Route Weather Resilience and Climate Change Adaptation Plans

South East

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Purpose of this document

This document sets out a Weather Resilience and Climate Change Adaptation (WRCCA) plan for South East Route supported by an evaluation of the resilience of rail infrastructure to historical weather events and an awareness of potential impacts from regional climate change projections. The resilience of rolling stock operating within the Route is not specifically assessed.

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

Director Route Asset Management statement

I am delighted to endorse our Weather Resilience and Climate Change Adaptation (WRCCA) plan.

We have determined our greatest risks local to the Route by using information provided from a number of sources. Following analysis of this and hands-on experience of recent weather disruption we have located those assets vulnerable to weather. In particular we have targeted locations affected by storms in 2013 and by landslips during the wet weather across Kent and Sussex in late 2013 and early 2014. These locations caused disruption to the public when a number of lines had to be closed.

We have learnt from this and now have clear Route strategic objectives. These are described in this WRCCA plan. The plan focuses on vegetation management, flooding and landslips in particular, but also covers the effects of low temperature and wind.

We will now be working closely with local external stakeholders and train operators to progress these plans to reduce disruption from weather. When weather does cause disruption, we will aim to communicate clearly and early so passengers can make alternative plans if necessary.

Derek Butcher, C.Eng. FICE
Acting Director of Route Asset Management
September 2014

Executive Summary

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

South East Route, established in 2014 following the merging of Sussex and Kent Routes, has developed a Weather Resilience and Climate Change Adaptation (WRCCA) plan based on assessments of weather-related vulnerabilities, identification of root causes of historical performance impacts and an understanding of potential future impacts from regional climate change projections. Using this information, South East Route has determined whether previous investments have mitigated weather impact risks, if actions planned during Control Period 5 (CP5) (2014 to 2019) are addressing these vulnerabilities, and where additional actions could further enhance weather and climate change resilience.

An analysis of Schedule 8 performance costs (the compensation payments to train and freight operators for network disruption) during the period 2006/07-2013/14, Figure 1, reveals 48 per cent of the delays are attributed to snow and cold, 32 per cent to wind and adhesion. There is an element of commonality throughout these impacts and that is vegetation, more specifically, trees. Flooding and earthslips make up 15 per cent of the delays.

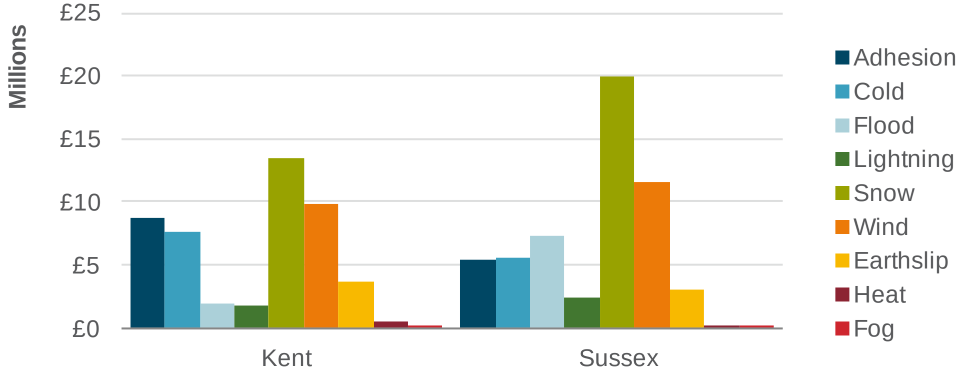

Figure 1 South East Route weather attributed Schedule 8 costs 2006/07 to 2013/14

South East Route is committed to supporting the delivery of improved weather and climate change resilience through Route-specific objectives:

- increase the understanding of potential climate change impacts on South East Route
- rehabilitate existing drainage systems. This can be achieved through direct labour teams, as demonstrated by the efforts of the Sussex Drainage Trial
- ensure high-risk earthwork assets have suitable mitigations in place for severe weather and investment plans in place to remove the need for special mitigations in the long term
- establish a sustainable lineside environment which minimises performance and safety risk and maintenance intervention by removal of problem vegetation and all trees with the potential to cause damage
- work with lineside neighbours to establish an environment beyond the boundary that does not negatively affect safety of the line or performance
- undertake works necessary to reduce the impact of groundwater flooding and to protect sensitive equipment from the hazard of flooding by raising or relocating the equipment
- raise awareness of the key actions to mitigate against deteriorating track geometry in response to clay bank desiccation
- work with key stakeholders and lineside neighbours in the implementation of our strategy through sharing knowledge on climate change trends and their impacts on infrastructure and operations.

South East Route has identified actions planned in CP5 that will increase weather and climate change resilience:

- increase forecasting capability in order to predict flooding and earthwork failures at high-risk locations
- engage with the Environment Agency and local authorities to reduce flood risk
- increase the volume of removal of lineside vegetation so that the impact of trees can be removed or reduced
- promote the use of the ‘Earthworks Watch’ condition monitoring system as early warning of raised vulnerability to adverse (dry and wet) weather, *‘forewarned is forearmed’*
- roll out strategic programmes of Remote Condition Monitoring
- engage with wider industry, including train operating companies, to minimise delay impacts.

South East Route will deliver the WRCCA plan in a timely, cost efficient and safe manner.

Introduction

Weather events can be a cause of significant disruption to the railway network. Recent prolonged periods of rainfall and extreme storm events demonstrated much of the network is resilient. However, asset failures in the South East Route, established in 2014 following the merging of Sussex and Kent Routes, such as earthslips at Ockley and Stonegate, and the widespread tree fall during the St. Jude storm in December 2013, reveal the vulnerability of the rail network and the severe impact these weaknesses in resilience have on train services and our resources.

