Route Weather Resilience and Climate Change Adaptation Plans

Wales

Contents

Purpose of this document

This document sets out a Weather Resilience and Climate Change Adaptation (WRCCA) plan for Wales 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

Wales Route is committed to improve our management of the risks posed by weather impacts, and the severe storm events over the last winter highlighted the challenge we face to understand and increase resilience of our infrastructure to climate change.

As part of our asset management plans, in 2013 we began an evaluation of the whole of our coastline to quantify the risks to support cost-effective investment on our coastal assets. The recent storm damage on the Cambrian line, and consequent disruption to train services, further supports the efforts we are making to improve the management of these assets.

In CP5 we are investing to increase the capability of our assets to be resilient to weather and to improve our operational responses to minimise disruption to services. We are delivering earthwork renewals, bridge scour works, weather forecasting tools, remote condition monitoring equipment, and we have instigated a proactive drainage management programme which is improving resilience of our drainage systems at flooding risk sites.

Wales Route will continue to work with its external partners, including Natural Resources Wales, the Environment Agency and local authorities, to develop and implement holistic plans for weather and climate change resilience.

Jonathan Pegg
Director Route Asset Management
September 2014

Executive summary

Weather events can cause significant disruption to the operation of train services and can damage 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.

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

Using this information, Wales 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 to 2013/14 shows flooding, wind, and snow-related events have had the most significant impact on the Route.

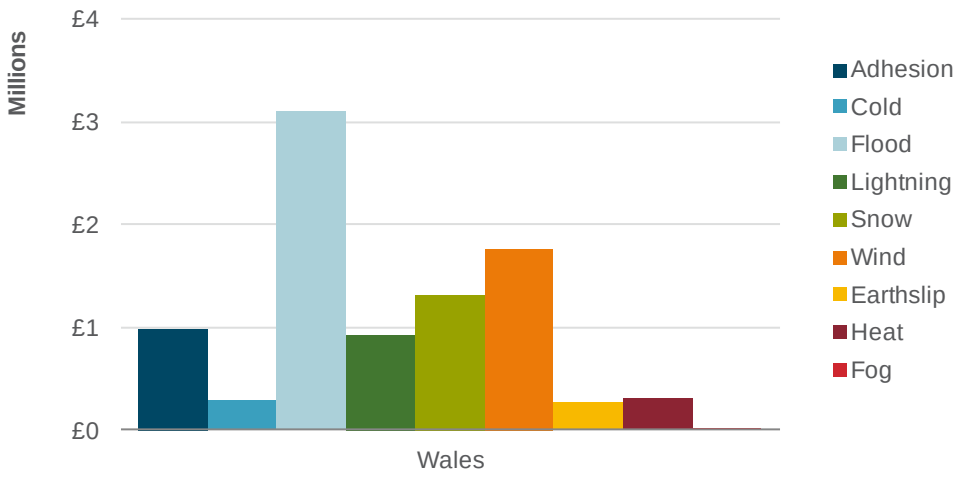

Figure 1 Wales Route weather attributed Schedule 8 costs 2006/07 to 2013/14

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

- improve understanding of climate change impacts and cost effective resilience measures
- predict the impacts of weather and use weather forecasting and asset monitoring to manage locations vulnerable to adverse weather
- establish a coastal and estuarine asset management strategy to identify future weather risks and develop a plan to mitigate
- develop and manage a Route WRCCA plan to inform current and future Control Period investment plans and workbanks
- maintain and improve relationships with external organisations, including Natural Resources Wales and the Environment Agency, for improved weather resilience
- improve operational flood plans and weather alerts
- improve asset records, inspection, and maintenance regimes in order to support the replacement and/or maintenance of high-risk or poorly performing assets

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

- earthworks renewals schemes
- improved drainage investment for capital schemes
- bridge scour protection work
- further development of weather forecasting systems
- implementation of coastal asset schemes

Wales 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 that much of the network is resilient. However, asset failures such as: the Bargoed earthslip; the Cambrian Lines closure due to tidal surge and severe wave damage; and the widespread tree fall following the St. Jude storm, reveal the vulnerability of the rail network and the severe impact these weaknesses in resilience have on train services and our resources.

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

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

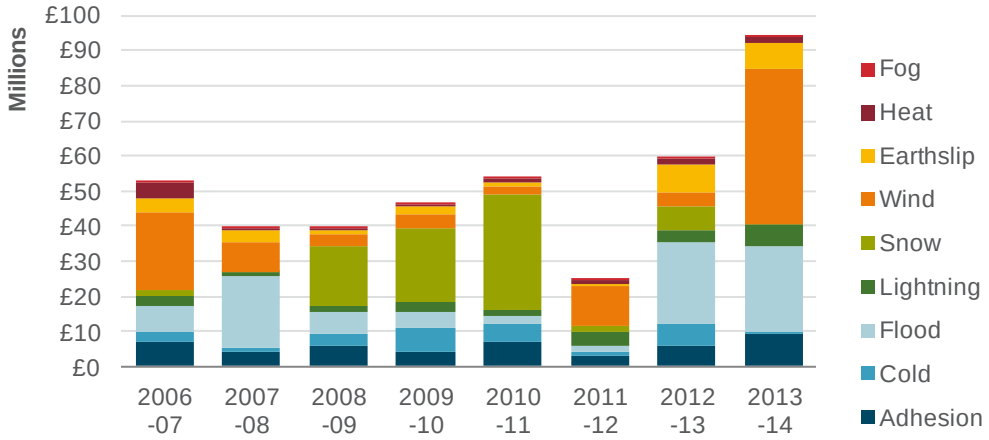

Figure 2 Network weather attributed Schedule 8 delay costs, 2006/07 to 2013/14

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

These levels of performance cost, consequential costs of repairing the 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 Rail's efforts to improve collaborative understanding of the wider impacts of weather-related events and our role in supporting regional and national resilience.

Potential escalation of these impacts from climate change supports the business case to increase weather resilience actions and presents a challenge to identify further actions to deliver a resilient rail network for the future.

