2019 – 2024

Wessex

Route CP6 Weather Resilience and Climate Change Adaption Plans

Contents

Purpose of this document

This document; defines the Wessex 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.

Wessex Route Weather Resilience and Climate Change Adaptation Plan – Version 1 October 2020.

Director of Engineering & Asset Management statement

The railway network has been significantly affected by severe weather conditions including wind, snow, rainfall, lightning, heat and cold, all of which can impact our passengers.

Figure 1
Repairing a track washout in the Axe Valley, Salisbury to Exeter line – November 2012

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, earthslip and coastal storm surges. Hotter and drier Summers will increase track buckles and the risk of desiccation related track quality problems respectively.

Wessex Route is particularly vulnerable to predicted changes in precipitation as significant parts of the route are constructed on moisture sensitive clay. These parts of the route are susceptible to desiccation, which impacts track quality in Summer and Autumn, and embankment failure during extended wet periods. While we are able to mitigate the safety risk from these failures, they have a direct and unacceptable impact on journey times and passengers. Approximately 1/3 of the route runs in cuttings which are vulnerable to earthslip during extended periods of wet weather and during intense storms. The track in these areas is also vulnerable to flooding as the capacity of drainage systems is insufficient for increased precipitation. There are several parts of the route vulnerable to flooding from rivers and the sea, funding to address these issues does not form part of the CP6 investment plan. Plans to address these strategic risks will be developed in CP6 and funding to implement changes to the infrastructure requested in future control periods. Through careful investment in the highest risk sites, better monitoring of vulnerable locations and more comprehensive seasonal planning, Wessex Route will continue to reduce the impact of severe weather on the passengers and our lineside neighbours through CP6.

Stuart Kistruck
Southern Region Director Engineering & Asset Management

Executive summary

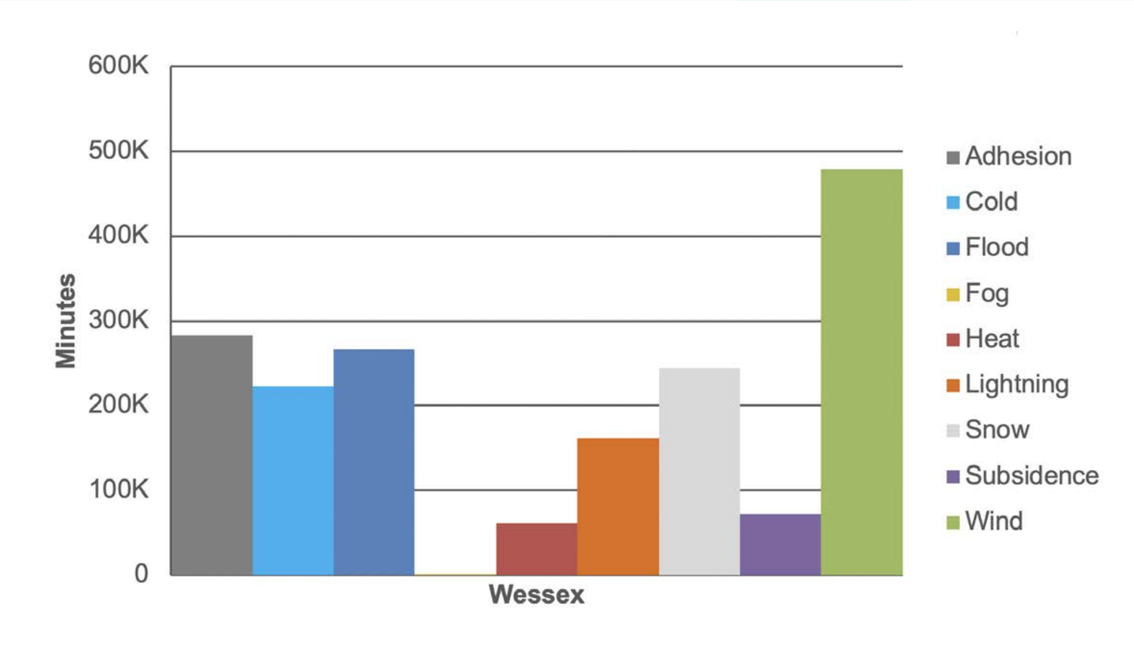
Current weather events can cause significant disruption to the operation of train services and damage to rail infrastructure; this has a negative impact on our customers.

Disruption leads to delays and cancellations to train services, and infrastructure damage can lead to lines being closed to rail traffic for extended periods. 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.

Wessex 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 UKCP18 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 actions that we would take to mitigate these and highlighted future considerations.

Figure 2
Wessex 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.

Key aspects of our CP5 delivery were;

- A significant pumped drainage system, constructed in 2017 at Fullwell in South West London to address a long-standing track flooding problem,
- Over 135,000m of track drainage refurbishment and renewal, reducing the incidence of track flooding at locations throughout the route,
- Renewed or refurbished crest drainage to the top 10 highest risk cuttings, significantly reducing landslip and derailment risk,
- A significant Department for Transport (DfT) funded project, constructed in 2018 to install two new bridges in the Axe Valley on the Salisbury to Exeter line to reduce the frequency of track flooding and the risk of flooding related embankment failure and bridge scour,
- A DfT funded programme of resilience improvements consisting of: enhanced crest drainage systems at Hedge End and Sway in Hampshire, and the replacement of a culvert at Sherburne Dorset with a significantly larger structure,
- Monitoring equipment installations at 22 high risk cuttings and one high risk embankment to alert engineers to earth movement that may indicate imminent landslips,
- River level monitoring equipment installations at 6 bridges at risk of flooding and scour to mitigate risk and minimize the use of operational restrictions to manage safety,
- Improved scour protection to 4No. bridges, reducing the risk of asset failure,
- Repair works, including relining to 2615m^2 of culvert structures,
- Refurbishment to 1700m^2 of coastal defences at Poole Harbour.

In CP6 Wessex Route will continue to deliver works to mitigate weather and climate risk, these include;

- A continuation of the programme of track drainage refurbishment and renewal,
- A significant programme of crest drainage improvements to high risk cuttings,
- Pro-active scour protection works to 4No. bridges, with risk score greater than 16,
- Further refurbishment of coastal defences at Poole Harbour,
- Renewal of high-risk earthworks at 36 locations,
- Refurbishment of high-risk earthworks at 77 locations,
- Culvert works including relining where required to 30No. poor condition culverts,
- Maintenance of existing monitoring systems on high risk earthworks, and the installation of monitoring on more high-risk sites, and
- Renewal of two bridges at Yetminster, Dorset at risk of failure during flood events.

During CP6 Wessex Route will continue to work to understand vulnerability to a changing climate and to develop investment plans to address the risks in future control periods.

Although the actions taken in CP5 improved aspects of our resilience, weather events continue to impact our operations. Wessex 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, resulting in significant inconvenience to customers who find their planned journeys delayed or cancelled.

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. During Summer 2018 an extended period of warm, dry weather led to extensive desiccation damage to the track in areas where the track is constructed on embankments in areas of moisture sensitive clay. This resulted in deformation to the track at 78 locations in the Wessex Route. In February 2019 train services were suspended between Basingstoke and Winchester for over 8 hours after a heavy fall of wet snow brought down trees, blocking the line.

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.

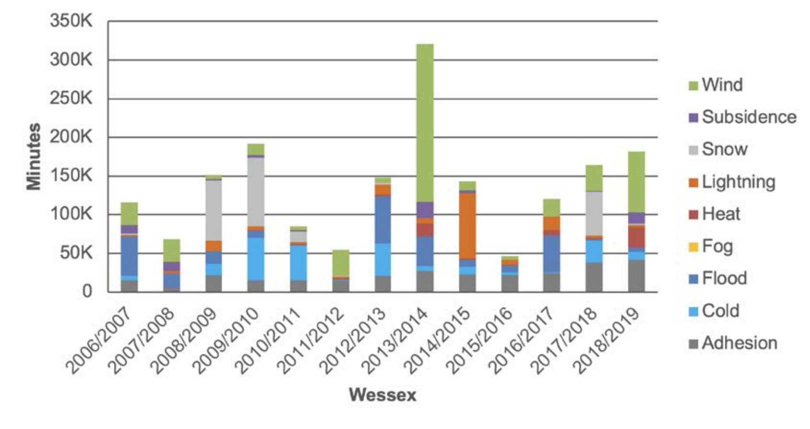
As this data includes the duration and location of each disruption, and attributes cause, it gives a high degree of granularity for use in analysing weather impacts and trends.

In the past 13 years (2006/07 to 2018/19) the average annual number of Schedule 8 delay minutes attributed to weather for the Wessex network was 137,838. This represents 12.9 % of the total number of delay minutes for all causes over that period and equates to an average annual cost of £6.5m.

The impacts of severe weather events on the Wessex Route can be clearly seen in Figure 3, for example;

- Snowfalls of 2009 through to 2011 and 2017/18,
- Wind in a number of years, but particularly 2013/14 and 2018/19,
- Flooding in all years, but particularly in 2009/10, 2010/11, 2012/13 and 2016/17,
- Extreme heat in 2018/19, and
- Significant delay attributed to lightning in 2014/15 largely due to a single storm that disabled a large signal box responsible for controlling trains on a key part of the route.

