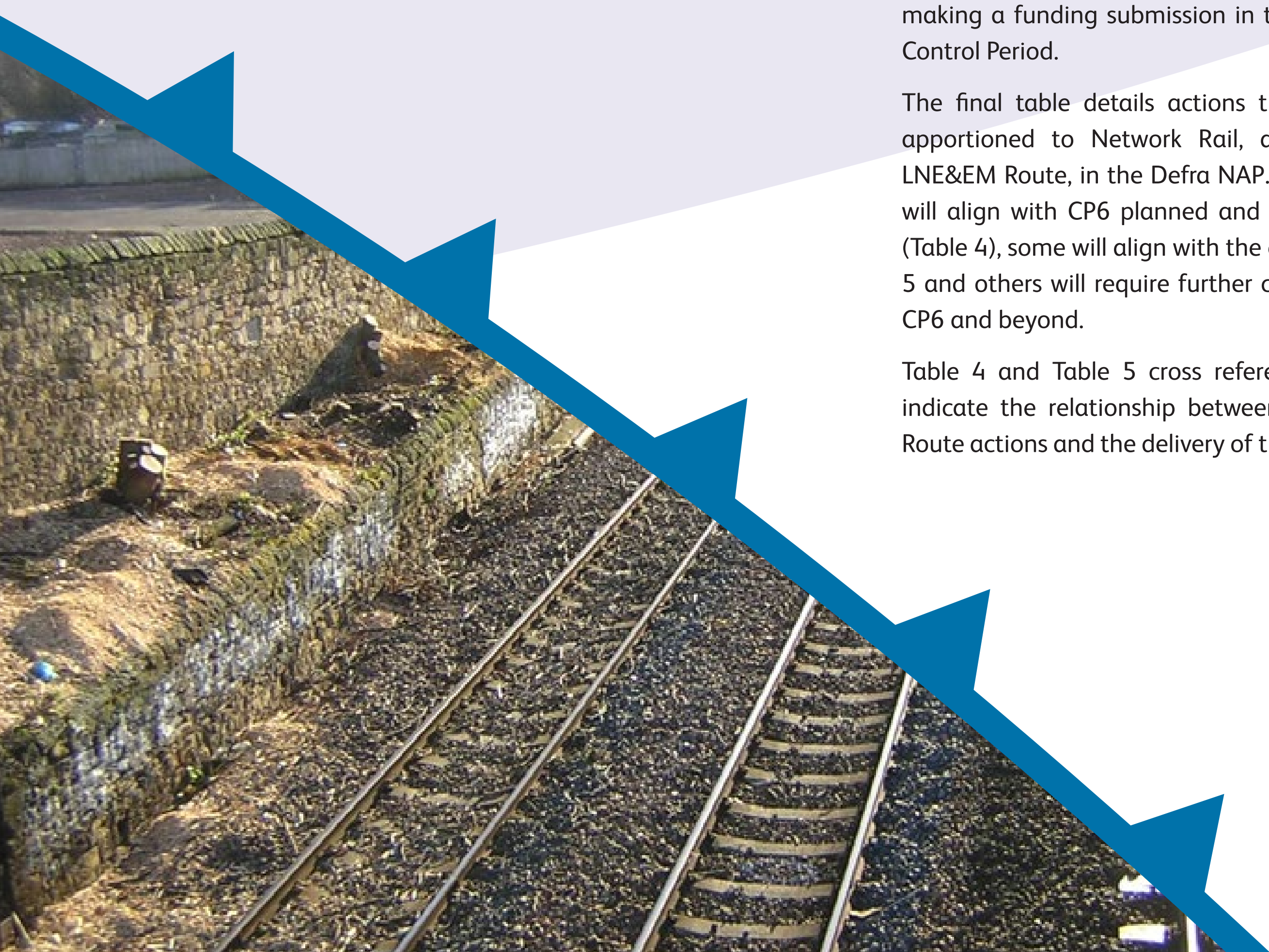


Table 3
2014 WRCCA Plan CP5 actions review

Vulnerability / Action	Target completion date	Actual completion date	Comments
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 – 2019	2014 – 2019	Top 24 flood sites complete
Vulnerability of drainage assets around tunnel portals – Risk-based, proactive campaign of drainage management 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 As Low As Reasonably Practicable (ALARP)	2014 – 2019	2014 – 2019	All 284 tunnel portals across LNE & M route were inspected and schemes completed delivering reduced risk at all tunnel portals
Asset knowledge –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 – 2019	2019	A full condition-based drainage survey was completed for all drainage assets throughout LNE&EM to comply with NR/L2/CIV/005 – Drainage Systems Manual
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 – 2019	2014 – 2019	The condition-based drainage survey (detailed above) captured the condition and capacity of all of our inflows. Improved management and targeted improvement schemes delivered reduced risk of flooding and asset degradation
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 – 2019	2014 – 2019	CCTV and telemetry has been installed to help predict rising water level at/in 15 key high risk locations
Sub 450mm underline assets – A programme of research and counter measures to manage risk of underline drainage assets with an internal diameter of less than 450mm. Risks to be mitigated including voiding of track, loss of line and level, flooding, ballast contamination and nuisance to third parties	2014 – 2019	2014 – 2019	All underline drainage assets with an internal diameter of 450mm or less were captured in the condition-based survey and a prioritised plan of works implemented to reduce risk
Water management issues relating to TSRs, L2 faults, Very Poor Eighths (VPES) of a mile of track 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 the likelihood of safety and performance impact to ALARP	2014 – 2019	Ongoing	This activity is continual cycle following each track geometry recording undertaken by out Track Maintenance Engineers. All locations which identify a risk to the track are mitigated through targeted track and drainage maintenance
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 – 2019	Ongoing	This activity is also a continual cycle ensuring compliance with Land Drainage Acts