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

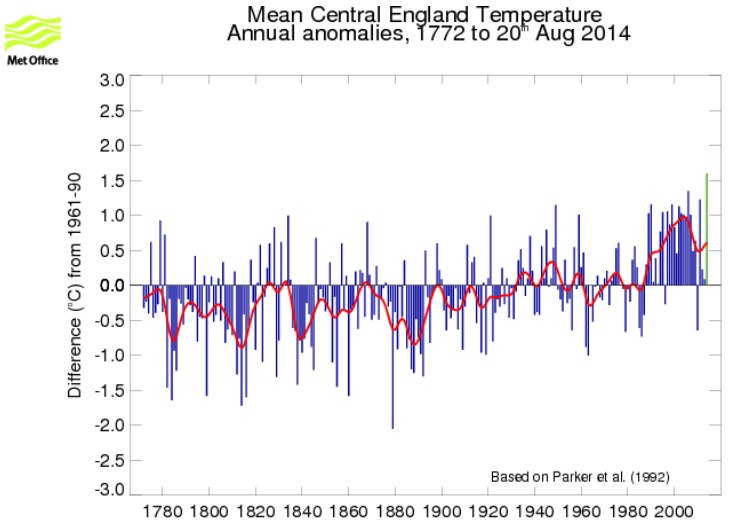

Figure 3 Mean Central England temperature record

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

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

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

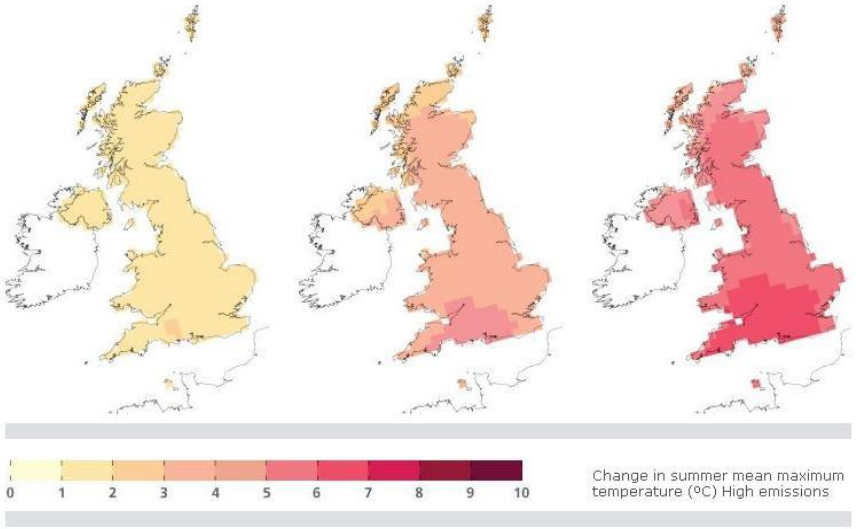

Figure 4 Change in summer mean maximum temperature (left 2020s, middle 2050s, right 2080s) (© UK Climate Projections, 2009)

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

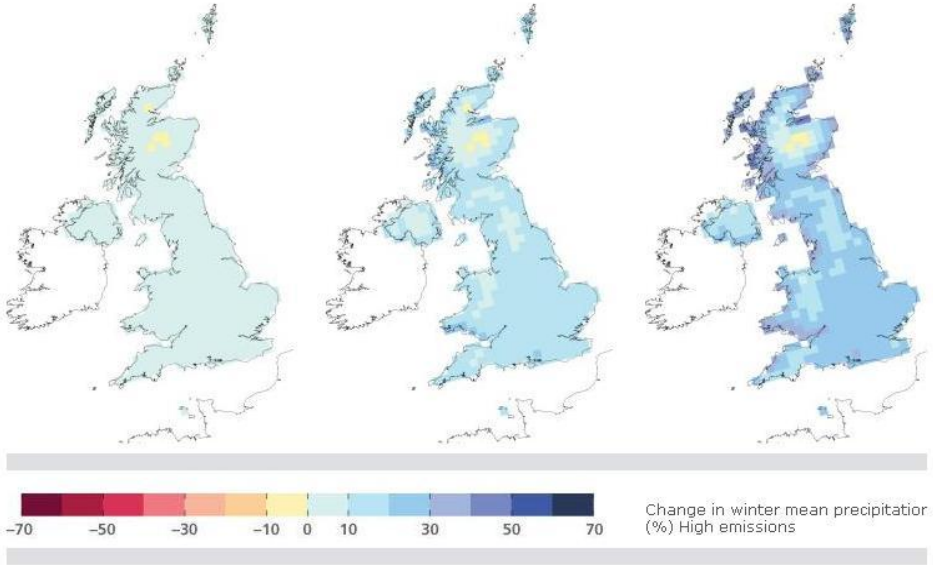

Figure 5 Change in winter mean precipitation (left 2020s, middle 2050s, right 2080s) (© UK Climate Projections, 2009)

To ensure WRCCA 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 Wales Route WRCCA plan.

Figure 6 Weather resilience and climate change adaptation framework

Network Rail WRCCA actions will include a range of measures appropriate to the strength of evidence and level of risk:

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

The following sections provide findings from the Wales 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.

Llanaber following completion of emergency works

Wales Route WRCCA strategy

The Network Rail Sustainable Development Strategy outlines corporate WRCCA 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*.

Chester and Holyhead Line, Mostyn sea wall, December 2013

Wales Route strategy

The Wales Route is committed to supporting the delivery of this strategy through Route-specific WRCCA objectives:

- improve understanding of climate change impacts and cost-effective resilience measures
- predict the impacts of weather and use weather forecasting and asset monitoring to manage locations vulnerable to adverse weather
- establish a coastal and estuarine asset management strategy to identify future weather risks and develop a plan to mitigate
- develop and manage a Route WRCCA plan to inform current and future Control Period investment plans and workbanks
- maintain and improve relationships with external organisations, including Natural Resources Wales and the Environment Agency, for improved weather resilience
- improve operational flood plans and weather alerts
- improve asset records, inspection, and maintenance regimes in order to support the replacement and/or maintenance of high-risk or poorly performing assets

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

Wales Route vulnerability assessment

This section provides the details of the general vulnerability of the rail network in Great Britain and Wales 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 7 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.