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

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

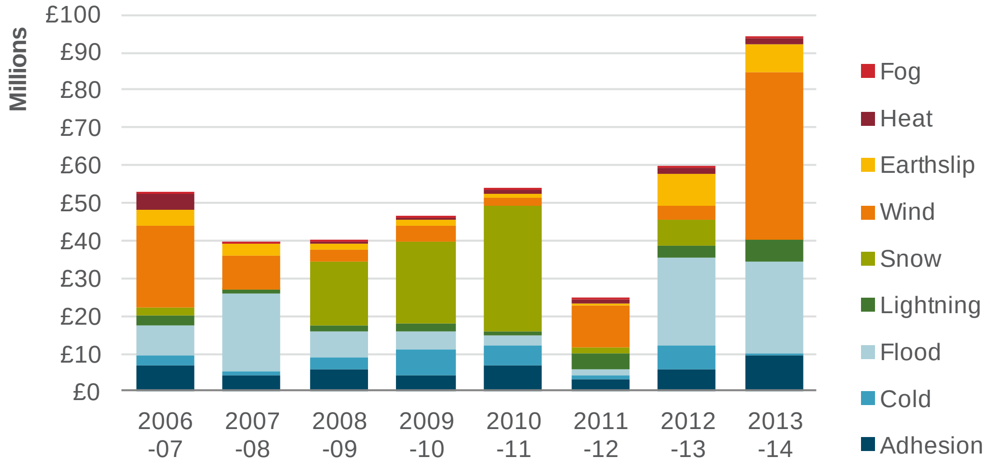

Figure 2 Network weather attributed Schedule 8 delay costs, 2006/07 to 2013/14

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

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

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

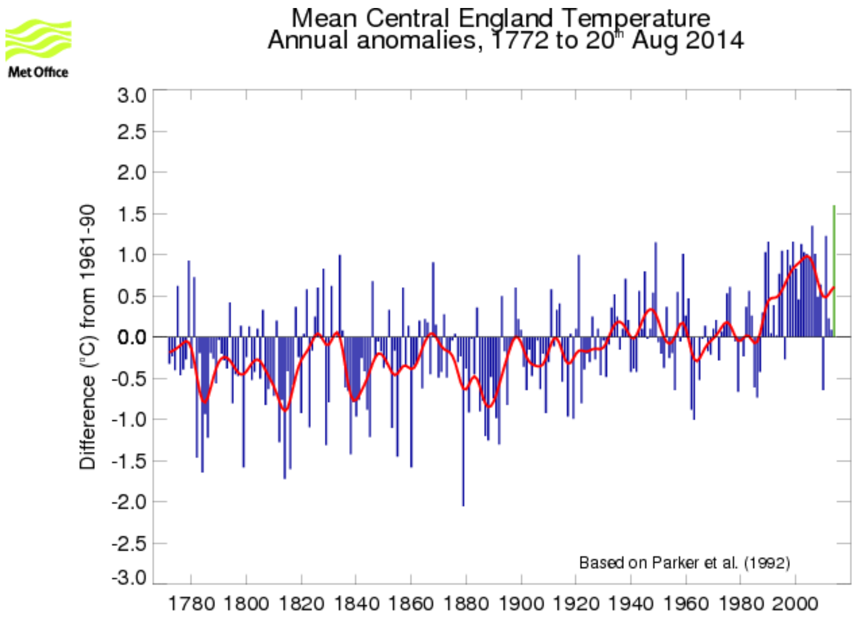

Figure 3 Mean Central England temperature record

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

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

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

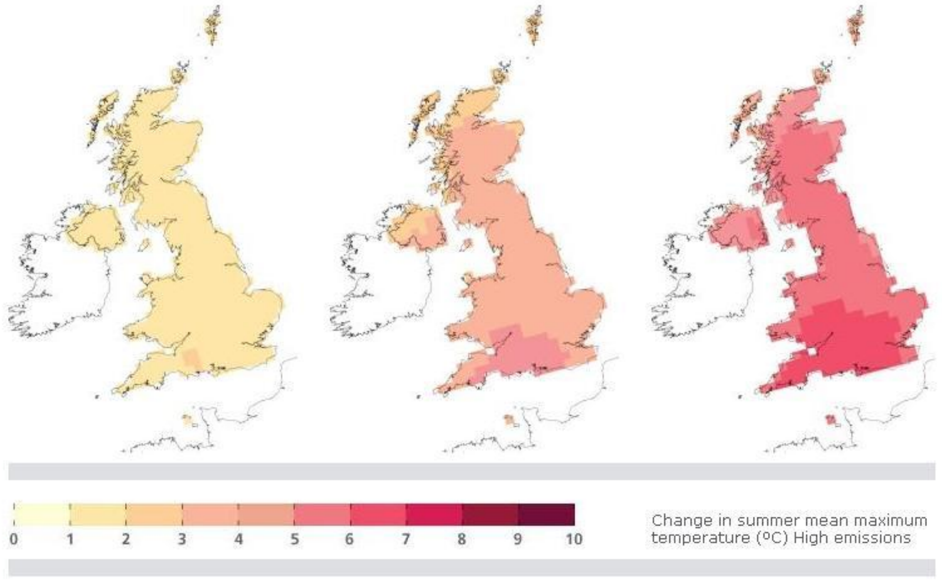

Figure 4 Change in summer mean maximum temperature (left 2020s, middle 2050s, right 2080s) (© UK Climate Projections, 2009)

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

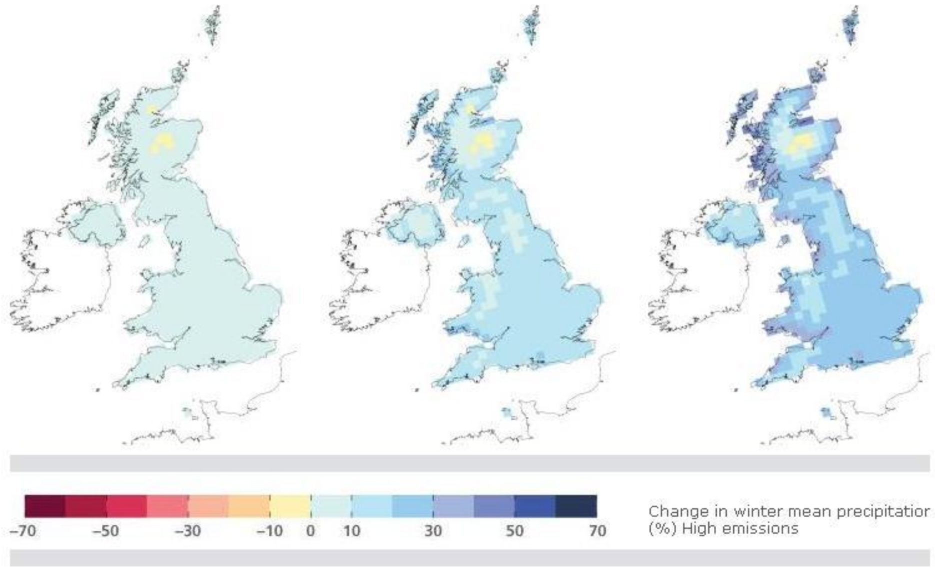

Figure 5 Change in winter mean precipitation (left 2020s, middle 2050s, right 2080s) (© UK Climate Projections, 2009)

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

Figure 6 Weather resilience and climate change adaptation framework

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

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

The following sections provide findings from the South East Route vulnerability and impact assessments, and details of the WRCCA actions; both completed and planned in CP5, and potential additional actions, that aim to increase weather and climate change resilience.

Figure 7 River Arun occupies the full flood plain traversed by the TBH at Amberley, February 2014

South East Route WRCCA strategy

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

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

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

Figure 8 Cutting failure on TTH at Mountfield, Kent, in December led to major slope stabilisation

South East Route strategy

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

- increase the understanding of potential climate change impacts on South East Route
- rehabilitate existing drainage systems. This can be achieved through direct labour teams, as demonstrated by the efforts of the Sussex Drainage Trial. Implement a sustainable inspection and maintenance regime. Replace or upgrade poorly performing drainage systems
- ensure high-risk earthwork assets have suitable mitigations in place for severe weather and investment plans in place to remove the need for special mitigations in the long term
- establish a sustainable lineside environment which minimises performance and safety risk and maintenance intervention by removal of problem vegetation and all trees with the potential to cause damage. Establish a robust regime for ongoing maintenance to avoid return of tree-related issues
- work with lineside neighbours to establish an environment beyond the boundary that does not negatively affect safety of the line or performance
- undertake works necessary to reduce the impact of groundwater flooding and to protect sensitive equipment from the hazard of flooding by raising or relocating the equipment
- raise awareness of the key actions to mitigate against deteriorating track geometry in response to clay bank desiccation
- work with key stakeholders and lineside neighbours in the implementation of our strategy through sharing knowledge on climate change trends and their impacts on infrastructure and operations.

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

South East Route vulnerability assessment

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

Network-wide weather vulnerability

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

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

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

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

Network Rail has moved from subjective and expert review-based knowledge of weather and climate change risks to more detailed internal analysis of asset failure and weather data to understand thresholds at which failure rates significantly change. Figure 9 provides an illustrative example of the analysis identifying assets with higher sensitivity to weather impacts. The horizontal lines are thresholds where there is 'no significant' (green), 'significant' (amber) or 'very significant' change in incident rates (red). This deeper dive analysis is critical to understanding the resilience of operational assets today and potentially in future climates.

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

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

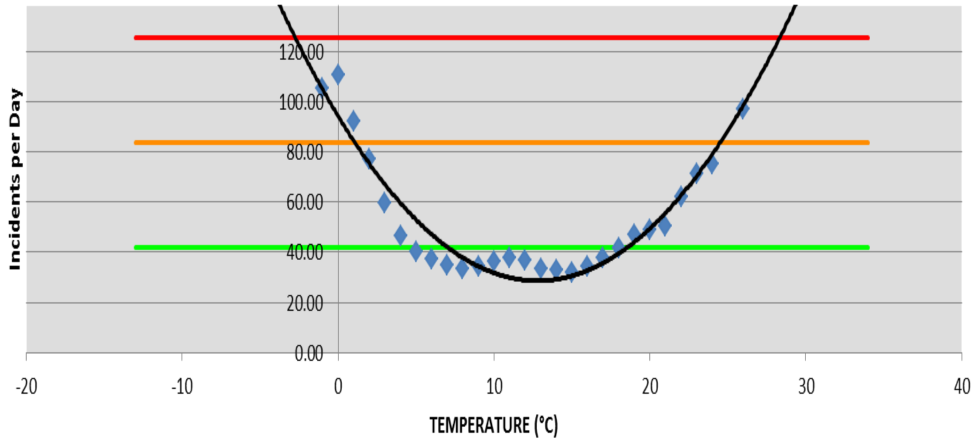

Figure 9 Example of asset failure and weather analysis

Managing operational response to weather vulnerability

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

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

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

Network Rail seeks continuous improvement of weather-based decision support tools, including flood, temperature, wind speed and rainfall alerts. A trial aiming to significantly improve real-time weather forecasting has installed approximately 100 weather stations on the Scotland rail network, Figure 10. The pilot study is currently being evaluated to support a potential wider roll out of this level of weather service.