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 investigation where required. Place scour protection (e.g. rock armour) to structures found to be high risk from scour	2014 – 2019	Ongoing	All sites have been risk assessed, and physical works completed at 34 of the highest risk scour sites

LNE&EM Route WRCCA actions
continued

Table 3
2014 WRCCA Plan
CP5 actions review

Vulnerability / Action	Target completion date	Actual completion date	Comments
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 wash out of fine materials and undermine foundations or track formations	2014 – 2019	Ongoing	All buildings assets are subject to examination and risk assessment. Any defects likely to cause an issue during stormy weather are mitigated as a priority
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 – 2019	Ongoing	Investigations continue and all drainage issues are being addressed in a prioritised plan
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 – 2019	Ongoing	The identification of high-risk third party slopes has been completed and we have 7577 5-chain lengths which will be reviewed/risk assessed. The embankment at Browney Curve has and continues to be investigated with a view to implement major works within CP6
Vulnerability of all sites on the adverse weather list – Review adverse weather list and determine a fix for each site to improve resilience	2014 – 2019	2014 – 2019	Mitigation plans have been produced for the top 100 vulnerable sites across LNE&EM
Tunnel portal slopes at risk from climatic changes – High risk tunnel portal slopes to be identified and schemes developed	2014 – 2019	2014 – 2019	All tunnel portal drainage has been fully inspected as part of the condition-based drainage inspection regime across LNE&EM route
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 and renewal. Consider temperature remote monitoring at high-risk rock cuttings for freeze thaw monitoring	2014 – 2019	–	–
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 interventions and flooding of low-lying coastal areas. Details to be worked up in the next few months	2014 – 2019	–	–
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 – 2019	–	–
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 – 2019	Ongoing	Study not yet complete for the full Route. Some assessments have been completed where other assets are being affected especially track