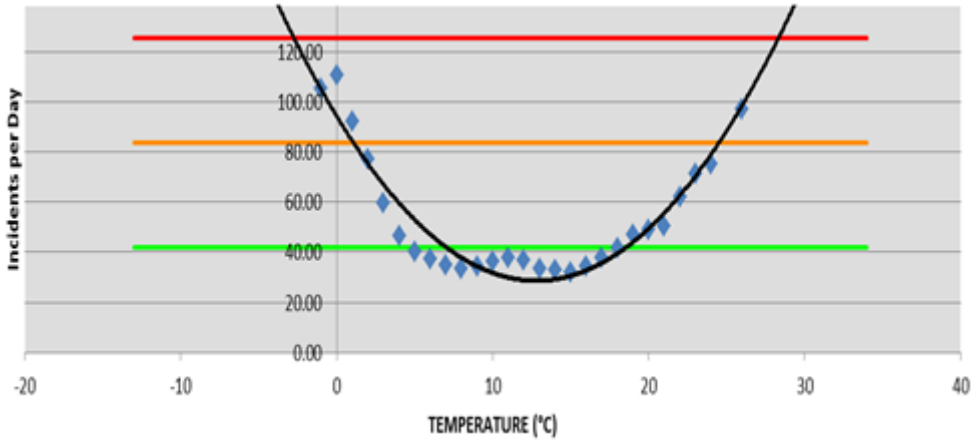

Figure 7 Example of asset failure and weather analysis

Managing operational response to weather vulnerability

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

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

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

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

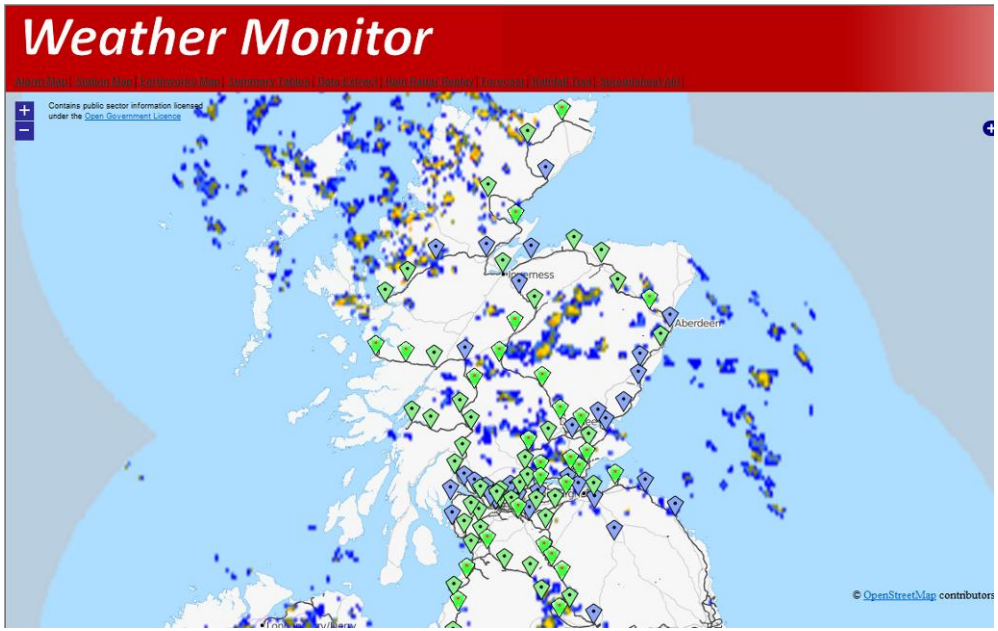

Figure 8 Scotland Route real-time weather monitor

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

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

Improving our network wide resilience

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

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

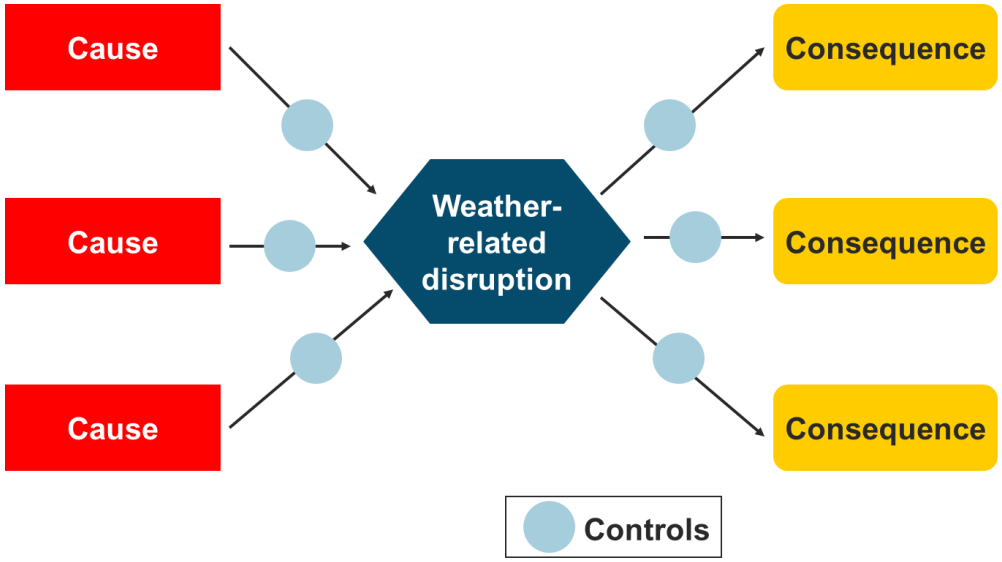

Figure 9 Bow tie risk assessment

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

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

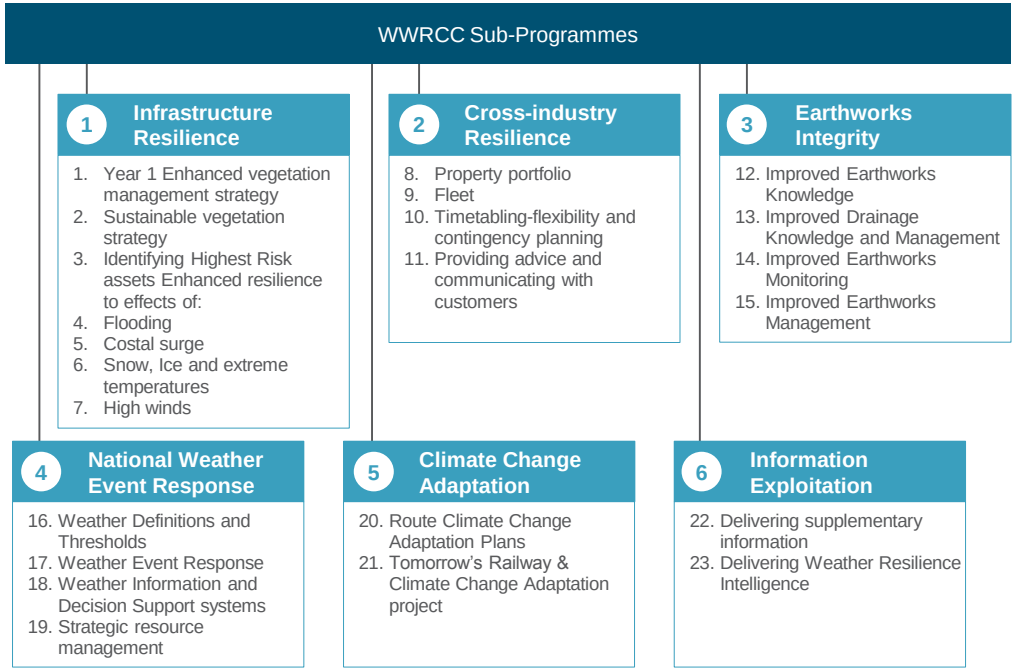

Figure 10 The constituent components of Network Rail's WRCC programme

The WRCC programme is currently supporting the delivery of:

- an enhanced Vegetation Management project: £10m of accelerated funding to address high-risk trees and mitigate the impact of both extreme winds and adhesion issues
- points enhancements: Installation of up to 7,000 points heat insulation and covers in support of Key Route Strategy
- forensic Investigation of Earthworks Failures in 2012/13 and 2013/14: the 261 failures that occurred during this two-year period have been investigated with Deep Dive analysis being undertaken on 89 of them
- carthworks 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 Wales Route manages a large percentage of Network Rail's coastal assets; 34 miles are vulnerable to overtopping, coastal erosion and storm surges.

Several sections of the sea wall supporting the Cambrian Line near Tywyn, Afon Wen, Llanaber were damaged by storms in December 2013, Figure 11 and Figure 12 . This resulted in full closure of the line and repairs were completed by 1 May 2014.

Figure 11 Cambrian Line, Llanaber sea wall, December 2013

Figure 12 Cambrian Line, Tywyn, December 2013

Sections of the sea wall supporting the South Wales Main Line including the Ferryside St. Ishmael's and Pwll sections were recently damaged by storms, Figure 13.