Figure 3
Wessex 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]

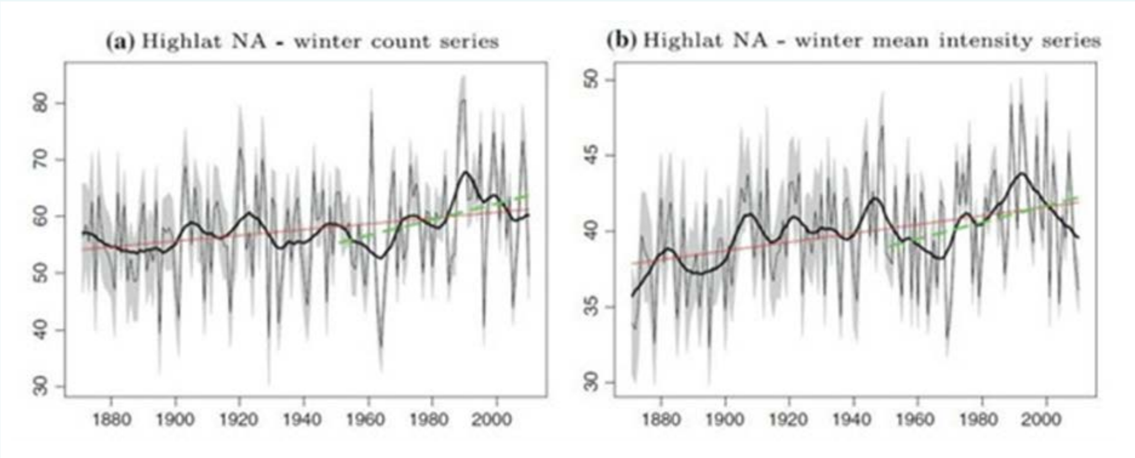
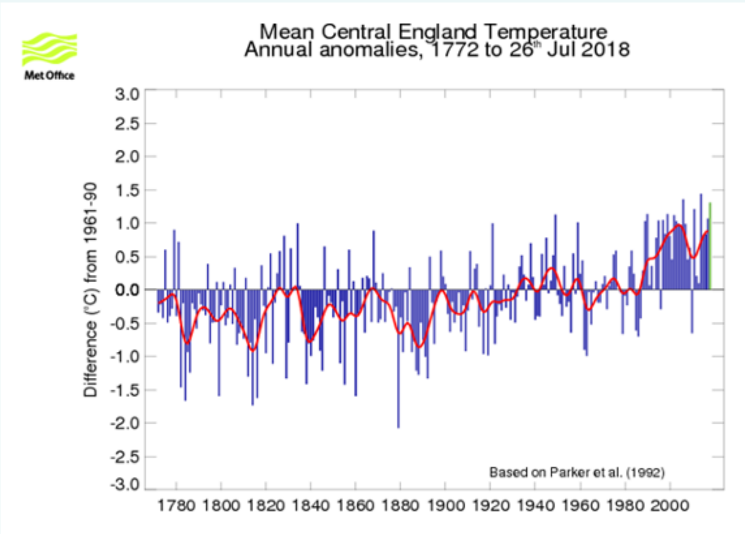


Figure 5
Mean Central England Temperature record[4]



[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 daily maximum Summer temperature and Figure 7 for Winter precipitation.

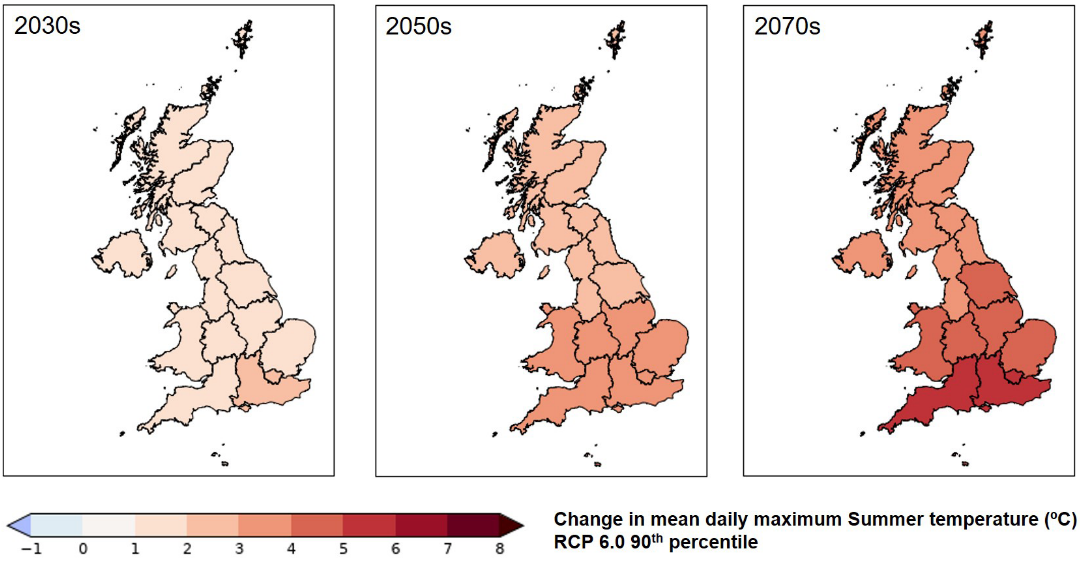


Figure 6
Change in mean daily maximum Summer temperature (˚C) (left to right; 2030s, 2050s and 2070s) based on a 1981–2000 baseline[5]

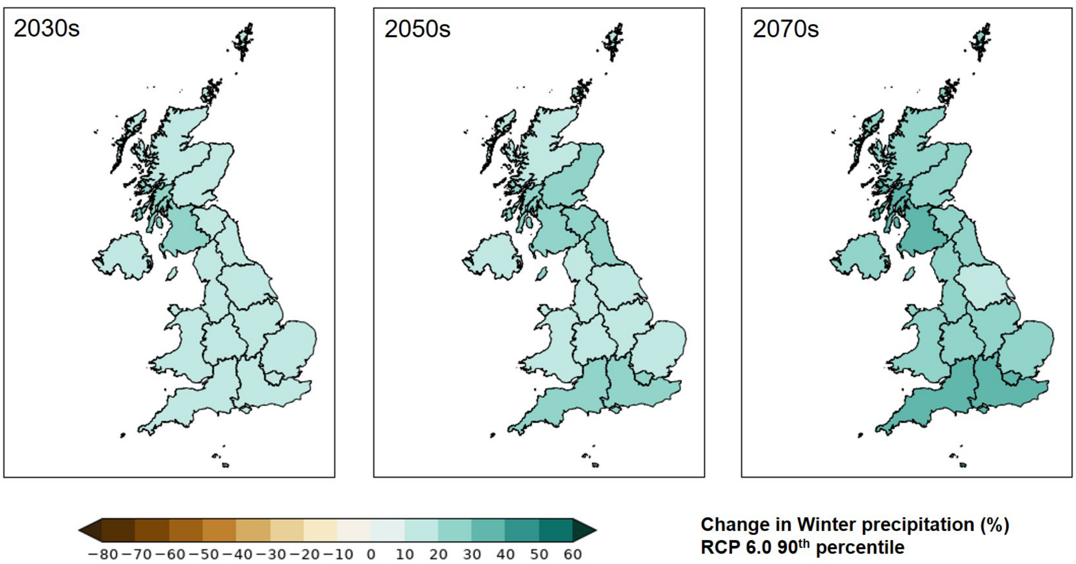


Figure 7
Change in Winter precipitation (%) (left to right; 2030s, 2050s, 2070s) based on a 1981–2000 baseline[6]

[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 Wessex 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.

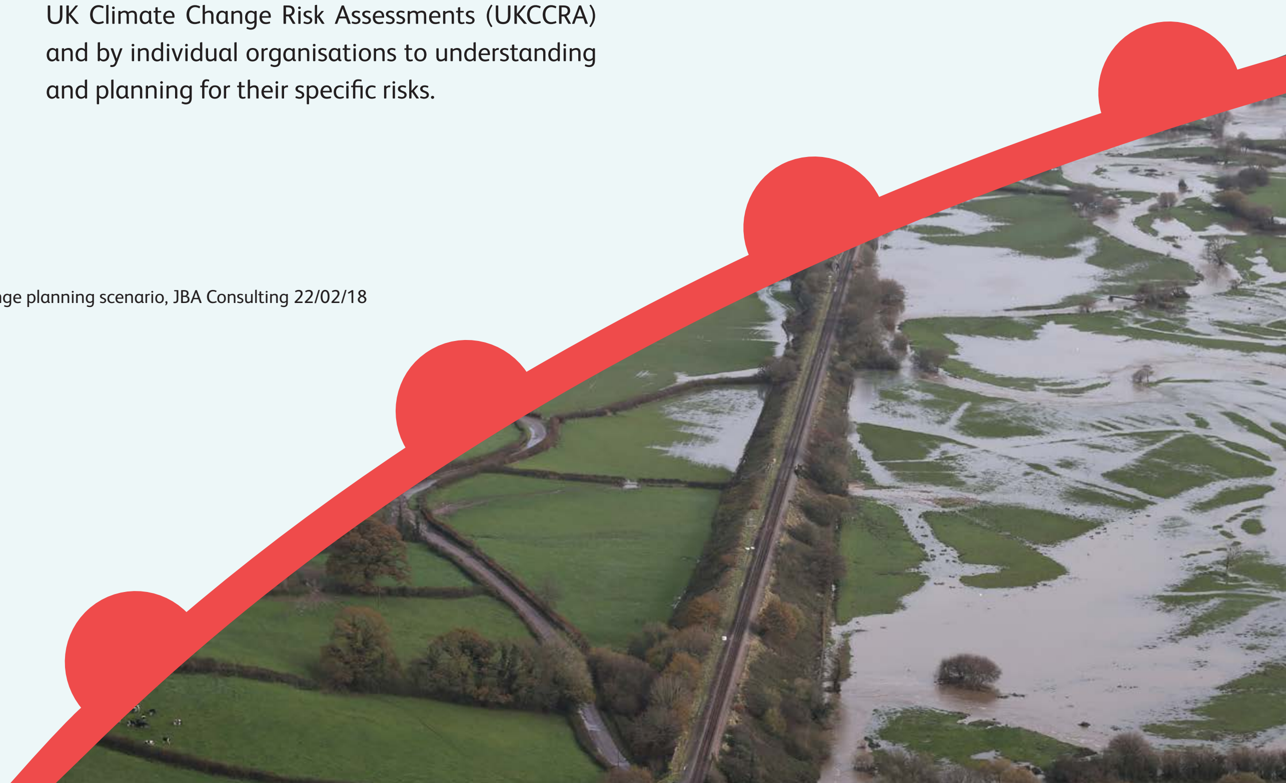
For the 2014 Route WRCCA Plans, Network Rail's national guidance was to use the UKCP09 High scenario, 50th percentile probability projections as an appropriate benchmark on which to base evaluations and decisions. In 2017 Network Rail commissioned a review of its guidance taking into account the Paris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

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

- UKCP18 – RCP6.0, 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 to use 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