Table 3
2014 WRCCA Plan CP5 actions review

Vulnerability / Action	Target completion date	Actual completion date	Comments
Failure of Signalling and Telecoms (S&T) and Electrical and Plant equipment due to heat in lineside buildings – Target funding to enhance air conditioning equipment in vulnerable locations or fit where none currently exists	2014 – 2019	2014 – 2019	Highest risk sites are complete. All re-signalling and electrification schemes consider this risk and mitigate in the early stages of development
Failure of vulnerable track assets caused by increase in rail temperatures – Plan to upgrade jointed track at key locations to CWR as part of the CP5 renewals strategy	2014 – 2019	2014 – 2019	51km of jointed track renewed with CWR in CP5
Upgrade timber Switches and Crossings layouts to concrete	2014 – 2019	2014 – 2019	234 units completed in CP5
CWR will need to withstand higher rail temperatures – Review required to consider the benefits of increasing the Stress Free Temperatures on a site specific geographical basis to increase the Critical Rail Temperatures	2014 – 2019	Deferred	Strategy for approach to Stress Free Temperatures to be developed in conjunction with the national professional head for track. Likely implementation CP7 and prioritise highest category routes
Flooding of vulnerable S&T assets – provide funding to renew and raise location cabinets	2014 – 2019		This has been completed at all known historic flood sites plus this is included in the specification when undertaking re-signalling work through known flood plains
Risk of ballast wash out – Further work is required in conjunction with the EA 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 better understand the investment plans required by any third parties to reduce the impact, e.g. improved river flood defences	2014 – 2019	Ongoing	Work has been completed at known historic locations to engage with the relevant lead flood authority at each one
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 – 2019	2014 – 2019	5 yearly survey for assessing the health of trees growing lineside is complete. This included assessing third-party trees where they are visible from the boundary fence. Actions to manage the risks identified will continue through CP6 and beyond including removal and/or mitigation of third party trees where appropriate
Failures in level crossings due to highway salting – Target funding to flush crossings susceptible to failure	2014 – 2019	Ongoing	The locations which regularly suffer from this are on a cyclic flushing regime during the winter period. We have also actively engaged with local authorities requesting them to suspend gritting across level crossings
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 – 2019	Ongoing	All OD level crossing and those barriered level crossings with ‘skirts’ are regularly inspected and cleared as necessary to mitigate the effect of heavy snowfall
Identify all sites that suffer high levels 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	2014 – 2019	Ongoing	This is undertaken prior to the start of the season as part of the Autumn working strategy and led by our Seasons Delivery Specialists
High-risk veg removal programme – Undertake Dead, Dying and Diseased Tree (DDDT) removal programme to remove risk	2014 – 2019	2019	DDDT survey was completed in the final year of CP5 and all the category 4 – 7 trees removed
Installation of traction get applicators – Annually review sites currently fitted with traction gel applicators. Add additional as required based on risk	2014 – 2019	Ongoing	This is undertaken prior to the start of the season as part of the Autumn working strategy. Preparation includes the fitment of fixed traction gel applicators as well as the programme of train borne Rail Head Treatment
S&T equipment hit by lightning – Provide funding for enhanced lightning mitigation works	2014 – 2019	2014 – 2019	Mitigation installed at highest risk sites

LNE&EM Route WRCCA actions continued

Table 4
2019 WRCCA Plan CP6 actions

Vulnerability	Location	Action to be taken	Cost of action	Expected benefits	Target completion date	Resilience change	NAP action reference
Falling trees in high winds	Route wide	Programme of clearance and maintenance of lineside vegetation targeted at highest risk safety and performance sites. Includes programme to remove dead, diseased and dying trees	£37m	Train accident risk reduction through reduced likelihood of train striking a tree. Reduction in number of incidents will also drive train performance benefit and reduction in overhead line damage	2019 – 2024	Increase in resilience to high winds	–
Flooding & Landslip Mitigation	Route wide	Programme of drainage resilience renewal schemes	£15m	Reduction in likelihood of flooding and/or earthslip at sites with most significant failure history. Reduction in associated service affecting delays	2019 – 2024	Increased resilience to intensive rainfall events	NRNAP5
Flooding & landslip mitigation	Route wide	Programme of drainage jetting	£15m	Drainage systems are fully functional and able to run at full capacity providing improved resilience reducing service affecting delays. Improved long term sustainability of track ballast	2019 – 2024	Increased resilience to flooding and ballast degradation	–
Landslip mitigation	Route wide	Earthworks Management Plans in place for all earthworks assets	£6m	Management Plans in place for all earthworks assets, providing improved asset sustainability. Reduce likelihood of failures and associated safety and performance impacts	2019 – 2024	Increased resilience of earthworks	NRNAP4
Landslip mitigation	Hessel Foreshore and Browney Curve	Geotech support works at two key locations	£26m	Improved performance of the two geotech assets and support for track assets	2020 – 2024	Increase resilience of earthworks	–
Bridge Scour	Route wide	Mitigation of all Level 1 sites with risk score ≥16, including emerging sites. Currently there are 75 active schemes	£20m	Train accident risk reduction through reduced likelihood of asset failure in storm flows	2019 – 2024	Increase in resilience to scour	–
Heat related track buckling	Route wide	Programme of upgrading Jointed track to CWR, 34km planned	£26m	CWR is far more resilient to hot weather and track buckle	2019 – 2024	Increased track resilience to heat	–
Heat related Track Buckling	Route wide	Programme of upgrading timber S&C layouts to Concrete, 265 units planned	£235m	Concrete S&C layouts are far more resilient to hot weather and track buckle	2019 – 2024	Increased track resilience to heat	–
Mitigate heat and lightning risk	Durham Coast	Resignalling scheme	£45m	Improved performance of the signalling assets	2019 – 2024	Increased signalling resilience	–
Mitigate heat and lightning risk	Ferrybridge – Goole	Resignalling scheme	£44m	Improved performance of the signalling assets	2019 – 2024	Increased signalling resilience	–
Mitigate heat and lightning risk	Middlesborough/ Whitehouse	Resignalling scheme	£45m	Improved performance of the signalling assets	2019 – 2024	Increased signalling resilience	–
Mitigate heat and lightning risk	South Kirkby	Resignalling scheme	£24m	Improved performance of the signalling assets	2019 – 2024	Increased signalling resilience	–
Mitigate heat and lightning risk	Route wide	Various recontrol schemes	£57m	Improved performance of the signalling assets	2019 – 2024	Increased signalling resilience	–