Figure 13 South Wales Main Line, Ferryside St Ishmaels sea wall January 2014

Approximately, three miles of the South Wales Main Line between Chepstow and Lydney, are vulnerable to the erosion of the soft adjacent Severn Estuary material.

Many of the adhesion-related incidents relate to the 'leaf fall season' and are a result of leaves on the railhead. Wales Route has a relatively high level of vegetation and removing lineside trees can reduce disruption, and in the past vegetation management has been specifically focused on this. However within Wales, this is not always entirely effective unless all the trees in the area are removed, as 'third-party leaves' contribute to railhead contamination.

One of the most recent significant weather events, the St Jude storm, brought down hundreds of trees across the Route and highlighted the potential safety and performance impacts from such extreme weather events. As the frequency and intensity of storms increase, the impacts could also increase unless the number of trees able to fall on the line is reduced.

Future climate change vulnerability

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

The UKCP09 provides regional climate change projections across 13 administrative regions in Great Britain, including Wales, Figure 14.

Figure 14 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 Wales, Figure 15, 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 over 2.8°C, reaching 21.4°C by the 2050s, and by over 4.6°C, reaching 23.2°C by the 2080s. Average maximum daily temperature in January is expected to increase by 2°C, reaching 8.1°C by the 2050s, and by 2.9°C, reaching 9°C by the 2080s.

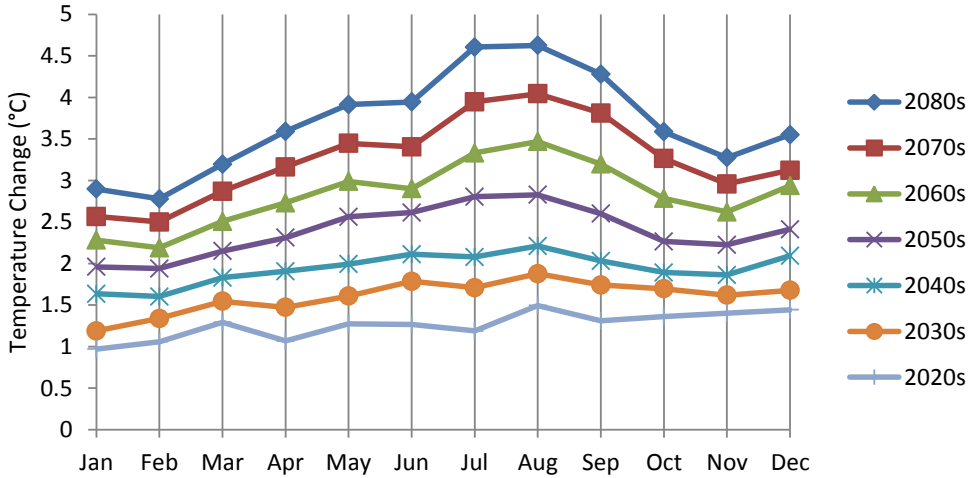

Figure 15 Wales mean maximum temperature change (50th percentile)

Mean daily minimum temperature change

The mean daily minimum temperatures in Wales are also projected to increase throughout the year, Figure 16.

Average minimum daily temperatures in July are projected to increase by 2.5°C, reaching 13.4°C by 2050s, and by 4°C reaching 15.0°C by the 2080s. Average minimum daily temperature in January is projected to increase by 2.6°C, reaching 3.9°C by 2050s, and by 3.8°C, reaching 5.1°C by 2080s (Figure 11).