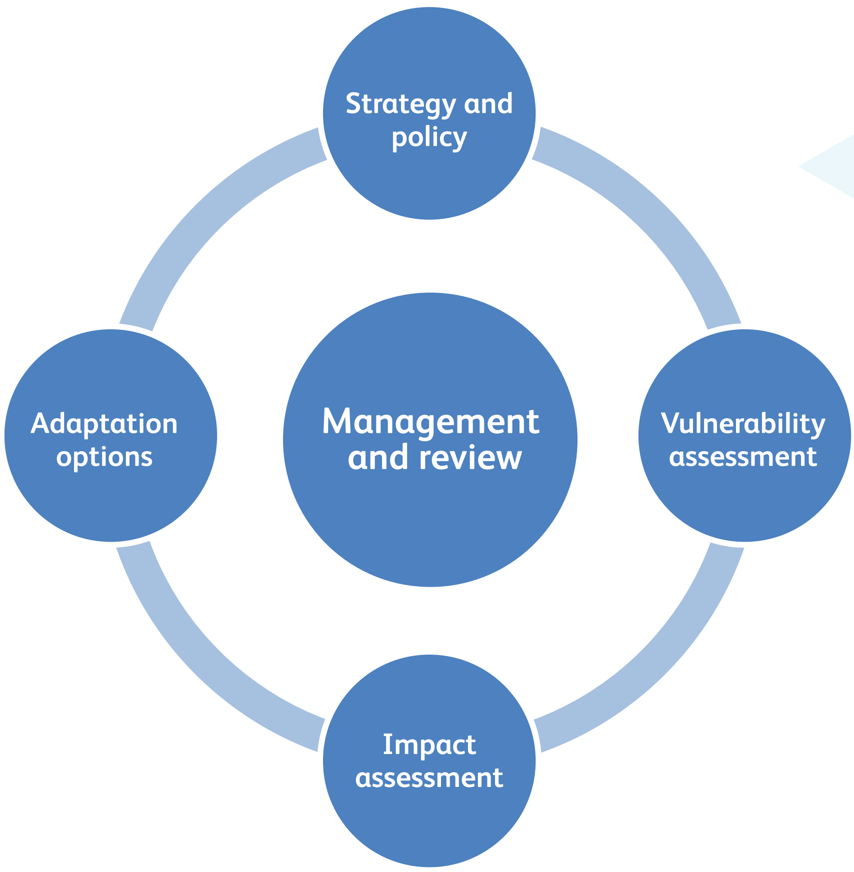
The NAP is based upon the UKCCRA and is published by Defra every 5 years. It contains a summary of the impacts expected for each sector of the UK economy and tables detailing adaptation actions that the UK Government requires those sectors to undertake to ensure the continuing resilience of the UK economy.

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 Wessex Route are included in Table 6 in the Wessex 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. Wessex 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 Wessex 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
Track defects resulting from desiccation in a clay embankment near Guilford – September 2018

Wessex 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 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.

Wessex Route Plan

Wessex Route is committed to including current and future weather impacts when prioritising, developing and delivering capital investment and to ensuring that weather and climate change resilience is achieved at lowest whole life cost, where sufficient capital budget is available to achieve that aim. The route is committed to renewing on a like for better basis when catastrophic asset failure occurs.

Wessex Route has developed a register of areas and assets vulnerable to weather and climate risk, these registers will be maintained and improved during CP6, with mitigations for the highest risks developed. Where route funding cannot address risks, high level investment plans will be developed, and schemes added to the enhancement work bank for future funding.

Wessex Route will continue to improve operational procedures used to mitigate weather risk and will work with professional partners to develop integrated plans to manage shared risks.

Figure 10 Undertaking temporary repairs to a storm damaged embankment at Yeovil Somerset – February 2014

Wessex Route vulnerability assessment

In the 2014 Route WRCCA Plan this section provided details of the general vulnerability of the national rail network and Wessex 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.

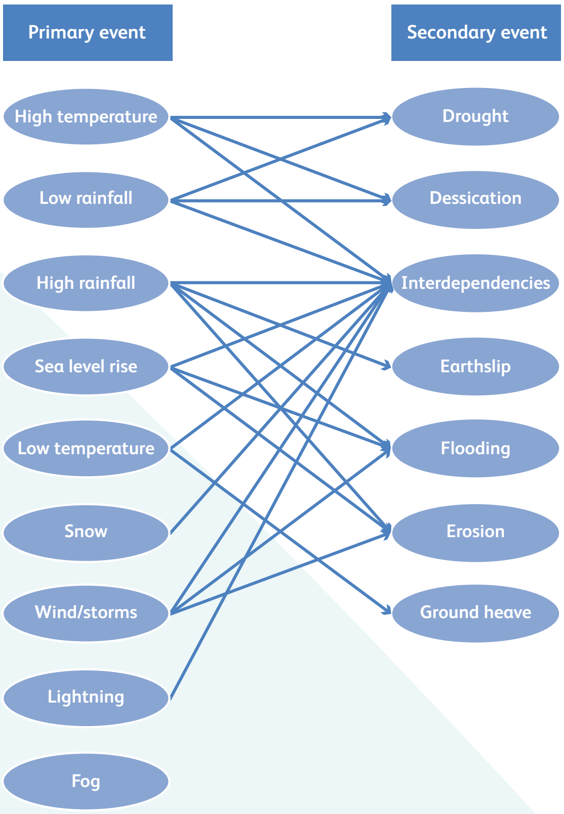


Figure 11
Examples of primary and secondary events

Wessex Route vulnerability assessment continued

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, OLE 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

Wessex Route has some specific vulnerability to severe weather. The western parts of the route pass through difficult topography requiring the original railway builders to use numerous deep, steep cuttings, tunnels and large embankments to maintain acceptable gradients. To minimize construction costs the lines were routed down river valleys where possible, this has resulted in this part of the route suffering from a high risk of earthslips and flooding in wet weather conditions. This risk is raised further by the effect the Blackdown Hills has on locally increasing rainfall rates, and the east west orientation of the Route in this area that means that storms tend to track along the line resulting in flooding in multiple locations. Roads in the area are also prone to flooding and earthslip often making it difficult or impossible for maintenance staff to access sites to quickly rectify problems. All tunnel approach cuttings on this line had crest drainage improved during CP5 to reduce the risk of landslip, and all of these cuttings have also had monitoring installed during CP5 to alert engineers should a landslip occur.

In large areas at the eastern part of the route the underlying geology is of moisture sensitive clay, a material that is prone to softening and expanding in wet Winter conditions and shrinking when desiccated, a risk in dry Summers. This results in an elevated risk of landslip in wet Winters and difficulty in maintaining track geometry in late Summer and early Autumn.

The repeated seasonal expansion and contraction can also, over long periods, push over retaining walls and results in embankments becoming lower and wider over many years. This requires maintenance to maintain track geometry more intensively than in areas with more stable geology.

Southern parts of Wessex Route pass through the tidal flood zone, this causes infrequent disruption at present, however future risk must be quantified so that appropriate plans can be made before the risk of tidal flooding and coastal erosion becomes unacceptable. During CP5 a study was undertaken to quantify the coastal flooding and erosion risk and some erosion protection work has been progressed at Poole Harbour.

Specific vulnerabilities on the Wessex Route to weather impacts include high-risk earthworks on the Salisbury to Exeter line. This area of the network passes through the Blackdown Hills which are prone to failure during periods of heavy rain due to very soft geology and over steep earthworks. Honiton tunnel is a good example of the challenge in managing these assets. Improved drainage has been constructed during CP5, and the most vulnerable areas are programmed for investment in CP6 to arrest active landslips in the cutting. Similar conditions exist on parts of the Weymouth to Bristol line and elsewhere on the route.

Figure 12
Honiton tunnel earthwork failure – February 2012

Wessex Route vulnerability assessment continued

Large sections of the Salisbury to Exeter line near Axminster run in the River Axe flood plain. Some of the embankments and up to nine river crossings in this area require modification to reduce the risk of flood damage. The embankment near Broom Level Crossing was strengthened with sheet piles in CP4 to reduce the chance of washout at this location in the future. In 2018 two new bridges were built, one at Broome Level Crossing and one at Axe Farm Level Crossing to reduce the risk of future embankment failure. The line remains at significant risk of flooding due to the increasing river flows and the low height of the embankments throughout the area.

Several bridges within the route are at higher risk of flood damage including those at Yetminster on the WEY line and at the River Frome on the Bournemouth main line. The Yetminster bridge will be replaced in early CP6, but due to technical constraints the new bridges will not offer significantly improved performance during flood events. While the bridges remain at significant risk of inundation, they will however feature more resilient construction, therefore reducing the risk of asset failure during flood events, and reducing the time taken to re-open the line following flooding. River level monitoring via Remote Condition Monitoring (RCM) and a robust procedure to stop traffic when river levels are unsafe will be maintained to ensure safety.

Figure 13
Track washout at Broom Crossing, Axe Valley – November 2012

Figure 15
Yetminster bridge during high river flows – January 2008

Figure 14
Construction of new railway bridge in the Axe Valley to reduce future flood impact – September 2018

Recent severe Winters have exposed the route to significant flooding. The line at Datchet was closed for several days in early 2014 as a result of the River Thames experiencing the highest levels recorded for over 40 years, reminding all that significant parts of Greater London are at risk of flooding. The Environment Agency (EA) has designed a scheme to improve the flood performance of this section of the Thames. The EA is planning to undertake significant works in late CP6 to reduce the flood risk to communities in the Datchet area. This will require the construction of two new bridges under the Windsor and Eaton Riverside branch and a new river channel adjacent to the railway to connect these two bridges to the main river channel. Wessex Route is actively engaged with the project. Network Rail's Capital Delivery function has entered into an agreement with the EA to build the 'on railway' portion of this project consisting of removal of all railway infrastructure from the new bridge locations, construction of the two new bridges and reinstatement and commissioning of railway assets and systems.

Large parts of the route near the South Coast are vulnerable to sea level rise including sections of line near Poole Harbour and the Portsmouth line as it approaches through Portcreek Junction and crosses Portcreek Viaduct. This viaduct will require replacement before mid-century as track level is currently predicted to be below flood levels at that time and is below the crest level of the new flood defences recently constructed to protect Portsmouth from rising sea levels.

Figure 16
Portcreek viaduct at high tide – month not known 2018

Large parts of Wessex Route are built on moisture sensitive clay. Embankments constructed from this material are prone both to conventional failure when saturated in Winter but also to desiccation where track quality is very difficult to maintain in dry Summer and Autumn conditions. This affects several lines but is most pronounced on the BKE line between Reading and Basingstoke, the GTW line from Guildford to Ash, the NGL line from Guildford to Surbiton, the ETF line from Eastleigh to Fareham, the BAE2 line from Gillingham to Yeovil, and elsewhere on the route, including the BML line between Wimbledon and Woking.