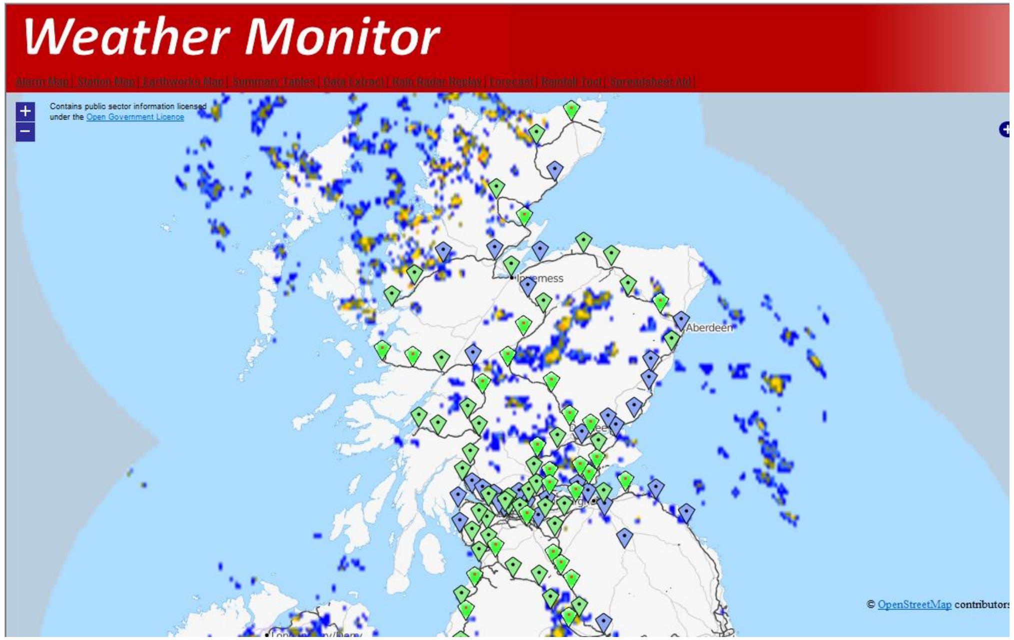

Figure 10 Scotland Route real-time weather monitor

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

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

Improving our network wide resilience

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

The WRCC programme is founded on a bow tie risk assessment of weather-related disruption, Figure 11 – this risk assessment methodology is used widely across Network Rail. The bow tie assessment provides a detailed understanding of the adequacy of the controls that are in place to reduce the causes of disruption and consequences, and highlights those controls that need to be enhanced.

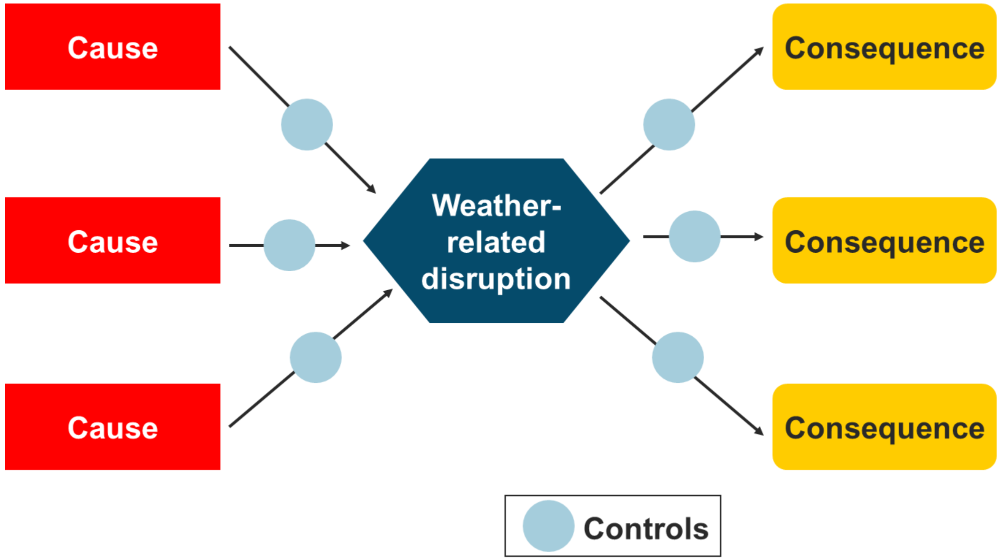

Figure 11 Bow tie risk assessment

The programme consists of six sub-programmes and their 23 constituent projects; these are described in Figure 12 below. Although the bulk of the outcomes that are currently defined expect to be delivered within the next 18 months, the programme is expected to extend throughout CP5.

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

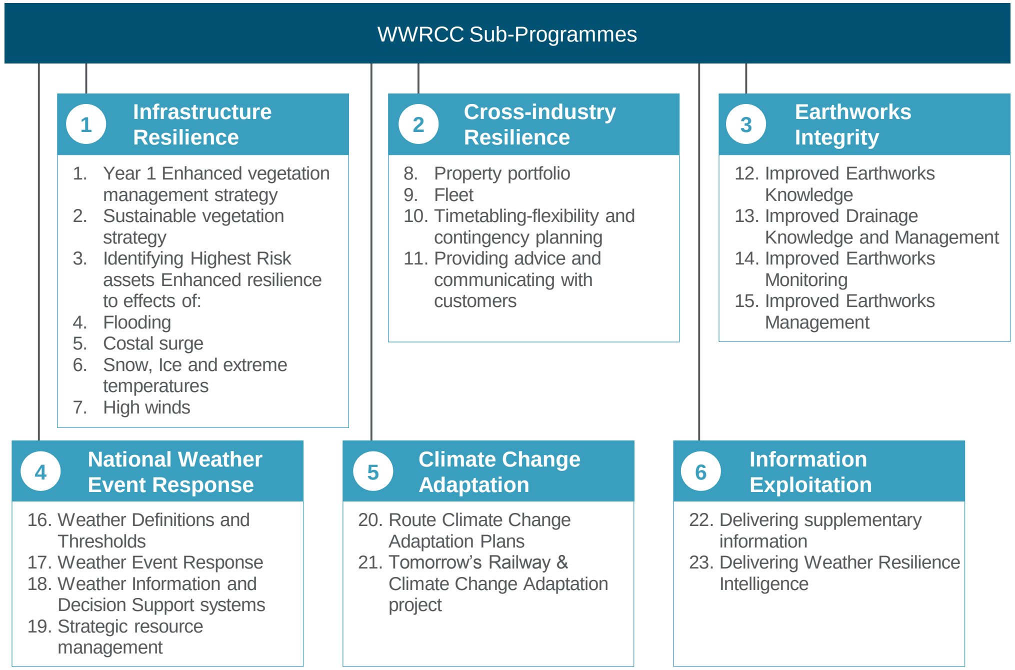

Figure 12 The constituent components of Network Rail's WRCC programme

The WRCC programme is currently supporting the delivery of:

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

Route weather vulnerability

The characteristics of the Kent and Sussex areas are largely influenced by the physiography or surface expression and underlying geology.

The harder chalk formations give rise to the higher ground of the North and South Downs, while the intervening softer clays have eroded away to leave tracts of lower ground and valleys. The older more mixed strata (sandstones and mudstones) of the High Weald give rise to more undulating country, through which the railways must meander, such as the Tonbridge to Hastings line.

These factors influence the orientation of the primary lines and, consequently, the track situation, in terms of being within a cutting, 'at grade' or on embankment. Approximately 60 per cent of the lines are situated on or within earthworks, the remainder being on level ground, on structures within urban areas or within tunnels.

Thus, the principal Kent Routes are East-West, parallel to the structural trend of the Wealden Anticline, and, as such, run largely along the chalk of the North Downs (VIR) or along the lower ground of the gault (SBJ) or Weald clay (XTD).