Table 4
2019 WRCCA Plan CP6 actions

Vulnerability	Location	Action to be taken	Cost of action	Expected benefits	Target completion date	Resilience change	NAP action reference
Mitigate heat and lightning risk	Route wide	Various signalling renewal schemes	£125m	Improved performance of the signalling assets	2019 – 2024	Increased signalling resilience	–
Mitigate heat and lightning risk	West Hampstead	Life Extension scheme	£48m	Improved performance of the signalling assets	2019 – 2024	Increased signalling resilience	–
Mitigate heat and lightning risk	East Midlands	Various other life extension work	£10m	Improved performance of the signalling assets	2019 – 2024	Increased signalling resilience	–
OLE resilience in hot weather	East Midlands	Refurbishment of 88 wire runs resetting balance weights and pulley wheels	£5m	Improved performance of OLE and balance weights	2020 – 2024	Increased resilience to longer, hotter Summers	–
OLE resilience in hot weather	Nottingham PSP	Renewal of the Forced Air Cooling System with Air Conditioning	TBC	Improved performance of power supply in hot weather	2021 – 2023	Increased resilience to longer, hotter Summers	–
Points performance in cold weather	Alrewas	Installation of point heating at a site with historic issue of frozen points	£0.05m	Improved performance of points	2020 – 2021	Increased resilience in cold weather	–
Points performance in cold weather	Corby	Installation of point heating at a site with historic issue of frozen points	£0.09m	Improved performance of points	2021 – 2023	Increased resilience in cold weather	–
Points performance in cold weather	LNE	Installation of point heating at five sites with historic issue of frozen points	£0.45m	Improved performance of points	2019 – 2021	Increased resilience in cold weather	–
OLE Development work for CP7 schemes	East Midlands	Various schemes including: • OLE balance weight conversion to Tensorex C+ • OLE head span conversion to Mechanised Independent Registration (MIR) • Fixed tension wire run conversion to auto-tension	TBC	Improved performance of OLE	2019 – 2024	Increased resilience to hot weather	–
D&P Development work for CP7 schemes	East Midlands	Various schemes including: • Flood risk mitigation for lineside D&P assets • Kings Cross renewal of pumping system	TBC	Improved performance of D&P equipment	2019 – 2024	Increased resilience to heavier and more frequent rainfall	–

LNE&EM Route WRCCA actions continued

Table 5
High priority actions not funded in CP6

Vulnerability	Location	Potential action	Target completion date	Predicted benefit	NAP reference
Hazardous Trees blowing onto Track/OLE	Route wide	Early delivery of Hazardous Tree Survey and proactive removal of Ash Trees in light of Ash Die Back Disease	Ongoing	Increase in resilience during high winds	–
Bridge Scour	Route wide	Mitigation of all Amber sites with risk score between 15.1 and 16 on route criticality 1 and 2. Currently there are 34 active schemes with an additional 36 sites to be further assessed	Ongoing	Increase in resilience to scour	–
Earthworks resilience	Hessel Foreshore	Completion of piling work for full length of Geotech asset	Ongoing	Increased resilience to scour	–
Heat Related Buckling	Route wide	Accelerate further jointed track converted to CWR	Ongoing	Increased resilience in hot weather	–
Heat Related Buckling	Route wide	Accelerate further upgrading of timber S&C layouts to Concrete	Ongoing	Increased resilience in hot weather	–
Heat Related Buckling	Route wide	Consider the benefits of increasing the Stress Free Temperatures for rail on a site specific basis	Ongoing	Increased resilience in hot weather	–
Flood resilience	Draycott, Kirk Sandall and other repeated flood sites	Land purchase and construction of attenuation systems upstream of the railway	Ongoing	Increased resilience to flooding	–
'Blow off' protection of OLE in high winds	ECML	Programme of portalisation of the OLE and sites prone to high cross winds	Ongoing	Increased resilience to high winds	–