The BKE line forms part of the strategic freight network and there is no freight diversion due to restricted gauge on all alternatives. Significant works are required to improve resilience of the BKE line and in order for this work to take place a freight diversion is likely to be required to facilitate sufficient access to undertake such significant work. Desiccation is likely to be an increasing challenge to manage as longer, drier Summers with higher average and peak temperatures lead to increased desiccation and therefore more shrinkage which is likely to lead to more track quality issues.

Wessex Route vulnerability assessment continued

Wessex Route is largely DC electrified and this technology although extremely resilient in most conditions is prone to icing. The worst effect occurs when rain falls on a conductor rail that is below freezing. This happens infrequently but the consequences are very disruptive, particularly if this occurs early in the morning before rail traffic is busy enough to clear ice as it forms. Conductor rail icing is likely to be a reducing problem in the future, and well targeted rail head treatment with hydrophobic products can significantly reduce the impact of these conditions by preventing water freezing to the con-rail. DC electrification is also unreliable if flooding occurs, this is likely to increase in frequency unless significant improvements are made to the drainage asset. The areas of the route most at risk from coastal flooding are DC electrified. During CP6 the impact of this emerging risk must be better understood and plans drawn up to mitigate them in the long term. A significant proportion of snow related delay in Winter 2018/19 was as a result of coppiced hazel in chalk cuttings overturning onto track and blocking the line. This vegetation cannot be removed as it is valuable dormouse habitat, but it can be managed in a way that prevents it posing a risk to the passage of trains.

Figure 17
Pinks Hill embankment failure – July 2014

Heat speeds are currently well managed and most jointed track has been removed from heavily trafficked parts of the route with the small areas of jointed track remaining largely programmed for removal in CP6. Maintenance work is programmed to minimize formation disturbance during the Summer months. Increased maintenance volumes in CP6 will allow the track to enter the Summer period with better geometry and more consistent stressing, increasing resistance to desiccation and high temperatures. As average temperatures increase, the length of Summer in effect lengthens, and the window for intrusive track maintenance will reduce. This will be a significant challenge for maintenance teams who do not currently have access to any additional maintenance shifts in Winter.

As embankments weather they tend to become narrower at the crest and over time they settle. Most current track maintenance practices maintain the height of or raise the track, and the position of the track must be maintained over structures. These factors together have resulted in parts of the route suffering from having no space at the crest for a safe cess and insufficient space to maintain a compliant ballast shoulder. As temperatures increase, we must find a cost-effective way to lower track in areas where this is possible, so it fits on the underline bridges and embankments, or undertake works to make space for the track formation on the narrow embankments. The lack of cess width in places not only makes maintaining track difficult, it increases the chance of track buckling during hot weather, therefore requiring speed restrictions during hot weather to manage safety. A narrow cess also increases the chance of earthwork failures during wet weather, such as at Pinks Hill near Guildford which failed in July 2014 following a very wet Winter.

One of the most significant weather-related safety and performance incidents in recent years was the St Jude storm of the 27th and 28th October 2013; this brought down hundreds of trees across the route. If storm intensity and frequency increases, the impact of such weather events will be significant unless the number of trees able to fall on the line, both owned by Network Rail and third-party owned, is reduced.

Summer 2018 was the driest recorded for Wessex Route since we started tracking Soil Moisture Deficit in 2000. The extended dry period coincided with the highest number of days with an average temperature over 20˚C, 29 days exceeded this threshold. The previous highest number of days over 20˚C was 22 days, recorded in 2003 and in 2017. This run of hot dry weather had a devastating impact on performance as desiccation led to a significant upturn in track defects needing a speed restriction to manage safety. During September 2018 there were up to 62 speed restrictions imposed; this led to a PPM attrition of over 3 %.

Figure 18
Track impacted by desiccation between Guilford and Ash – Summer 2018

Wessex Route vulnerability assessment continued

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.

UKCP18 provides regional projections across 13 administrative regions in Great Britain (Figure 19), The Wessex Route falls within two of these regions, South East England and South West England. 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 emissions 50th percentile probability scenario for the two 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 to match 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).

Figure 19
Map of UK administration regions used in UKCP18[8]

[8]Source: 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]

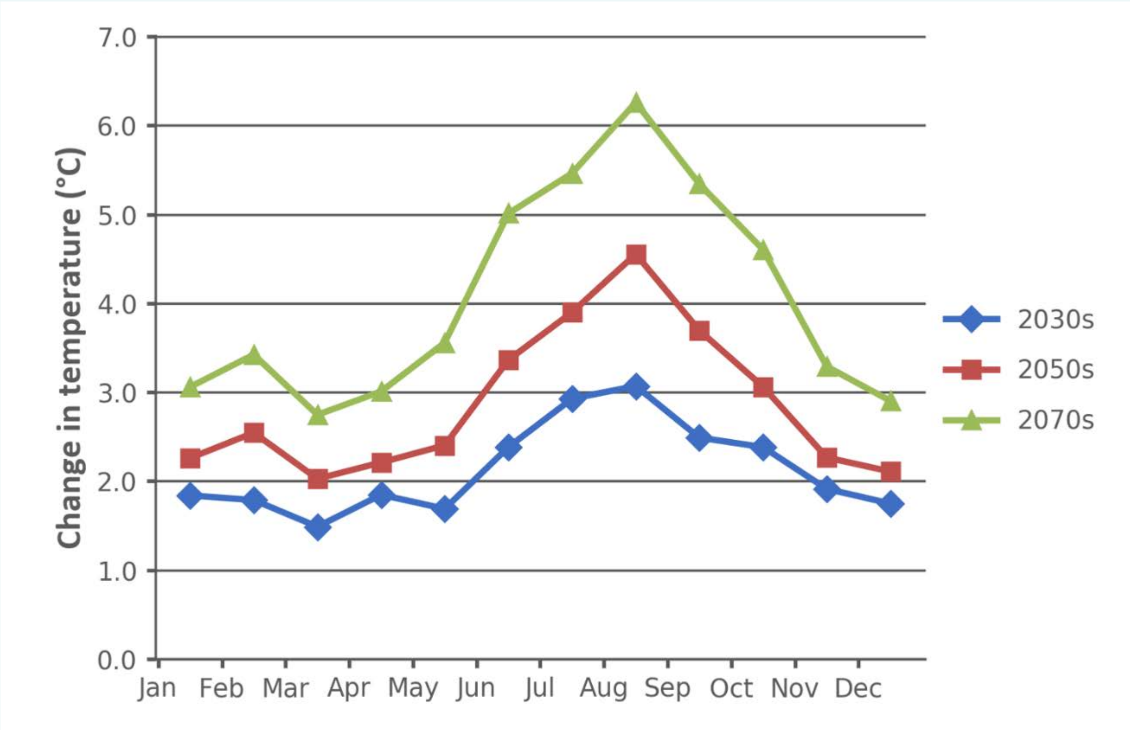
Mean Daily Maximum Temperature change

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

South East England

The highest mean Summer temperatures are expected to be in August for both the 2050s and 2070s with increases of 4.6˚C to 26.4˚C and 6.3˚C to 28.1˚C respectively. In Winter the highest mean temperatures will be seen in December, with increases of 2.1˚C to 10.1˚C and 2.9˚C to 10.9˚C respectively.

Figure 20
South East England, mean daily maximum temperature change (˚C) (RCP 6.0 90th percentile)



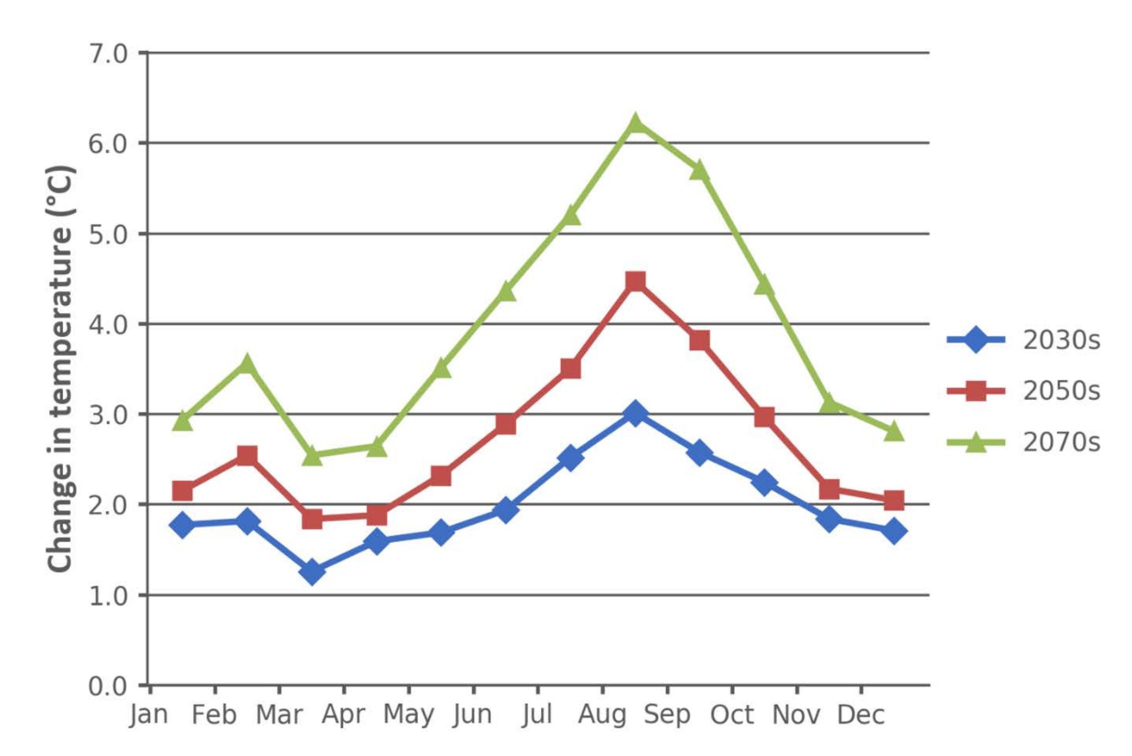
Wessex Route vulnerability assessment continued

South West England

The highest mean daily maximum Summer temperatures are expected to be in August for both the 2050s and 2070s, with increases of 4.5˚C to 25.0˚C and 6.2˚C to 26.8˚C respectively.