In contrast, the principal Sussex Routes are North-South, at right angles to the axis of the Wealden Anticline, and pass quickly through the formations with shorter sections within deep chalk cuttings and less exposure to the troublesome clay formations.

These geographical features also influence the localised weather behaviour, with the escarpments of the North and South Downs forming physical barriers to the moist winds of the Atlantic airstreams with increased rainfall occurring through the process of orographic rainfall intensification.

The history of railway construction is another factor affecting Route vulnerability to adverse weather. Much of the network was developed from the 1840s as lines radiating out from London built by competing companies using the best of their engineering ability available at that time. While the understanding of the behaviour of man-made materials was commendable, that of natural materials was limited, as the science of soil mechanics was not established for another 60 years. This factor, combined with the shareholders pressure for returns on their investments, led to minimal land take and maximum slope angles, a legacy of timed-out earthworks which are far more vulnerable to weather than those designed and built to modern day standards.

Earthworks

One of the most significant aspects of weather impact, which is particular to the South East Route, is susceptibility of earthworks, i.e. embankment and cuttings, to adverse or extreme weather. The following chart, Figure 13, summarises the five key variables which determine the performance of our earthwork assets:

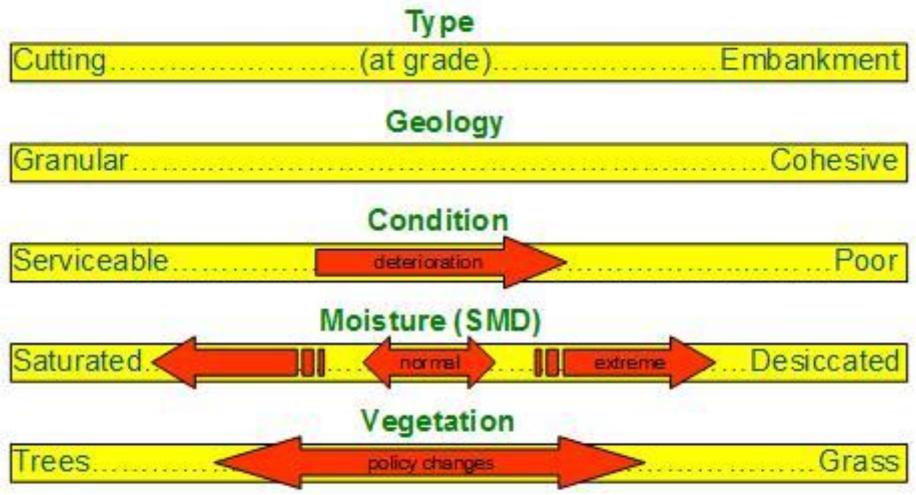

Figure 13 Five key variables affecting earthwork performance

- **type**: ranging from steep-sided deep cuttings through 'at grade' to high embankments over areas of low ground or river valleys
- **geology**: the geology of the South East Route is dominated by weak, moisture-sensitive, over-consolidated clays. These contrast with areas of stronger limestones (chalk) and sandstones which give rise to the undulating terrain of the High Weald and the upland regions of the North and South Downs
- **condition**: earthwork 'condition' is regularly determined by our programme of earthwork examinations. Condition trend is always deteriorating until such time as there is intervention, which brings the condition back to a satisfactory level
- **moisture**: this is the most significant factor as excess moisture causes mobilisation of materials, in particular where embankments are composed of the weak over-consolidated clays. At the reverse end of the moisture cycle is the drying out, or desiccation, of the same clays, which shrink and cause a loss of track quality on clay-cored embankments
- **trees**: the management of vegetation is crucial to minimise the re-growth of high water-demand trees, which can exacerbate track geometry defects during periods of hot weather. Research has determined that deformation of soil slopes is 10 times greater where trees are present compared with grassed slopes.

Type and geology are highly constrained factors. However, variations in condition, moisture and vegetation can be managed, to a degree. Extreme variance, especially in moisture, may cause failures due to excessive moisture, or track defects due to desiccation, which represent safety and serviceability risks, respectively. It is this aspect which is set to be a feature of climate change.

Vegetation

Vegetation on embankment and cutting slopes is detrimental to performance. Given that the expectation of climate change is for warmer summers and heavier rainfall, the management of woody growth will present an increasing challenge.

Worth considering is the already occurring threat from 'ash die back', which can be seen on the east coast of Kent, and the currently unknown impact of the introduction of alien species in response to changing climate, such as insects or plants.

Flooding

The geological fabric also controls the propensity for flooding. The softer clay bedrocks give rise to tracts of low-lying, poorly drained landscape where fluvial flooding occurs through the limited ability of the natural watercourses to cope with heavy rainfall. Gatwick is situated within such an area.

River and estuarine flooding occurs in main river valleys where outfall is impeded by natural or man-made constrictions, such as in the Arun Valley south of Pulborough.

Groundwater flooding occurs less frequently* when the water level in the chalk aquifers of the North and South Downs rise into the floor of the railways cuttings and tunnels, Figure 14. This occurs on the Sussex Route where the Redhill line passes through a deep cutting in chalk south of Coulsdon and again on the Brighton line at Pangdean, just north of Brighton. Further groundwater flooding occurs at Shalmsford Street on the Kent Route where the Ashford line passes through the chalk escarpment of the North Downs by way of the River Stour valley. (*Previous to last winter, these locations were flooded during the very wet winter of 2000/01.)

Figure 14 Groundwater flooding at Woodplace, Sussex, in February 2014.

Future climate change projections

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

The UK Climate Change Projections (UKCP09) provides regional climate change projections across 13 administrative regions in Great Britain, Figure 15. The South East England projections provide South East Route with indications of future climate change.

Figure 15 UKCP09 administrative regions

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

Mean daily maximum temperature change

The mean daily maximum temperature in South East England, Figure 16, is projected to increase throughout the year, with greater increases expected in the summer months through the century. Average maximum daily temperature in July is expected to increase by 3.1°C, reaching 24.3°C by the 2050s, and by over 5.1°C, reaching 26.3°C by the 2080s. Average maximum daily temperature in January is expected to increase by 2.2°C, reaching 8.7°C by the 2050s, and by 3.2°C, reaching 9.7°C by the 2080s.

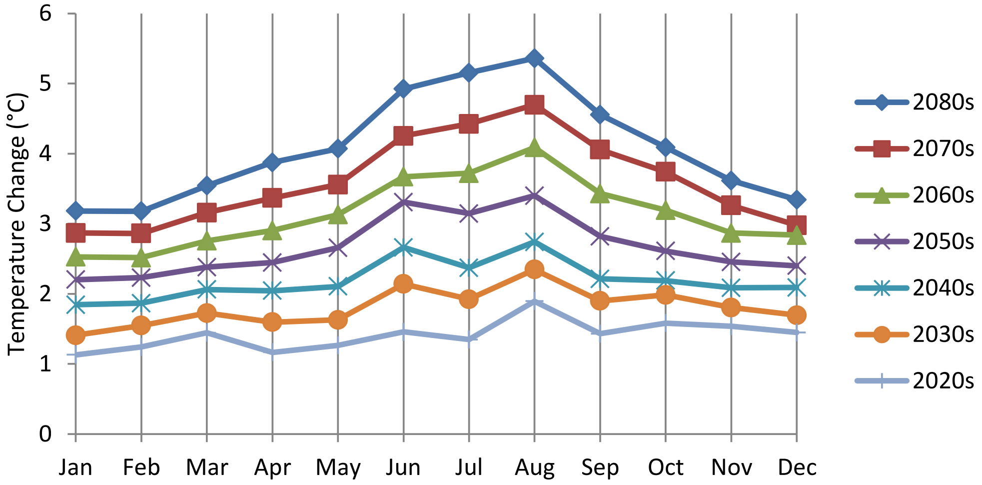

Figure 16 South East England, mean maximum temperature change (50th percentile)

Mean daily minimum temperature change

The mean daily minimum temperature in South East England is also projected to increase throughout the year, Figure 17. Average minimum daily temperatures in July are projected to increase by 3°C, reaching 14.8°C by 2050s, and by 4.8°C reaching 16.6°C by the 2080s. Average minimum daily temperature in January is projected to increase by 2.9°C, reaching 4.3°C by 2050s, and by 4.2°C, reaching 5.6°C by 2080s.