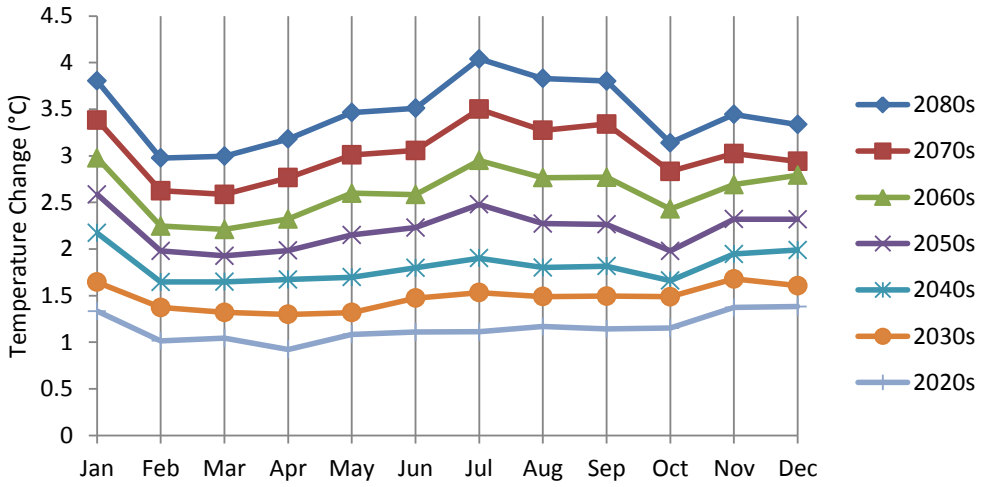

Figure 16 Wales mean minimum temperature change (50th percentile)

Mean daily precipitation

The mean daily precipitation in Wales is projected to increase significantly in winter months and decrease in summer months, Figure 17. The greatest increase is expected to occur in February, projected to be 14 per cent, reaching 4.4mm per day by the 2050s, and 27 per cent, reaching 4.9mm per day by the 2080s. The greatest decrease in precipitation is likely to occur in August. Mean daily precipitation is projected to decrease by 27 per cent by the 2050s, to 2.4mm per day, and by 43 per cent, to 1.9mm per day by the 2080s.

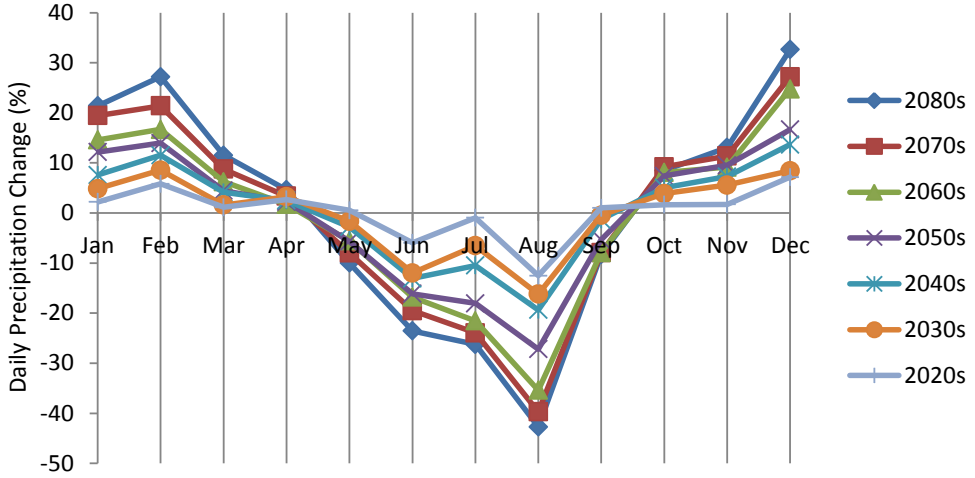

Figure 17 Wales mean daily precipitation change (50th percentile)

Sea level rise

Sea level rise for the Wales Route coastal and estuarine assets can be represented by the projections for the Cambrian coast, near Barmouth, Figure 18. For the high emissions scenario, the projections for the 50th percentile for 2050 is 0.237m and 0.525m by the end of century (the rise is unlikely to be higher than 0.381m and 0.848m respectively).

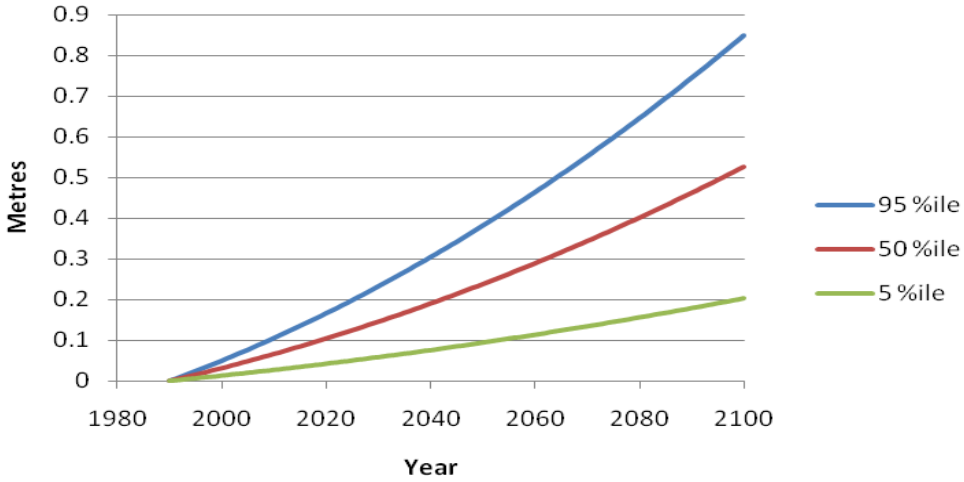

Figure 18 UKCP09 sea level rise projections for the Barmouth area

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

Wales Route impact assessment

This section provides the findings from the Wales 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 Wales Route have been analysed to provide an assessment of weather impacts, Figure 19.

- '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.

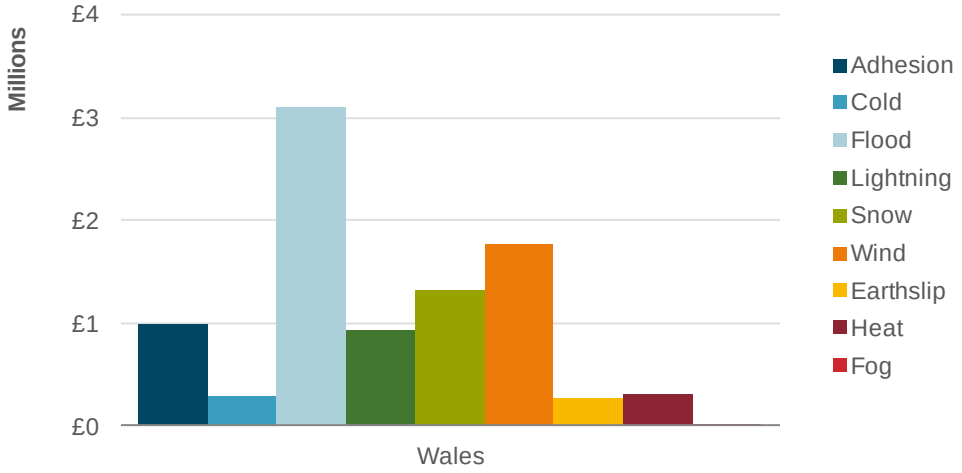

Figure 19 Wales Route weather attributed Schedule 8 costs 2006/07 to 2013/14

The analysis shows that flood-related incidents have been the most significant weather impact for the Route, with Schedule 8 costs of over £3m during the period 2006/07 to 2013/14.