In Winter the highest mean temperatures will be seen in December for the 2050s, with increases of 2.0˚C to 10.4˚C and February by the 2070s with increases of 3.6˚C to 11.3˚C.

Figure 21
South West England, mean daily maximum temperature change (˚C) (RCP 6.0 90th percentile)



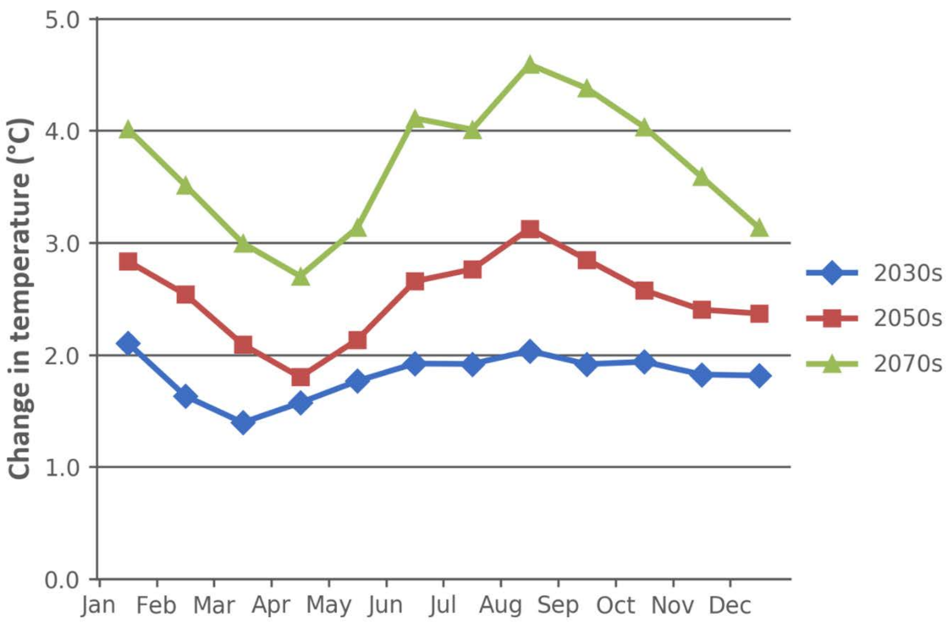
Mean Daily Minimum Temperature change

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

South East England

The highest mean daily minimum temperatures for Summer are expected to be in August, with increases of 3.1˚C to 15.0˚C by the 2050s and 4.6˚C to 16.5˚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 3.6˚C, and by 3.5˚C by the 2070s to 4.5˚C.

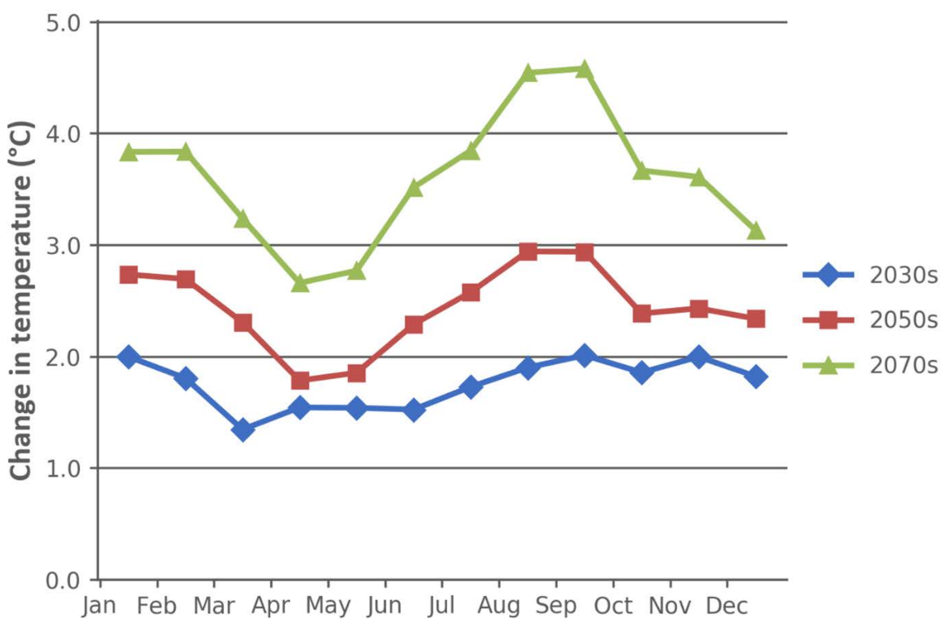
Figure 22
South East England, mean daily minimum temperature change (˚C) (RCP 6.0 90th percentile)



South West England

The highest mean daily minimum temperatures for Summer are expected to be in August, with increases of 2.9˚C to 14.7˚C by the 2050s and 4.5˚C to 16.3˚C by the 2070s. The lowest mean minimum temperatures will still occur in February with expected increases being 2.7˚C by the 2050s to 4.3˚C, and 3.8˚C by the 2070s to 5.5˚C.

Figure 23
South West England, mean daily minimum temperature change (˚C) (RCP 6.0 90th percentile)



Wessex Route vulnerability assessment continued

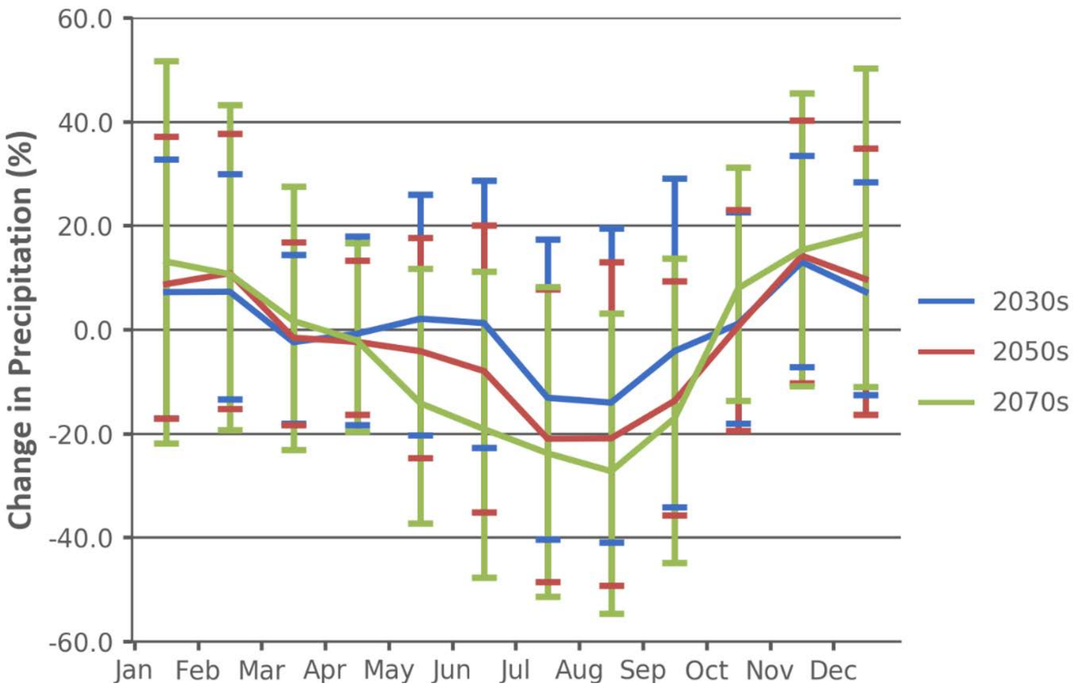
Mean daily precipitation

The UKCP18 narrative for mean daily precipitation in the regions is of significantly wetter Winters and drier Summers. Network Rail's chosen climate change planning scenario (RCP 6.0 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 RCP 6.0 10th percentile projections. Figure 24 and Figure 25 therefore plot the RCP 6.0 50th percentile projections with error bars that indicate the wider range of change associated with the 10th and 90th percentiles.

South East England

In the 2050s and 2070s December will be the wettest month with mean daily rainfall increases of 34.8 % to 3.8mm/day and 50.3 % to 4.2mm/day respectively. The driest month will be July showing decreases of 48.6 % to 0.8mm/day by the 2050s and 51.3 % to 0.7mm/day by the 2070s.

Figure 24
South East England, mean daily precipitation change (%) (RCP 6.0 50th percentile with the wider range showing the 10th and 90th percentiles)

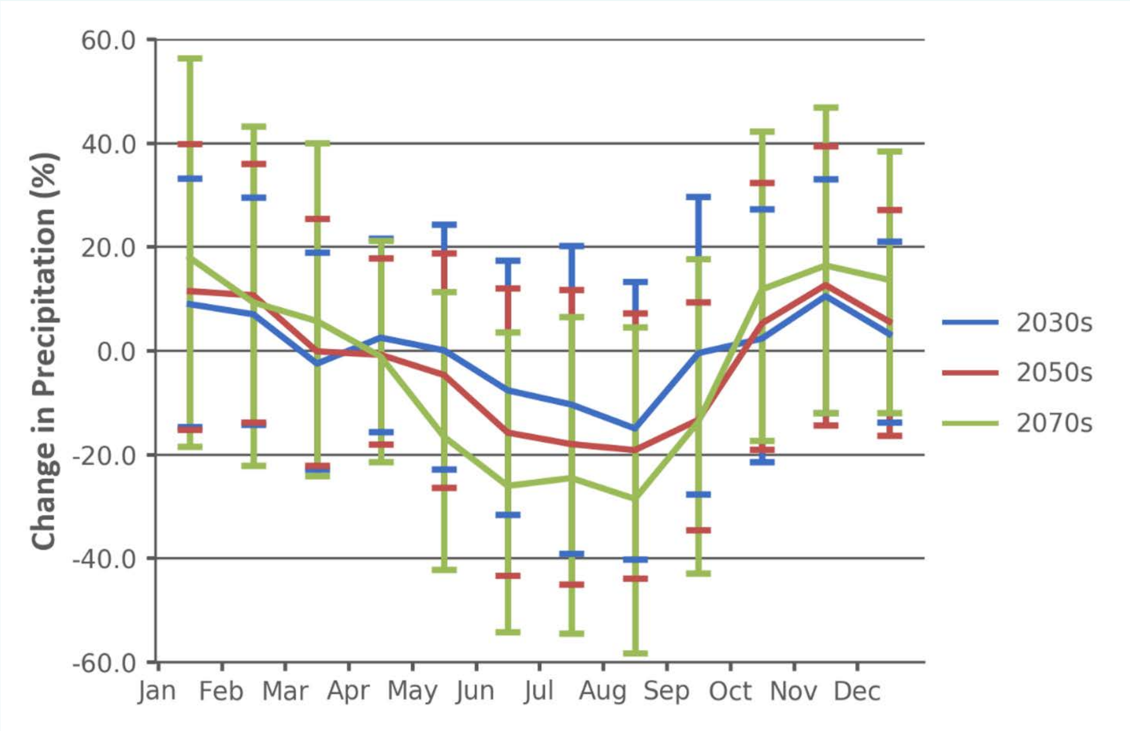


South West England

In the 2050s and 2070s December will be the wettest month with mean daily rainfall increases of 27.2 % to 5.4mm/day and 38.4 % to 5.8mm/day respectively (and in the 2070s, both January and December receive 5.8mm/day).