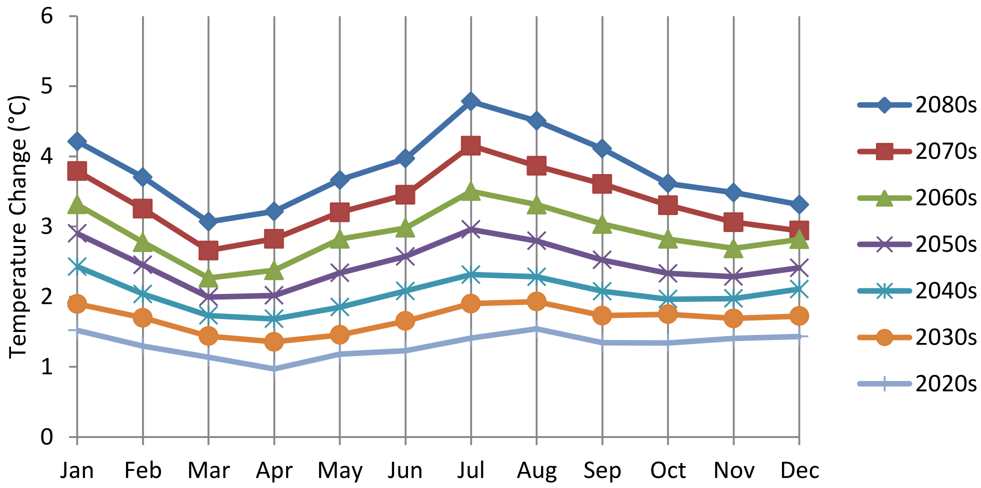

Figure 17 South East England, mean minimum temperature change (50th percentile)

Mean daily precipitation

The mean daily precipitation in South East England is projected to significantly increase in winter months and decrease in summer months, Figure 18. The greatest increase is expected to occur in February, projected to be 25 per cent, reaching 2.3mm per day by the 2050s, and 42 per cent, reaching 2.6mm per day by the 2080s. The greatest decrease in precipitation is likely to occur in August. Mean daily precipitation is projected to decrease by 20 per cent by the 2050s, to 1.4mm per day, and by 32 per cent, to 1.2mm per day by the 2080s.

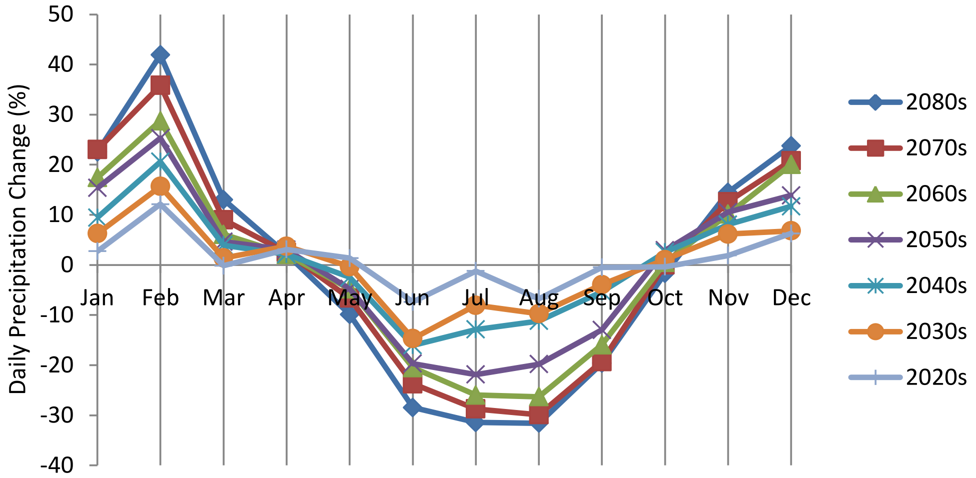

Figure 18 South East England, mean daily precipitation change (50th percentile)

Sea level rise

Sea level rise for the South East Route coastal and estuarine assets can be represented by the projections for the Folkestone area. For the high emissions scenario, the projection for the 50th percentile for 2050 is 0.259m and 0.565m by the end of century (the rise is unlikely to be higher than 0.403m and 0.888m respectively), Figure 19.

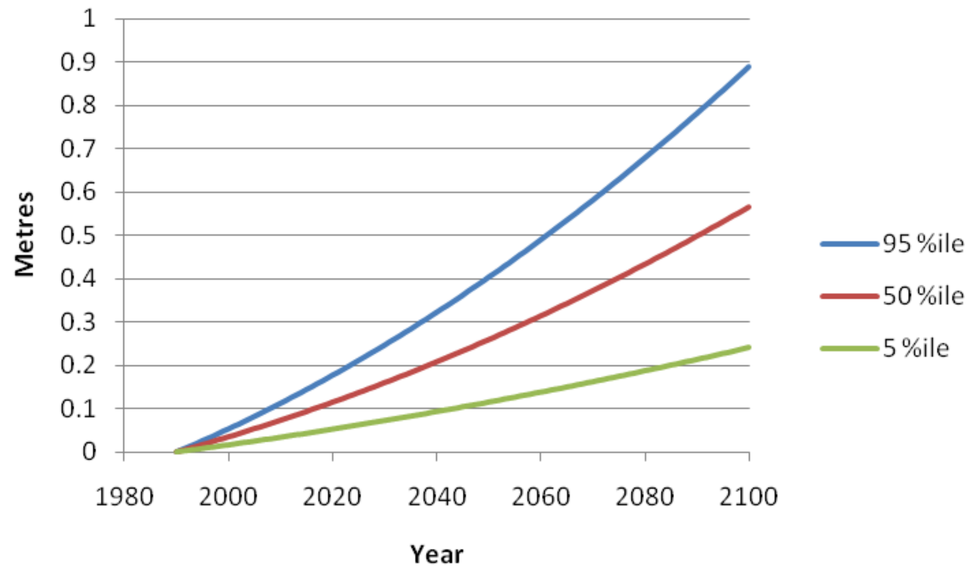

Figure 19 UKCP09 sea level rise projections for the Folkestone area

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

South East Route impact assessment

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

Performance impacts

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

Schedule 8 costs for the past eight financial years for the two areas Kent and Sussex, Figure 20, have been analysed to provide an assessment of weather impacts.

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

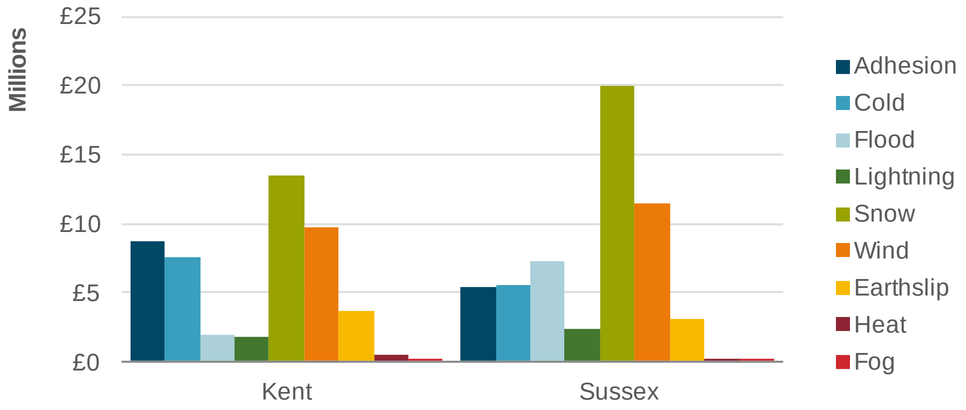

Figure 20 South East Route weather attributed Schedule 8 costs 2006/07 to 2013/14

The analysis shows that snow- and wind-related impacts are significant for the Route, with total Schedule 8 costs over £33m and nearly £21m respectively during the period 2006/07 to 2013/14.

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

Climate modelling cannot provide strong projections for future changes to wind speeds, although increased storminess is generally projected and may increase the risk of wind-related incidents on the Route.