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

Wind impacts have also been significant. Climate modelling cannot provide strong projections for future changes to wind speeds, though, increased storminess is generally projected and may increase the risk of wind-related incidents on the Route.

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

Table 1 Prioritisation of weather-related impacts on Wales Route

Weather-related impact	Schedule 8[1] costs	Projected future impacts	Prioritisation
Flooding	£619k	Up to 25 per cent increase in February mean daily precipitation[2]	High
Earthslips	£53k	Up to 25 per cent increase in February mean daily precipitation[2]	High
Sea level rise	Not applicable	0.27m increase in sea level rise[3]	High
Wind	£352k	Wind changes difficult to project however generally projected to increase	High
Adhesion	£198k	Complex relationship between adhesion issues and future climate change.	Med
Heat	£62k	Up to 3.1°C increase in July mean daily maximum temperature[2]	Med
Snow	£262k	Up to 3°C increase in January mean daily minimum temperature[2]	Med
Cold	£57k	Up to 3°C increase in January mean daily minimum temperature[2]	Low
Lightning	£185k	Storm changes difficult to project however generally projected to increase	Low
Fog	£1k	Complex relationship; however, research suggests fog events may decrease	Low

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

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

Identification of higher risk locations

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

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

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

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

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

Flooding impact assessment

Based on 2006/07 to 2013/14 data, Wales Route flood-related delays totalled 42,400 minutes per year and on average cost £619k per year in Schedule 8 costs. This amounts to 35 per cent of weather-related delay minutes.

In previous decades, the Route's drainage suffered from under investment. That has recently been reversed, and has resulted in noticeable improvements in flood resilience.

During the 2013/14 financial year, 82 drainage schemes were completed across the route including:

- Crew North to Holyhead Line, Bodorgan, renewal of failed drainage system
- Cardiff and Rhymney Line, Bargoed, install crest drain
- Neath and Brecon Line, Cilfrew Culvert, culvert and flume failure
- Swansea District Line, Tircoed, installation of crest drain, flume and toe drain
- Hereford to Newport Line, Llancillo, crest drain
- South Wales Main Line, Llandavenny, crest drain, repair collapsed sections/outfall
- Vale of Glamorgan Line, Sutton Farm, clean existing and install new sections, Figure 20
- Shrewsbury – Hereford Line, Marsh Farm, re-profile ditch and lower invert of side structures.

Figure 20 Vale of Glamorgan Line, Sutton Farm, prior to drainage capacity improvement

With the exception of coastal flooding, analysis of the METEX data reveals that historic flood vulnerabilities have been largely mitigated and the Wales Route is currently proactively managing flood risk. The improved investment in CP5 includes:

- Cardiff and Rhymney Line, Caerphilly tunnel North Portal
- Crew North to Holyhead Line, Llysfaen - clean and dredge existing system and ditch
- Sutton Bridge Junction – Aberystwyth Line, Talerddig cutting, cess drain renewal
- Bristol and South Wales Union Line, Severn tunnel Eastern Portal, new drain/repair
- Crew North to Holyhead Line, Bangor tunnel, replace failed pipes and catch pits
- South Wales Main Line, Gaer – repairs to be confirmed.

A programme of bridge scour protection is underway that will significantly reduce the risk of bridge failure due to scour at the foundations. This will also reduce the number of areas that incur line restrictions during periods of flooding.

Earthslip impact assessment

Based on 2006/07 to 2013/14 data, earthslip-related delays totalled 4,040 minutes per year on average, costing £53k per year in Schedule 8 costs. This amounts to 3 per cent of weather-related delay minutes.

Intense rain and flooding can cause the failure of geotechnical assets via a number of mechanisms each with a different suite of mitigations:

- washout failure due to water flowing over the crest of cuttings; mitigated by increasing capacity of crest drainage and works to stabilise cutting slopes
- cutting failure due to saturation of face; mitigated by face drainage and stabilisation
- cutting failure due to wet cutting toe, often accompanied with track quality problems; mitigated by cutting and track drainage
- embankment failure due to saturation during rainfall events; very difficult to mitigate against, as the slope must be re-engineered to retain a factor of safety of greater than unity when saturated, requires assessment and engineering intervention, usually toe support such as gabion walls or sheet piles. A re-grade is also frequently required
- embankment failure due to saturated toe, drainage of toe, many embankments are land locked and this is difficult to achieve in many cases, particularly in areas impacted by sea level rise, see sea level rise section
- embankment failure due to scour at the toe, this occurs where the toe of the embankment is adjacent to a river stream or drainage ditch which conveys water at high velocity during storm events, these failures can occur very quickly.

During the very wet winter of 2013/2014, Wales Route experienced three landslides resulting in extended periods of speed restrictions. For example at Llanvihangel, Figure 21, a 5mph restriction of speed combined with the steep gradient caused severe impact for the Freight Operating Company.

Five earthwork slips have been reactively treated in the past 12 months:

- South Wales Main Line – Nass Lane
- Cardiff and Rhymney Line –Tir Phil
- South Wales Main Line – Purton
- Sutton Bridge Junction to Aberystwyth Line – Talerddig
- Hereford to Newport Line, Llanvihangel, Figure 22.

Figure 21 Hereford to Newport Line, Llanvihangel before remediation

Figure 22 Hereford to Newport Line, Llanvihangel after remediation

As part of a national scheme, a tool was developed to assess all earthworks assets that were at risk during an extreme or severe weather event. Initially 166 sites were identified in Wales Route, and further analysis distilled this to approximately 60 sites at which mitigation was necessary. The Wales Route now subscribe to bespoke Meteorological Office triggers, which provide advance warnings based on rainfall per hour and soil moisture saturation. This allows the Route to mitigate risks by the use of speed restrictions. Between 70-80 per cent of sites are planned to be improved in CP5.