The driest month will be July showing decreases of 45.1 % to 1.0mm/day by the 2050s and 54.5 % to 0.8mm/day by the 2070s.

Figure 25
South West England, mean daily precipitation change (%) (RCP 6.0 50th percentile with the wider range showing the 10th and 90th percentiles)



Wessex 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 will 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 Wessex 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 Wessex Route regions are shown in Table 1.

Table 1
River flow uplifts (UKCP09)

River basin	2050s uplift	2080s uplift
Thames	25 %	35 %
South East England	30 %	45 %
South West England	30 %	40 %

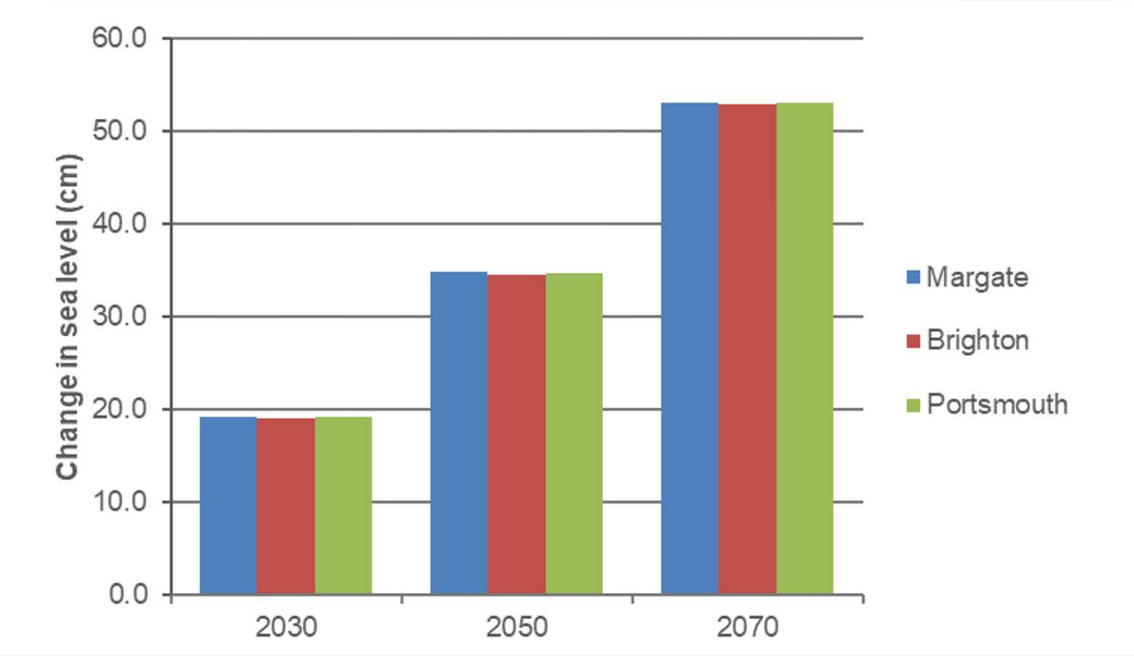
Sea level rise

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, UKCP18 projections have been obtained for 3 coastal locations in both of the administrative regions covered by the Wessex Route[10].

South East England

Margate will see the highest rises by 2050 and 2070 of 34.8cm and 53.1cm respectively and Brighton will see the lowest at 34.6cm and 52.9cm.

Figure 26
Sea level rise projections for South East England (cm) (RCP 4.5 95th percentile)

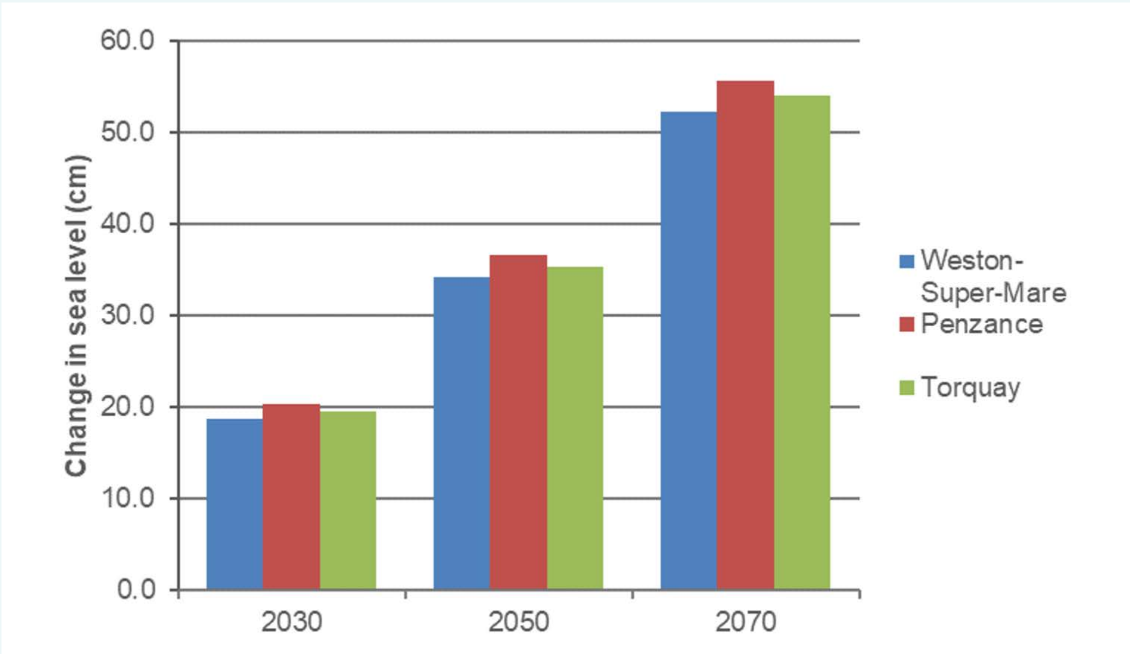


[9] EA higher central climate change estimate as the most comparable to Network Rail's climate change planning scenario.
[10] Sea level rise data in UKCP18 is not available for RCP 6.0, instead RCP 4.5 is used as a proxy on the recommendation of the Met Office. This is the most compatible with the Network Rail Primary planning scenario.

South West England

Penzance will see the highest rises by 2050 and 2070 of 36.5cm and 55.6cm respectively and Weston-Super-Mare will see the lowest at 34.1cm and 52.2cm.

Figure 27
Sea level rise projections for South West England (cm) (RCP 4.5 95th percentile)



Wessex Route impact assessment

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

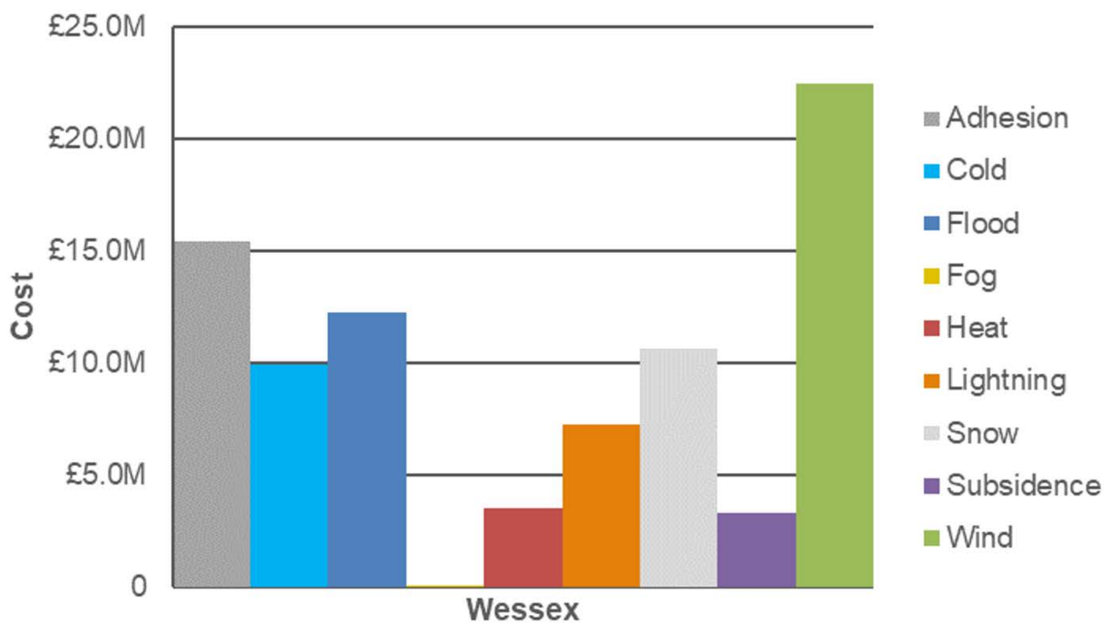
Performance impacts

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

It is acknowledged that Schedule 8 has limitations in recording the true cost of weather and disruption and does not account for the full cost of severe weather events. Schedule 8 disproportionately represents impacts that lead to delay, rather than those that close lines. Wind is over represented as operational processes require blanket speed restrictions to be used to mitigate safety risk when a threshold is exceeded. This generates a lot of delay versus the published timetable, whereas for landslip (recorded in S8 data as subsidence) failures often block lines, and the costs of recovering from landslip can run into several £million for a single site. A project to identify the true cost of weather and climate change disruption and recovery is being progressed in CP6.