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

Table 1 Prioritisation of weather-related impacts on South East Route

Weather-related impact	Schedule 8 costs[1]	Projected future impacts	Prioritisation
Snow	£4.1m	2.9°C increase in January mean daily minimum temperature[2]	High
Wind	£2.6m	Wind changes difficult to project, however, generally projected to increase	High
Adhesion	£1.7m	Complex relationship between adhesion issues and future climate change.	Medium
Cold	£1.6m	2.9°C increase in January mean daily minimum temperature[1]	Medium
Flooding	£1.1m	25 per cent increase in February mean daily precipitation[2]	Medium
Earthslips	£0.8m	25 per cent increase in February mean daily precipitation[2]	Medium
Sea level rise	Not recorded	0.26m increase in sea level rise[3]	Low
Heat	£74k	>3°C increase in July mean daily maximum temperature[2]	Medium
Lightning	£0.5m	Storm changes difficult to project, however, generally projected to increase	Low
Fog	£2k	Complex relationship, however, research suggests fog events may decrease	Low

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

The above data shows clearly the prevalence of snow, cold, wind and adhesion as the primary causes of lost minutes, totalling 80 per cent of all delays across the South East Route.

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

Identification of higher risk locations

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

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

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

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

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

Snow and cold impact assessment

Based on the 2006/07 to 2013/14 data, the combined impact of cold and snow was £67m, representing 48 per cent of the total Schedule 8 costs for Kent and Sussex combined. In recent years, Ashford and Brighton have incurred the most delays for this impact on the Route, amounting to almost £10m. Measures taken to mitigate the effects of snow and cold at these locations include installing more conductor rail heating, no splitting of trains in cold conditions and staff on the ground to react to incidents. While this is not sufficient to completely mitigate the risk, there has been an improvement in delays in the last few years, as the figures show.

While the climate change projections would suggest an improving situation for frequency of cold days, the fact is, that even the shortest periods of cold and/or snow have a debilitating impact on the network. We have increased the amount of conductor rail heating in both Kent and Sussex, we run anti-ice MPVs and we have a Key Route Strategy (KRS) to mitigate the risk, which involves the use of Snow Ice Treatment Trains (SITTs). However, cold weather had little operational impact last winter, and if the weather continues this way, it may become of reduced concern in the longer term.

Most assets are impacted by the effects of snow and cold, and measures are taken to reduce these impacts on all fronts. A concern for structures and buildings is the risk of shrinkage and fracture of metal components, leaks from accumulating snow on and around buildings, slippery conditions around buildings and on walkways, and snow and wind blowing platform copers out of alignment. Ice formation in tunnels also poses a risk to the running of trains, as sheets of ice can form icicles in front of the path of the train and cause damage, or break off without warning; this is also a potential hazard. To mitigate this, tunnel checks are carried out by track patrollers, who have equipment to remove ice sheets if found.

While conductor rail heating holds many benefits which can be seen through the positive effects of its installation, there is the drawback that it increases the power consumption required by the line. For example, con-rail heating on the partly fitted out Tonbridge to Hastings line already draws 1MW from the system. This means there is an increasing draw on the power supply during cold weather, as it is required not only to run the trains and power them, but also for points heaters and conductor rail heating, and this is a risk within itself.

Cold weather poses perhaps the biggest risk to track; ice formation on the third rail prevents trains from accessing the power supply via the shoe gear and often results in arcing and sparking which damages the train and the track, points can become frozen which prevents paths from being set by signallers, and a build-up of snow on the track simply means that trains cannot run until cleared by the SITT, much as roads need to be cleared by a snowplough before cars can drive through them.

While conductor rail heating and points heating go some way towards mitigating the effects of ice, a large amount of snow does render these ineffective, and often further costs are incurred in repairing the equipment. There was also an incident where disruption of services was exacerbated in the Kent snow of December 2010 because trains could not pass the trees, which had lent over the tracks from the weight of snow on their branches, Figure 21.

Figure 21 Wet snow in April 2006 brought the trees down over the tracks on TTH at Tunbridge Wells

Apart from snow melt, snow and cold has limited impact on earthwork stability. The more significant impact is from the freeze – thaw process which damages rock and, in particular chalk, cuttings. The lines through the Hooley cuttings were closed for several days in 1947 when a long period of freezing weather ended with a rapid thaw, which caused the vegetal debris and weathered chalk to slough off the cutting faces and block the lines.

The following mitigation will reduce the impact from snow and cold:

- better forecasting of snow conditions so that emergency timetables can be instigated in good time
- removal of lineside trees to prevent line blockage
- expand the programme for con-rail heating and points heating
- ensure adequate de-icing arrangements and material supplies in conjunction with train operating companies etc.

During 2014/15 the Route will invest c£1.9m in winter preparation. Previously in CP4 we invested £50m and deployed Conductor Rail Heating (CRH) at a number of locations, developed and delivered six snow and ice treatment trains and fitted anti-icing equipment to 20 class 375 trains.

In addition to the above, the works in 2014/15 completion of CRH, include developing remote condition monitoring for the CRH and detailed pre-winter checks on CRH.

Wind impact assessment

Based on the 2006/07 to 2013/14 data, the impact of wind was £31m representing 22 per cent of the total Schedule 8 costs for Kent and Sussex combined.

While our structures team have not reported any impact from high winds, the buildings team reported dislocation or damage to station canopies that have required immediate attention.

The impact on signalling and power systems relates principally to damage to equipment from wind-blown debris and uprooted trees. Being almost exclusively third rail traction current supply, the South East Route is not as vulnerable to winds as those reliant on catenary. However, debris caught up in the pantograph equipment on the train roof can be conveyed out of the Route leading to problems when entering OLE areas.

Line blockage from fallen trees and poor adhesion are the main issues to track, and serious damage to rolling stock has required removal from service for repair.

Although there is little direct impact from wind on earthworks, those localities where wind has combined with long-term flooding have suffered minor embankment damage, where the fetch and wind speed have been sufficient to create significant wave action on unprotected embankment slopes.

The following mitigation will reduce the impact from high winds:

- greater emphasis on removal of trees from within toppling range, including third-party trees, and on the maintenance of a tree-free railway network. While hazardous trees are identified by a 2011 survey, the experience is that these trees are not necessarily the ones that fall. Thus the proper approach is for full clearance and ongoing attention to preventing re-growth
- review legal constraints on clearing trees
- we will be considering the broader costs relating to vegetation risk, including wider industry costs such as rolling stock damage in our decision-making.

Figure 22 Tree collapsed in the VIR cutting at Sole Street, Kent, in August 2007.

Adhesion impact assessment

Based on the 2006/07 to 2013/14 data, the impact of adhesion issues was £14m, representing 10 per cent of the total Schedule 8 costs for Kent and Sussex combined. It is difficult to pinpoint locations which are severely affected by adhesion, as often the worst cause of delays is the reactionary impact. Safety incidents are a far greater risk of contamination on the line than delay minutes, and this is what the Route attempts to mitigate.

Adhesion loss can be caused by leaf mulch, snow or ice, or heavy dew creating contamination on the line. The train loses traction as it passes over the contaminated track and this can result in a variety of incidents:

- station overshoots – in case of severe contamination, the train may not have sufficient friction between the wheel and the rail to brake in time, resulting in it slipping past a station
- wrong side track circuit failures (WSTCFs) – contamination of the railhead may prevent the wheel and the rail from touching, effectively causing the train to 'disappear' from the signalling system as the circuit is broken
- Signals Passed At Danger (SPADs) – again, this occurs when a train cannot gain enough traction to stop at a red signal and slips past it; this is a particular risk at junctions and level crossings, where a train being unable to stop at a red signal could cause a collision with an oncoming train or car.

Contamination caused by leaf mulch is most effectively mitigated by removing the source of the issue, i.e. clearing lineside vegetation. This has been seen to have a direct impact on the number of safety incidents encountered on the Route. For instance, 2011 was a particularly successful year for vegetation management in the Sussex area and through the autumn season we encountered only one station overshoot and four wrong side failures.