In CP5, expenditure is provisionally planned over 37 sites including:

- Treherbert Branch Line – Llys Faen
- Crew North to Holyhead Line – Trehafod
- Treherbert Branch Line – Station Road Dinas Rhondda
- Cardiff and Merthyr Line – Radyr
- Cardiff and Rhymney Line – Brithdir
- Gwaun-Cae-Gurwen Branch – Cwm Garnet
- South Wales Main Line – Naas Lane Phase 2
- South Wales Main Line – Gelli
- Shrewsbury – Hereford Line – Saltmoor

Sea level rise impact assessment

Large parts of the Route run adjacent to the coast and are vulnerable to sea level rise coupled with increasing storm frequency.

Several coastal sections of the Route were recently damaged during the severe storms of December/January 2013/14, and highlighted the assets' vulnerability to extreme coastal weather. The damage included:

- sections of the sea wall supporting the Cambrian Line near Tywyn, Afon Wen, and Llanaber, Figure 23
- sections of the sea wall supporting the South Wales Main Line including Ferryside, St. Ishmael's and Pwll
- sections of the parapet of the sea wall supporting the Chester and Holyhead Line at Mostyn that were demolished by the combined effect of a spring tide, a tidal surge and a storm
- storm damage was also recorded at Mostyn, Hollywell and Lord Vivian's embankments.

Figure 23 Llanaber, January 2014

Investment during CP5 will improve the resilience of 12 sites including:

- Deganwy sea wall, installation of rock armour to protect pitching
- Llanfairfechan sea wall, concrete bench toe protection and refurbishment
- Tal-Y-Cafn, pitching
- Lord Vivian's embankment, refurbishment
- LJT sea wall, pitching and defences
- Old Colwyn sea wall, extensive re-pointing.

In 2013, the Route procured a coastal and estuarine defence study to identify future weather risks. The North Wales pilot study delivered its findings in July 2014. This methodology is currently being rolled out across the whole of the Wales Route, due by December 2014. A tidal warning system is also being developed known as 'Forecoast' and will provide the Route with advanced weather event warnings and allow appropriate operational mitigation measures to be put in place.

Wind impact assessment

Based on 2006/07 to 2013/14 data, wind-related delays totalled 18,800 minutes per year on average, costing £352k per year in Schedule 8 costs. This amounts to 15.5 per cent of weather-related delay minutes.

Wind impacts performance directly, in that blanket speed restrictions are imposed when thresholds are reached. Wind also affects performance indirectly as a result of damaging lineside trees that then fall, or drop branches, on the line. Wind also moves other debris on to the line from the lineside environment, frequently from neighbouring sites. High winds can also lead to significant waves (even in waters protected from the open sea) and these can cause damage to the infrastructure, as evidenced at the Carmarthen sea walls.

The primary operational risk mitigation for strong winds is to impose speed restrictions on the parts of the Route forecast to be impacted, or in extreme conditions, to suspend operations completely.

The primary longer-term mitigation is to remove trees that are able to fall on to the line. Wales Route plans to remove a substantial number of trees in CP5 as part of its compliance with off track management standards. There is also a significant risk associated with trees on third-party land, many are sufficiently tall enough to fall across the running lines. Clearing such trees is an enormous undertaking and sensitive as many trees are protected by preservation orders. They also form an important visual screen for our neighbours.

Adhesion impact assessment

Based on 2006/07 to 2013/14 data, adhesion-related delays totalled 14,700 minutes per year on average, costing £198k per year in Schedule 8 costs. This amounts to 12 per cent of weather-related delay minutes.

Adhesion is extremely complex with many interlinked causes, both infrastructure and operational. Many cases of adhesion delays are attributed to a lack of appropriate railhead treatment.

The weather that causes the greatest adhesion problems is still cold mornings, and evenings that promote heavy dew. If combined with leaf fall, the railhead can become contaminated.

Removing lineside trees will help and in the past vegetation removal has been specifically focused on this. This has not always been entirely effective unless all the local trees were removed as 'third-party leaves' can also be problematic. A programme of railhead treatment also helps. Today we mainly rely on the Railhead Treatment Train (RHTT) to deliver high pressure water jetting to clear leaf debris from the railhead, but it needs to be done frequently to work well. The RHTT consists of converted and specially adapted wagons hauled by a locomotive at each end. The maximum speed of trains when water jetting is 40mph, and many sites are treated daily during the leaf fall season.

The Wales Route is currently in the early stages of reviewing adhesion. Some of the problem areas include:

- South Wales Main Line – Llanwern
- Bristol and South Wales Union Line – Severn Tunnel Exit
- Wolverhampton North Jn to Saltney Jn Line – Wrexham General to Gobowen
- Wolverhampton North Jn to Saltney Jn Line – Wrexham General to Shrewsbury
- Hereford to Newport Line – Abergavenny to Tram Inn
- Hereford to Newport Line – Pontrilas
- Neath and Brecon Line – Swansea Burrows S.S. to Onllwyn Washery
- Cardiff and Rhymney Line – Heath Junction.

More modern rolling stock with wheel slip detection reduces the impact of railhead contamination, and good forecast and robust alternative timetables that build sufficient time in to allow trains to slow and accelerate gently when conditions are poor can also significantly reduce impact.

Heat impact assessment

Based on 2006/07 to 2013/14 data, heat-related delays totalled 3,400 minutes per year on average, costing £62k per year in Schedule 8 costs. This amounts to 2.8 per cent of weather-related delay minutes.

The impact of high temperatures is largely a problem in the management of the track asset. Track maintenance teams put significant resource into managing the track asset in a way that limits the number and length of heat speed restrictions required to manage safety. They are largely successful and the current impact is relatively small as a result.

The biggest heat-related risk to track are track buckles.

Given that the risk of track buckling increases with the number of days with air temperature over 20°C, climate change may increase the risk of track buckling. This is not to say that we

will have more buckles, as buckles are the result of heat and a combination of typically two or more localised deficiencies. These deficiencies combine to cause a weakness in the lateral stability of the track, these include:

- for track with Continuously Welded Rail (CWR): low Stress Free Temperature (SFT), weak ballast shoulders, poor track alignment, poor sleeper support (voiding), lighter track construction with wood rather than concrete sleepers, changes in track construction type and small radius curves
- for track with jointed rails: lack of expansion joints, lack of rail joint lubrication, over-tightened fishbolts, poor track alignment, poor sleeper support (voiding), changes in track construction and small radius curves.