In the 2014 plan eight financial years of Schedule 8 data were analysed to give an assessment of the weather impacts for the Wessex Route. This Plan updates that assessment using additional data from the past 5 years, see Figure 28.

Figure 28
Wessex Route weather attributed Schedule 8 costs – 2006/07 to 2018/19



The updated analysis shows that wind continues to be the most significant weather impact costing a total of £22.4m in the last 13 years. This is around one third or so more than the costs of adhesion and flooding and more than double that of snow and cold related incidents which cost £15.4m, £12.2m, £10.5m and £9.9m respectively 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 Wessex 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 Wessex Route

Impact	Schedule 8 Cost per year[11]	Climate projections[12]	Prioritisation
Wind	Average £1.73m Highest £6.91m	Changes difficult to project, however generally expected to increase	High
Adhesion	Average £1.19m Highest £2.57m	Complex relationship between multiple causes and their climate projections	Medium
Snow	Average £0.82m Highest £3.73m	Changes difficult to project, but increases in Autumn, Winter and Spring minimum temperatures suggest reduced snow days	Medium
Lightning	Average £0.56m Highest £3.18m	Changes in storms difficult to project, however generally expected to increase	Medium
Cold	Average £0.76m Highest £2.14m	Increases in mean minimum daily temperatures across the regions in Autumn, Winter and Spring ranging from 1.8°C in April to 2.9°C in September for the 2050s and 2.7°C in April to 4.6°C in September for the 2070s	Low
Subsidence	Average £0.25m Highest £0.72m	Increases in mean daily rainfall across the regions for late Autumn, Winter and early Spring months, for example; 13.2 % in April and 39.8 % in January by the 2050s becoming 16.7 % in April and 56.3 % in January by the 2070s Decreases in mean daily rainfall for late Spring through to early Autumn, for example; 26.3 % in May and 49.3 % in August by the 2050s becoming 37.2 % in May and 58.4 % in August by the 2070s Increased frequency and intensity of Winter and Summer storms	High
Heat	Average £0.27m Highest £1.87m	Increases in mean maximum daily temperatures across the regions range from 2.0°C to 2.5°C (Winter) and 2.9°C to 4.6°C (Summer) by the 2050s. In the 2070s this becomes 2.8°C to 3.6°C and 4.4°C to 6.3°C respectively	Medium
Flooding	Average £0.94m Highest £3.60m	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 <£0.01m Highest <£0.01m	This is a complex picture with low confidence[13], however possible seasonal changes across the regions for the 2080s have been indicated as: Winter +7 % to +4 %, Spring -40 % to -42 %, Summer -69 % to -70 % and Autumn -28 % to -31 %	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.

[11]Range in cost per year over the last 13 years from 2006/07 to 2018/19
[12]UKCP09 projections still used for wind, snow, lightning and fog as UKCP18 does not contain updates
[13]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

Wessex Route impact assessment continued

Identification of higher risk locations

Since the publication of the last Plan the Wessex 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 analysis of the delay minute and Schedule 8 cost data and 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 Wessex 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.

Heat impact assessment

Between 2006/07 and 2018/19 heat related incidents accounted for an average of 4,745 delay minutes and £0.27m in Schedule 8 costs per year. This is 3.4% of Wessex's annual average weather-related delay minutes and 4.1% of the annual average cost.

Track asset

As we experience longer periods of dry and hot weather, the management of the track asset needs to change. The increasing number of train services coupled with our desire to minimise passenger disruption means that the track asset needs to be managed in a way that makes it more resilient to the changes in weather the Route is experiencing than was previously the case.

The management of the track asset will now need to include more robust preparation in advance of the Summer. This will comprise completion of hot weather preparation works to eliminate deficiencies such as unstressed rails and ballast shortages earlier in the spring, and to improve geometry. The management of track geometry and ballast disturbance works will need to be reduced in Summer to help prevent track buckles. Any shortfall in this activity leads to staff being deployed on watchman duties and speed restrictions being imposed – the more extreme temperatures get, the wider the need for blanket speed restrictions.

The current process and framework with which we balance the risks of track geometry faults and track buckle needs to evolve. The development and delivery of requirements set out for the hot weather preparation of the track asset needs to achieve a reduction in the overall number of deficiencies and specifically target no deficiencies on certain parts of the network. Requirements for the management of the track asset during prolonged periods of hot and dry weather also need to be made more robust – giving front line teams clearer guidance on the management of deteriorating track geometry versus track buckle risk. Network Rail standards will also need to be reviewed and updated as part of this process.

Vegetation

Although current research is not advanced enough for us to be able to understand the detailed risks and impacts of climate change on our line side vegetation at this time, we can make some general assumptions that allow us to consider our responses going forwards.

As the year will become warmer on average in all seasons, growing patterns will change significantly over time. Some species may not tolerate the new local conditions and their distribution patterns may change. Long lived species, for example some broad leaved trees will potentially be less able to adapt. There is also emerging evidence that some tree diseases, such as Ash die back, are increasing in prevalence due to climate change induced tree stress. If the health of trees suffers they will need to be felled to manage safety risk, this is likely to be both very expensive and will require careful management to protect organisational reputation. In areas where currently dominant vegetation dies back, or is removed, there is the potential for pioneer species to colonise the rail corridor. Many of these are likely to grow vigorously in the warmer prevailing conditions and may potentially grow for more of the year. Under these circumstances the intensity of lineside management may need to increase to maintain rail safety. Changes in species range may also introduce species completely new to the UK, potentially including species injurious to health. More vigorous growth would mean that core safety activity such as examination of earthworks, drainage and structures may be more difficult if the asset is obscured by greater vegetation growth year-round. This could drive a greater need for vegetation management. Our ability to achieve such management may face greater constraints if the bird nesting season shifts or expands. Changes in our lineside habitats and the wider climate issues may mean that we will need to consider changes in our current vegetation management practices, for example; we may not wish to leave significant cut and chipped material on site due to increased risk of line side fires.

Buildings

As the year will become warmer on average in all seasons, and heatwaves will increase in frequency, intensity and duration, the current building stock will require modification or enhancement to provide an internal environment suitable for customers, staff and equipment (for example electrification, signalling and vital communications equipment). Much of our current lineside and depot building stock comprises lightweight modular buildings with poor thermal performance

Longer dryer Summers will lead to increased desiccation, this is likely to represent an increased risk of desiccation related subsidence to buildings constructed on moisture sensitive clay.

Wetter Winters and a greater frequency of intense rainfall events will test the water tightness of the building stock and it may be necessary to upgrade rainwater goods, particularly on large station and train shed roofs.

Structures

Longer dryer Summers will lead to increased desiccation, this is likely to represent an increased risk of desiccation related subsidence to structures constructed on moisture sensitive clay.

As structures tend to have a significant operational life the predicted temperatures are outside the range envisaged when many of the current structures were designed and constructed. Some structural elements will expand beyond design limits, initially freezing expansion joints, then generating significant stresses and strains within the structures for which they were not designed. The impact of this is currently poorly understood as each structure is unique and calculating the impact of such heat induced load would require work on a structure by structure basis, with high quality survey data available.

Wessex Route impact assessment continued

Cold and snow impact assessment

Between 2006/07 and 2018/19 cold related incidents accounted for an average of 17,151 delay minutes and £0.76m in Schedule 8 costs per year. This is 12.4% of Wessex's annual average weather-related delay minutes and 11.7% of the annual average cost. Over the same period snow related delays averaged 18,817 delay minutes and £0.82m in Schedule 8 costs per year. This is 13.7% of the annual average weather-related delay minutes and 12.5% of the annual average cost.

The year will become warmer on average in all seasons. Spring will move earlier, 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 business case for maintaining equipment to manage ice and snow will weaken but failing to do so would have dire consequences when less frequent cold periods do occur.

Flooding and sea level rise impact assessment

Between 2006/07 and 2018/19 inland and coastal flood related incidents accounted for an average of 20,539 delay minutes and £0.94m in Schedule 8 costs per year. In combination these represent 14.9% of Wessex's annual average weather-related delay minutes and 14.4% of the annual average cost.

Fluvial and Pluvial 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 significantly.

The capacity of track and off-track drainage systems will be exceeded with increasing frequency, causing more frequent incidences of track flooding and potentially washout failure in cuttings and ballast washouts. The increased flashiness will be most pronounced in small catchments, this is likely to lead to flows in minor watercourses increasing significantly. Many minor watercourses pass under the railway in relatively small culverts, demonstrably too limited in capacity for today's extreme weather events. As this problem is exacerbated the risk of culvert collapse, or track washout in the vicinity of culverts, will increase. A similar risk exists in small catchments that drain into the rail corridor where the line is in a cutting, flashy flood events will likely overwhelm crest drainage systems. Both of these failure mechanisms tend to be sudden and have the potential to result in derailment. Increased flashiness in larger rivers will increase both scour risk, and the risk of bridges being damaged by hydrostatic lift, or track washout. Increased unplanned operational restrictions, including temporary line closures will be required to manage this risk.

Sea level rise

Sea level will rise along the Wessex 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. The areas currently at risk of flooding and coastal erosion are well understood, and a study completed during CP5 highlights additional areas at risk in future control periods.

Earthslip and Desiccation

Between 2006/07 and 2018/19 earthslip and desiccation related incidents accounted for an average of 5,550 delay minutes and £0.25m in Schedule 8 costs per year. This is 4.0 % of Wessex's annual average weather-related delay minutes and 3.9 % of the annual average cost. However this is far less than the true impact, as lines are frequently blocked by flooding prior to earthslips occurring, and consequently the delays are attributed to flooding. Also because the landslips close lines, sometimes for several days, there are no delays, and the disruption takes the form of cancelled services. As desiccation tends to lead to track quality problems, the delays are attributed to track in many cases.

The cost of recovering from landslip tends to far outweigh the cost of resulting delays. Most years several significant landslips occur and recovery costs tend to be in the £0.5-£6m range. Delivering this reactive work has an impact on the delivery of planned works increasing costs in the wider portfolio.