However, while vegetation is perhaps the single most contributory factor, we cannot highlight it as the only one that causes adhesion issues. At times, several factors working in conjunction will result in an exacerbation of the issue. For instance, in autumn 2013, multiple wrong side track circuit failures were caused on the Uckfield line as the first train of the morning proceeded down the line. The reasons for this were multiple: the Uckfield line is a known high-risk location due to the vegetation in the area; the track circuits there are weak; the first train down was a two car train which, being lighter, is less easily detected by the signalling system anyway; and the MPV circuits were not running as they should have been. All of this led to a spate of safety incidents on the line, which proves that several forms of mitigation need to be in place to combat the issue of adhesion. Vegetation is one that has already been mentioned, other forms include:

- running treatment trains (multi-purpose vehicles and railhead treatment trains) which water jet the tracks and 'wash off' any contamination build up. MPVs also lay sandite, a gluey sandy substance, in some locations which helps trains gain traction. It is important to run these trains before the start of service where possible, to remove any build up from the previous night
- maintaining assets on the network to ensure that they can be relied upon; the Uckfield line is only one example where weak assets contribute to delays caused by adhesion. Work has now been carried out on this line to strengthen the track circuits, and work is ongoing in conjunction with re-signalling schemes to fit axle counters where possible, which aid with train detection
- working with train operating companies to run longer formations where possible, to terminate late running trains early to minimise the impact of reactionary delay during autumn, to train drivers to drive to conditions experienced on the track and report when they experience low contamination
- installation of traction gel applicators where there are known issues with adhesion; for example on Kent Route, there have been several overshoots at Ravensbourne in the last few years, and two more TGAs have been fitted here for autumn 2014.

Vegetation clearance has been carried out at approximately 90 per cent of high-risk sites identified from the autumn 2013 review on the South East Route, but the most important part of vegetation clearance is maintenance: *once clear, maintain clear.* Therefore, a comprehensive strategy is being pulled together for CP5 to ensure that once sites are cleared, they do not become an issue again.

Previously, the South East Route only used multi-purpose vehicles (MPVs) to treat the tracks but this year, six rail head treatment trains (RHTTs) are being brought down to the Route for use in autumn 2014. Not only does this greatly enhance the resources available to us, but it is also believed that RHTTs are more effective than MPVs in clearing contamination off the track due to the higher pressure water jetting sprays and their larger water capacity, meaning they can run for longer. We therefore expect to see adhesion having a greatly reduced impact on the Route this year. Train operating companies also make minor changes to their timetables during autumn to allow for treatment trains to run on the network, and also to reduce the impact of reactionary delays.

New weather systems are also going to be used to forecast low adhesion, taking into account factors such as vegetation, microclimates, and dew or the ‘wet rail syndrome’. These will help to understand where our resources and efforts to mitigate adhesion should be focused.

Flooding and earthslip impact assessment

Based on the 2006/07 to 2013/14, the combined impact of flooding and earthslips was £21m representing 15 per cent of the total Schedule 8 costs for Kent and Sussex combined.

Most of the earthslip issues in Sussex and Kent have been remediated by the completion of both planned works and reactive remedial works. Those locations where emergency response was limited to removal of debris, additional works are being carried out through minor works to reinstate earthworks back to their pre-failure condition with additional protection and mitigation measures included, as necessary.

The Route has developed adverse weather plans as a part of the EWAT process for the management of adverse or extreme weather events. In terms of earthwork stability, the plan makes use of the ‘Earthworks Watch’ system, which provides forewarning of conditions which could facilitate earthslips during extreme weather events. This helps with the management of resources required for checks on sensitive earthworks which have been subjected to intensive rainfall, so that the safety of the line is not compromised.

Remote condition monitoring has been trialled successfully on one of our most vulnerable cuttings on the Redhill line at Hooley. The cutting has now been completely overhauled releasing the monitoring equipment for deployment on the adjacent Brighton line cutting where a number of failures were experienced over last winter. The success of this monitoring methodology allows its usage to be confidently applied wherever the same conditions and processes exist.

Flooding remains an increasing challenge as frequency and severity is projected to increase with climate change.

Flooding can generally be divided into river (fluvial), surface water (pluvial), tidal and groundwater. Pluvial flooding is a secondary impact of prolonged heavy rain or cloudbursts which can overwhelm rail drainage systems. Groundwater is where the geology is porous and acts as a sponge, or aquifer, which fills up in response to prolonged heavy rainfall, such as the chalk of the North and South Downs escarpments.

River and surface water flooding is the more common, while groundwater flooding only affects those locations where the railway has been constructed in the floor of river valleys within chalk bedrock, such as at Shalmsford Street on the Ashford line or been placed in deep cuttings or tunnels within chalk bedrock, such as at Pangdean, Woodplace on the Brighton line and Higham-Strood Tunnel on HDR.

Flooding can cause minor damage to station and lineside buildings through entering the building and leakage of flat roofs, while the impact on structures can be more severe where increased scour occurs around bridge abutments. Except for those tunnels passing through the permeable chalk of the North and South Downs, water ingress and disposal is becoming an increasing challenge requiring costly seepage interception systems and renewal of six foot drainage systems where their functionality has become compromised by track lowering schemes causing repeated track flooding and service interruption.

Figure 23 Groundwater flooding closed the ACR line at Shelmsford Street, Kent, in February 2014.

Both signalling (S&T) and power (E&P**)** are vulnerable to damage to equipment from surface or groundwater flooding and measures are being taken to enhance the protection of sensitive equipment and, where possible, relocate equipment away from locations prone to groundwater flooding, such as in Pangdean cutting.

The propensity for earthwork failure is raised during periods of wet weather and flooding through the raising of inter-granular pore water pressure, and mobilisation of material and through the physical removal of materials, as is the case with scour. A further process experienced over the last winter was the re-activation of sinkholes, both natural solution features and man-made chalk mines or 'dene holes'. The impact was not great, but our experiences were mirrored across southern Britain, which experienced a four-fold increase in reported collapses.

The following mitigations will reduce the impact from flooding and earthslips:

- raise sensitive equipment above flood levels; relocate sub-stations out of chalk cuttings
- develop and instigate and review Drainage Management Plans
- ensure cesses are kept clear to allow free discharge of floodwater caused by rising groundwater
- ensure '6 foot' carrier drains are fully functional and refurbish where necessary
- work with local water companies to monitor propensity for rising groundwater
- purchase standby pumps to alleviate minor flooding
- increased focus on drainage maintenance by the use of direct labour work teams
- re-profile earthwork slopes to an acceptable angle of stability.

Figure 24 Embankment failure on BTH at Ockley, Sussex, in December 2014.

Sea level rise impact assessment

The impact of rising sea levels alone is not identified in terms of train delays. However, the Route has a number of coastal and estuarine sections which could become increasingly exposed to storm events as sea levels undergo a gradual rise:

- Seasalter/Whitstable
- Folkestone to Dover
- Glynde Gap
- Cooden Beach
- Arun Valley.

All of these locations benefit from various forms of coastal protection installed at the time of railway construction. However, in most cases these defences have been incorporated into ongoing coastal protection schemes carried out and maintained by the Environment Agency. The main exception to this is the coastal section between Folkestone and Dover where the railway was built at the foot of the sea cliff or within tunnels just behind the sea cliff. However, the railway is at an elevation such that it is not affected directly by storm conditions affording a delay between any damage to the sea defences and any impact on the safety of the line.

A further location at risk from coastal/estuarine flooding is the Newhaven Port, where a recent storm surge caused seawater inundation with long-term issues over component corrosion.

Storms on the south coast have caused recent overtopping of coastal defences at Bulverhythe, where shingle was washed on to the tracks causing minor delays to train operations.

There has been little direct impact from sea level rise on earthworks apart from the Folkestone Warren landslide, which falls within the coastal section between Folkestone and Dover. The impact here will be from accelerated ground movements caused by a combination of inability to maintain ground water lowering within the slipped mass and increased ground water entering the slip surfaces from the Folkestone – Dover chalk block behind.

The following mitigation will reduce the impact from sea level rise:

- raising or strengthening of coastal defences
- construction of secondary defences where the relevant Shoreline Management Plan (SMP) has determined a strategy of ‘managed retreat’
- maintain liaison with the Environment Agency and relevant coastal groups regarding Coastal, Estuarine and River Defence (CERD) plans
- further coastal defence works to extend the life of the Folkestone Warren protective apron
- increased efforts to lower groundwater in the Folkestone Warren landslip complex
- the route intends to invest in CP5 in the resilience of the section of coastline between Folkestone and Dover.