Table 6
NAP actions

Objective	Action	Timing	Network Rail NAP reference	Monitoring and metrics
Network Rail will continue to address flood risk across its network by:	Ongoing monitoring of adverse weather through visual and thermal imaging	CP6	NRNAP1	Network Rail report on performance on a quarterly basis. This includes a running performance of each operator and the punctuality of its services. These are summarised in annual reports each year, allowing for yearly comparisons
	Building pumping stations in flood-prone locations	CP6	NRNAP2	
	Building in measures to address flood risk in new lines installing equipment at higher levels to avoid flooding	CP6	NRNAP3	
Network rail will continue to comprehensively manage its assets against geotechnical faults as part of its Asset Management Excellence Model (AMEM), this will include:	Ongoing identification of sites vulnerable to landslips with use of Light Detection and Ranging surveys, in-place motion sensors, CCTV and ground investigations;	CP6	NRNAP4	
	Slope stabilisation management via drainage, or steel rods, soil nails or slope re-profiling	CP6	NRNAP5	
	Service continuity management by rerouting services which are likely to be affected by embankment failure (via CCTV monitoring)	CP6	NRNAP6	
	Ongoing engagement with academia to research possible slope stabilisation techniques, in addition to modelling the response of slopes under different meteorological conditions	CP6	NRNAP7	
Transport interdependencies	Network Rail's Safety, Technical and Engineering (STE) Horizon Scanning Group will continue to identify, assess and manage external risks to Network Rail throughout their regional Strategic Business Plans for Control Period 6	CP6	NRNAP8	

Management and review

Corporate management and review

Successfully implementing WRCCA across the whole of Network Rail requires a long-term commitment to the regular review and management of the process at all levels of the business. This will ensure the timely delivery of the technical and cultural changes necessary to develop cost-effective WRCCA strategies and actions which will avoid unacceptable increases in safety risk, system unreliability or the compromising of downstream risk mitigation strategies.

Network Rail is committed to ensuring that we will appropriately govern and assure implementation of these plans. Although we are going through a reorganisation and the future governance structure is unclear, the Route WRCCA Plans are owned by the respective Director of Route Asset Management and the Office of Rail and Road (ORR – Network Rail's regulator) will monitor each route's progress in implementation during CP6.

Effective governance of the wider WRCCA programme including Route WRCCA Plans will be embedded within the new governance structure. Based on existing structures, the following high-level management, review and reporting will be undertaken:

- Routes will provide updates on implementation of their WRCCA Plans to ORR and the central WRCCA Team twice a year (at the end of Periods 6 and 13),
- A report combining progress from all routes will be presented to the National Asset Management Review Group and Quality, Health, Safety and Environment Integration Group (or future equivalents) twice a year,
- Progress in implementing milestones will be included in regular WRCCA reviews by the Network Rail Executive Leadership Team and the National Safety, Health and Environment Periodic Report (or future equivalent),
- Route WRCCA Plans form a key control in managing Network Rail's Enterprise Risk relating to weather related impacts on the railway which is managed through Route and National level Business Assurance Committees (or future equivalent),
- The WRCCA Working Group will review progress and identify any improvements which would be approved by the National Asset Management Review Group and Quality, Health, Safety and Environment Integration Group (or future equivalents) or Executive Leadership Team as appropriate, and
- The central WRCCA Team will use the information in the Route Reports to inform the next National Climate Change Risk Assessment being compiled by the Committee on Climate Change and as part of its Adaptation Report under the Climate Change Act which is due to be submitted to Defra by 2021.

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.

LNE&EM Route management and review

LNE&EM Route will be working closely with the EA, local authorities and other relevant bodies to ensure we have an aligned 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. Our specialist asset management teams will continue 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 Integration 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.

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