Winters are expected to become significantly wetter on average and the frequency and intensity of Winter storms will increase. Whilst Summers will become significantly drier the intensity and frequency of Summer storms is expected to increase markedly. Summer storm rainfall will be more severe than in Winter (see climate data). Increased storminess will increase the risk of washout driven earthslip. This will be from increasing exceedance of existing crest-drainage systems capacity and increasing vulnerability of overland flow areas currently with no crest drainage. During extended periods of wet weather in Winter, cuttings and embankments in softer geology will be more susceptible to failure. In the sandy parts of the route, there is an increasing risk of washout failures to embankments and cuttings due to increased frequency of intense rainfall.

Longer dryer Summers will lead to increased desiccation, this is likely to represent an increased risk of desiccation related subsidence to buildings and structures constructed on moisture sensitive clay. The predominate risk associated with desiccation is an increasing impact on track quality in Summer and Autumn, this is discussed in the Track Vulnerability section.

Wind impact assessment

Between 2006/07 and 2018/19 wind related incidents accounted for an average of 36,815 delay minutes and £1.73m in Schedule 8 costs per year. This is 26.7 % of Wessex's annual average weather-related delay minutes and 26.5 % of the annual average cost. Delay's attributable to wind are split between those accrued when an emergency timetable has to be instigated at short notice to manage safety, and those accrued when wind brings down trees onto the line, requiring line closures to clear fallen trees. Wind 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.

As the intensity of Winter storms increases buildings may require modification to prevent water ingress as wind speeds increase and rainfall intensity increases. Some of our large train shed roofs already struggle to cope with current storm conditions. As these buildings represent significant catchment areas and the rainwater management systems are often integral to the building structure, it can be impractical to increase system capacity without extensive building modification.

Higher wind speeds may bring some structural elements of some buildings close to, or beyond safe wind load capacity. Many historic station canopies, and some large train shed roofs are already vulnerable to wind damage. Structures such as masts, antennas and gantries will also be at increased risk of damage during more intense storm events.

As the intensity of storms is forecast to increase, wind speeds will increase, this will potentially increase the number of days where an emergency timetable is required to manage the safety risk posed by wind-blown trees. It is also likely to increase the number of trees blown over, a risk which will increase further as the extended growing season will result in more trees remaining in leaf as the stormy period in Autumn begins.

Wessex Route impact assessment continued

Lightning impact assessment

Between 2006/07 and 2018/19, lightning related incidents accounted for an average of 12,387 delay minutes and £0.56m in Schedule 8 costs per year. This is 9.0 % of Wessex's annual average weather-related delay minutes and 8.5 % of the annual average cost. Increased storminess may increase the frequency of lightning, but this is difficult to quantify. Much of the average delay attributed to lightning resulted from failures relating to certain vulnerabilities in specific signalling systems. Some of the disruption risk has already been reduced by retrofitting protection and will be further reduced as older vulnerable systems are replaced with more robust modern technology.

Adhesion impact assessment

Between 2006/07 and 2018/19 adhesion related incidents accounted for an average of 21,811 delay minutes and £1.19m in Schedule 8 costs per year. This is 15.8 % of Wessex's annual average weather-related delay minutes and 18.2 % 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. Increased storminess may remove leaves at additional times of year. These may change the pattern of leaf fall. It is not clear if these changes will have a positive or negative impact on performance.

Fog impact assessment

Between 2006/07 and 2018/19 fog related incidents accounted for an average of 22 delay minutes and less than £0.01m in Schedule 8 costs per year. This is less than 0.1 % of Wessex's annual average weather-related delay minutes and less than 0.1 % of the annual average cost.

With the exception of Winter, which is projected to see small increases, the seasonal projections are for significant reductions in fog days across all regions. However, these are low confidence projections (see climate data).

Wessex Route WRCCA actions

As the impacts of weather events are location specific Wessex 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 Wessex 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 Wessex 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 (Table 3), and
- WRCCA actions planned for CP6 (Table 4).

The third table, Table 5, contains potential additional actions that the Wessex Route has identified as desirable to deliver WRCCA resilience, but which are not funded in the current CP6 business plan. The delivery 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 Wessex 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 Table 6 to indicate the relationship between the Wessex Route actions and the delivery of the NAP actions.

Wessex Route WRCCA actions
continued

Table 3
2014 WRCCA Plan CP5 actions review

Action name	Target completion date	Actual completion date	Comments
Management plans for sites at risk of desiccation	Spring 2019	Spring 2019	A new process for more effective management of desiccation sites was established for Summer 2019, and will be reviewed and re-issued annually to embed learning and changing conditions on high risk sites
Improved Flood resilience in Axe Valley	N/A	Autumn 2018	Two flood conveyance structures constructed to reduce flood risk to railway assets and downstream community at Broom Crossing and Axe Crossing, Network Rail lead. Capacity improvements at a side of line bridge in Axminster has reduced the risk of flooding to the railway and to local houses, Devon County Council lead. Flood resilience has been improved at Chard following the demolition of the dairy and conveyance improvements being made to the river channel, EA lead. More work is required in future funding periods to further improve flood resilience
Coastal strategy	N/A	Spring 2016	Comprehensive risk assessment of coastal erosion and flood risk based on UKCP09 High Emission projection and 'upper end' sea level projection
Yetminster bridges	Summer 2020	Summer 2020	New bridge more resilient, but flood performance not substantially improved due to site specific constraints
Tree survey	Spring 2016	N/A	Addressed by Business As Usual processes including seasonal review and targeted vegetation management, comprehensive survey to be delivered in CP6
Review of conductor rail heating requirement	Spring 2017	Spring 2017	Review completed in partnership with Stagecoach South West Trains, concluded that very limited deployment may be beneficial in some locations
Lightening protection Waterloo to Woking	March 2017	2018	Fitment of thyristor protection to signalling systems completed. Fitting of lightning protection to signal boxes completed
Adhesion	N/A	N/A	Reviewed annually as part of seasonal review process, all Signals Passed At Danger investigated as per process, review used to inform future vegetation management plans
Flood Resilience at Fulwell	N/A	Summer 2016	Pumped drainage and flood water storage lagoon system constructed at Fulwell to reduce frequency of flooding at the site of the most frequent track flooding on Wessex Route
Western Resilience Project	N/A	Various	Significant flood resilience improvements made using a DfT resilience fund, supplemented with Route funding at Sherborne, Sway and Hedge End

Table 4
Planned WRCCA investment for CP6 – 2019 – 2024

Vulnerability	Location	Action to be taken	Cost of action	Expected benefit	Target completion date	Resilience change	NAP action reference
Rainfall and landslip	Various	Deliver Geotechnical Renewal and Refurbishment programme	£80m	Landslip risk reduced at 25 % of highest risk geotechnical assets	Spring 2024	Resilience and passenger safety improved at intervention sites	NRNAP5
Rainfall and flooding	Various	Deliver Drainage Renewal and Refurbishment programme	£20m	Track flooding, wet formation and landslip reduced at highest risk drainage locations	Spring 2024	Resilience and passenger safety improved at intervention sites	NRNAP5
Flooding and scour at structures	6No	Renewal of river level monitoring installations and review processes and procedures	£1m	Improved detection of flooding and flood damage to structures, reduced risk of delay due to over cautious processes	Spring 2022	Reduction in safety risk to passengers	
Scour at structures	4No	Scour risk reduction at 4No. high risk locations	£2.7m	Reduced risk of structure collapses due to scour	Spring 2024	Resilience and passenger safety improved at intervention sites	
Rainfall and landslip	Various	Renewal of RCM at high risk earthworks, expansion of monitoring network and review procedures and procedures	£6m	Reduced risk of train striking landslip	Spring 2022	Reduction in safety risk to passengers	NRNAP4
Flooding/ hydraulic conveyance	30No	Remediation including relining to poor condition culverts to maintain support to track and hydraulic conveyance	£2.4m	Reduced risk of culvert collapse or blockage	Spring 2024	Resilience and passenger safety improved at intervention sites	
Adhesion and Wind	Route	Route wide tree survey to inform future management plans	£0.2m	Better tree risk management including reduced tree strike during windy weather and reduced adhesion delay	Spring 2023	Enabling better planning and management	
Adhesion and Wind	Route	Route wide vegetation management in line with CP6 plans	£11m	Route wide vegetation management in line with CP6 plans	Spring 2024	Resilience and passenger safety improved at intervention sites	
Rainfall and landslips	Region	Partnership with Southampton University to provide PhD and MSc topics with industry placements for investigations into earthwork stability	TBC	Better modelling of and understanding and management of weather impacts on earthwork assets in CP7 and beyond	Spring 2024	Enabling better planning and management	NRNAP7

Wessex Route WRCCA actions continued

Table 5
High priority actions not funded in CP6

Vulnerability	Location	Potential action	Target completion date	Predicted benefit	NAP reference
Coastal flooding	Portcreak Viaduct	Initiate project to develop options and high-level costs for future CP funding submissions to manage flood risk at Viaduct and Portcreak Junction	Spring 2023	Improved coastal flood resilience and neighbouring community	
Coastal flooding and erosion	Various	Develop plans to address known high-risk coastal flooding and erosion sites	Spring 2023	Enable better investment and maintenance planning to improve resilience	
Flooding in the Axe Valley	Axe Valley	Update hydraulic model to incorporate works undertaken in CP6 and develop high level options for long term investment options to maintain or improve system resilience to flooding	Spring 2024	Enabling better planning and management to improve resilience	
Wind, adhesion and landslip	Route	Develop an integrated vegetation management strategy to balance operational requirements, access to assets for inspection, geotechnical asset stability and biodiversity objectives	Spring 2024	Enabling better planning and management to improve resilience	
Rainfall and landslip	Reading to Basingstoke	Develop costed options for route level investment in earthworks on the Reading to Basingstoke line	Spring 2024	Identification of resilience improvement options	NRNAP5
Rainfall and landslip	Reading to Basingstoke	Develop costed option for freight diversionary route (Reading to Basingstoke line) via Salisbury	Spring 2024	Identification of resilience improvement options	NRNAP6

Table 6
NAP actions

Objective	Action	Timing	NR 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	NR 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 Engineering and 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.

Wessex Route management and review

The Weather Resilience and Climate Change Adaptation Plan will be reviewed annually at the Southern Region Director of Engineering and Asset Management Periodical Business Review. Significant weather events may prompt an interim update to the plan, but it is expected that the next full update will be in CP7 (2024).

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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