Heat impact assessment

Based on the 2006/07 to 2013/14 data, the impact of heat was £1m representing 1 per cent of the total Schedule 8 costs for Kent and Sussex combined.

Several, if not all, assets on the railway are affected by heat, and if the trend recently identified of increasingly hot summers continues, it is something we need to mitigate against. Buildings and structures are perhaps the least affected; the main concern is overheating of station buildings, which requires more cooling equipment and increases electricity demand.

Signalling suffers from overheating of equipment cabinets/buildings, and they therefore require better insulation and more cooling equipment, which also increases electricity demand. Electronic equipment, such as printed circuit boards, may need to be more robustly manufactured to maintain functionality at higher temperatures.

From an electrical and power point of view, as mentioned already, increasing temperatures lead to a reduction in equipment rating and thus available power, with potential for having to reduce the number of trains drawing on the power. There are also increasing power demands as old train sets are replaced by those fitted with air conditioning, which draw extra current. While very limited on the South East Route, OLE equipment may need extra attention to counter increased loadings from overhead line expansion. The traditional third rail system will also need extra attention to reduce damage from con-rail buckling or flailing ramp ends, with associated risk of rolling stock damage.

Rail buckling is one of the main issues for track and requires increased vigilance and resources to manage it safely through heat speeds and extra tamping. Increased risk of lineside fires will require increased efforts to minimise litter and clear vegetation. There were several instances of this in the hot summer experienced this year; several initiatives have now been put in place to mitigate this in future.

It is estimated that over 65 per cent of embankments in the South East Route are composed of moisture sensitive clays. (The remainder of the embankments are made of less sensitive granular rock types with varying susceptibility to shrink-swell or chalk, which is insensitive to moisture change.) These ‘clay banks’ tend to be constantly shifting as shrink-swell processes occur in response to seasonal moisture changes. Embankments lose their shape by creeping away sideways and the losses have been made up in the past by the addition of boiler ash, which gives rise to the term ‘ash bank’. Now, the tracks are kept up by the addition of ballast. However, the tracks tend to move apart (become splayed) as the ‘six foot’ widens, such that safe cess ceases to exist. The rate at which the clay moves is proportional to the seasonal variations from wetting to drying, and climate change will increase the range causing acceleration in the demise of clay banks. This desiccation effect, which causes deteriorating track geometry, is exacerbated in the presence of trees which draw extra water to keep alive, especially late summer to autumn.

The following mitigation will reduce the impact from high temperatures:

- building in of system redundancy where equipment is prone to failure
- consideration to raising the Stress Free Temperature (SFT) with research abroad into what impacts this may have on track maintenance during both hot and cooler weather
- correction of settled and splayed banks by bringing tracks back together
- optimise opportunities for failure warning through increased Remote Condition Monitoring (RCM), utilising spare capacity of building monitoring systems
- use of the “Earthworks Watch” system for advanced warning of clay bank desiccation such that proactive tamping can be carried out rather than reactive.

Lightning impact assessment

Based on the 2006/07 to 2013/14 data, the impact of lightning was £6m representing 4 per cent of the total Schedule 8 costs for Kent and Sussex combined.

Lightning protection systems for buildings are generally adequate. However, one must be mindful of local changes, such as at Ashford depot, where the removal of lightning towers reduced the protection to the surrounding facilities.

Power systems can be tripped out by lightning surges, but this is currently managed by adequate supply protection arrangements. The main issue is in the cost of recovery, the capital cost of restoring Continental Junction after a recent lightning strike was around £0.8m.

The following mitigation will reduce the impact from lightning:

- improved earthing arrangements
- rapid response to reinstate damaged signalling or power equipment
- explore the application Dissipation Array Systems.

Fog impact assessment

Based on the 2006/07 to 2013/14 data, the impact of fog was £0.02m, representing <1 per cent of the total Schedule 8 costs for Kent and Sussex combined.

Fog is not expected to become an increasing problem with climate change as temperatures are projected to rise and current controls are considered adequate for now and the future.

South East Route WRCCA actions

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

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

Table 2 Planned actions in CP5

Vulnerability	Action to be taken	By when
All Impacts		
Climatic conditions and specific weather-related risks are not clearly communicated to asset renewal and enhancement processes	Include clear requirements for climatic conditions and resilience levels in Route Requirements Documents. Details described in Drainage Standards	Ongoing
Risk to staff from extreme weather conditions	Staff trained to use and supplied with appropriate equipment, e.g. life vests for flooding events, seasonal PPE, offices and depots temperature controlled	Ongoing
Improved Weather Alert and Information System	Allows response to be targeted to areas of most concern	2015
Flooding		
Level of engagement with flood risk management authorities is not supporting effective discussions	Strengthen relationship with the Environment Agency through setting up of a Local Liaison Group on flood risk management to share information and resolve issues	2015
	Engage with local flood resilience forums	Ongoing
	Flood proofing of Pangdean HV substation	2019
Earthworks		
Our most vulnerable earthworks are those embankments composed of moisture-sensitive clays	Our Business Plan comprises a prioritised work bank of embankment remediation schemes which will gradually reduce the level of vulnerability across the Route	Ongoing in CP5
Cuttings are less affected by adverse weather but carry the increased risk in the event of only minor debris falls	Many of our steep sided chalk cuttings have been protected by containment mesh schemes facilitated through the Enhanced Spend Programme. Further schemes have been identified for protection	Ongoing in CP5
Earthworks Remote Condition Monitoring pilot	Trial to understand applicability	National project 2015
High temperatures		
Equipment over-heating	Improve air conditioning	2016
Track buckling	Early intervention by track maintenance	2015
Clay bank desiccation	Use of 'Earthwork Watch' system for early warnings and appropriate mitigation	Ongoing
Coastal and estuarine		
Loss of track support and ballast contamination from seawater inundation	Liaise with Environment Agency regarding level of existing defences	2019
Works on Folkestone Warren sea defences	Repairs to storm damage and extension to existing rock revetment defences	2019
Wind		
Line blockages	Permanent removal of trees within falling distance of the running lines and sensitive equipment	**2019**
Poor adhesion	Permanent removal of trees within wind blow distance of the running lines	**2019**
Cold and Snow		
Line blockage through encroachment from snow-laden trees	Permanent removal of trees within leaning distance of the running lines	2019
Line blockage through snow depth	Earlier implementation of emergency timetables	2014
Adhesion and point heating	Expand programme for con-rail heating	2016
Adhesion		
Signalling faults	Permanent removal of trees within wind blow distance of the running lines	2019
Lightning		
Signalling faults	Improved earthing and protection arrangements	2019

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

Table 3 Potential additional WRCCA actions requiring further evaluation

Vulnerability	Action to be evaluated
Flooding	
Balcombe Tunnel Junction	The track drainage requires clearing with improvements to connectivity with peripheral cutting crest and over portal drainage network.
Earthworks	
Stoats Nest Jn : Earlswood	The deep cuttings at Hooley, which have been the subject of major stabilisation schemes, are under review for further investment in re-enforcement and control measures, including Remote Condition Monitoring. The sensitivity of weak clay-cored embankments to extremes of wetting and drying is to be reduced by better management of drainage, vegetation and burrowing.
Wind	
Route-wide	As with adhesion, vegetation requires constant maintenance and more attention is required to removing the hazard from outside party trees.
Cold and Snow	
Route-wide	As snow and ice has a large effect on SE Route, it would benefit from further points heating. The impacts of snow will be reduced with increased attention to tree removal.
Adhesion	
Route-wide	Vegetation is a continuous project; once sites are cleared they must be maintained and hence this is a workstream that will benefit from continuous investment
	The MPV fleet is a very old set of machines which need to be replaced; route would benefit from newer machines that could perhaps be multi-purpose, .e.g also carry tree/vegetation clearance equipment
Lightning	
Route-wide	Explore option of dissipation array systems

Management and review

Corporate management and review

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

Key actions being taken within corporate functions include:

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

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

South East Route management and review

The Route management is committed to maintaining engagement with the climate change reviews and to adjust, where necessary, the resilience actions set out in this document. The effectiveness of actions implemented, and identification of new risks requiring actions, will be a key component of this review.

Review of Route WRCCA plan actions

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

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

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

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

Network Rail
Cottons Centre
Tooley Streeet
London
SE1 2QG

networkrail.co.uk