Well maintained track will not buckle. Thus, if we are to have more hot days (and potentially hotter days) there will be merit in making sure that deficiencies are identified and promptly rectified.

Work on the track can cause weaknesses. For example: unconsolidated ballast following disturbance by tamping, or between the time new rail has been installed and when it is stressed to restore the SFT, so even on a well maintained railway CRT speed restrictions are required to manage safety risks. One way of avoiding heat-related issues is to plan work during periods when the weather is likely to be cooler. However, this is not always practicable, as it would not provide an efficient programme for our maintenance teams and contractors; and disruptive possessions are frequently only available at certain times of the year (for example in June between Newport and Shrewsbury). The balance of risk often results in work being actioned during sub-optimal times (for example, rectifying a serious track geometry fault versus the risk of a buckle).

It is to be noted that ballasted track of the same basic design is satisfactorily used in many countries with both higher and lower temperatures than found in the UK. The exceptions are the plastic and rubber parts (rail pads and insulators), which can be chosen to resist temperature extremes; and the chosen SFT as discussed below.

Increasing average temperature will have several other impacts with a need for appropriate mitigation:

- an increase in the active growing season for many plant species combined with wetter winters may lead to more vigorous spring growth. Vegetation management may thus become more expensive
- staff accommodation may also need to be modified to deal with increasing temperatures. Staff, undertaking safety critical roles such as signallers and electrical control room staff, share their work space with large electrical and electronic installations so must be provided with sufficient ventilation and air conditioning to maintain a safe working environment
- staff working outside will suffer increased heat exposure and fatigue. This will have implications for Personal Protective Equipment (PPE) and other welfare matters. Staff may have to be issued seasonal PPE and rules adjusted to accommodate it.

Snow and cold impact assessment

Based on 2006/07 to 2013/14 data, snow-related delays totalled 22,600 minutes per year on average costing £262k per year in Schedule 8 costs. This amounts to 18.6 per cent of weather-related delay minutes. Similarly, the 2006/07 to 2013/14 cold-related delays total 6,200 minutes per year on average, costing £286k per year in Schedule 8 costs. This is 5.1 per cent of weather-related delay minutes.

In cold weather the risk of broken rails increases, particularly for CWR track, where the tensile forces in the rail are at a maximum and can thus cause failure at any incipient weakness such as a rail or weld defect. With a reduction in the number of cold days the ‘risk’ of broken rails should also reduce.

The primary mitigation for snow and cold is good forecasting to enable robust emergency timetables to be implemented, and the provision of point heaters. Wales Route plans to fit a further 332 point ends in CP5 with electric strip heaters with heat retainers. Typical temperature performance of a point end will thus increase by some 2-3°C.

The risk of significant delays due to cold and snow may reduce and further investment in significant mitigations is a lower priority than mitigating other weather-related risks.

Lightning impact assessment

Based on 2006/07 to 2013/14 data, lightning-related delays totalled 8,800 minutes per year on average, costing £185k per year in Schedule 8 costs. This is 7 per cent of weather-related delay minutes.

There is little that can be done to mitigate the effect of lightning on existing signalling systems as vulnerabilities are fundamental of system design. As signalling systems are replaced over time, new systems should be specified with a greater degree of resilience. Until this is possible a good stock of spare parts in danger of failure during a lightning strike should be obtained to ensure service recovery is swift.

Fog impact assessment

Based on 2006/07 to 2013/14 data, fog-related delays total 53 minutes of delay per year, costing £1,000 per year in Schedule 8 costs. This is less than 1 per cent of weather-related delay minutes.

Current controls are considered adequate for the future management of fog.

Wales 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 Wales 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	Ongoing
Flooding		
Holistic management	Strengthen relationship with Natural Resources Wales through setting up of a local liaison group on flood risk management to share information and resolve issues Engage with local flood resilience forums	Ongoing
Scour management programme	Level 2 scour assessments for bridges have been funded by an authority paper. This will enable the intrusive checking of structures' foundation depths	2019
Scour	Implement approximately 25 scour work items during CP5 including: • Cegin viaduct • Bodorgan viaduct • River Towy viaduct • Seven viaduct • Gelli (River Eastern Cleddau).	2019
General flooding	The Wales Route subscribes to Meteorological Office forecasting data and receives data from Natural Resources Wales, and the Environment Agency for fluvial flood warning data to trigger adverse weather plans	Ongoing
Aged drainage infrastructure	Implement improved drainage investment for capital schemes including: • Caerphilly tunnel North Portal • Llysfaen • Talerddig cutting, cess drain renewal • Severn tunnel Eastern Portal, new drain / repair • Bangor tunnel, failed pipes and catch pits • Gaer.	2019
Earthworks		
Earthworks assets sensitive to extreme or severe weather events	The Wales Route now subscribe to bespoke Meteorological Office triggers, which provide advance warnings based on rainfall per hour and soil moisture saturation. This allows the route to mitigate risks by the use of speed restrictions	System established
	Implement approximately 35 earthworks renewals schemes during CP5 including: • Llys Faen • Trehafod • Station Road Dinas Rhondda • Radyr • Brithdir • Cwm Garnet • Naas Lane Phase 2 • Gelli • Saltmoor.	2019
Coastal and estuarine		
Flood warning management	Development of the Coastal 'Forecoast' system for extreme tidal events should be completed and operational in time for Winter 2014	October 2014
Coastal management strategy	Develop a CEAMP Strategy	2016

Vulnerability	Action to be taken	By when
Coastal flooding	Implement coastal defence works during CP5 including: • Deganwy, rock armour to pitching • Llanfairfechan sea wall, refurbish • Tal-Y-Cafn, pitching • Lord Vivian's embankment, refurbish • LJT sea wall, pitching and defences • Old Colwyn sea wall, extensive re-pointing.	2019
Wind		
Fallen trees obstructing the line	Remove a substantial number of trees as part of compliance with off track management standards	2019
Cold and snow		
Carmarthen gas points heating	Refurbishment of the Carmarthen gas sites that will improve its reliability by splitting the sites such that they have their own independent gas supplies	2019
Electric point heating	Fitting the remaining 332 points ends with electric strip heaters with heat retainers. Typical temperature performance of a point end by some 2-3°C	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	Potential future action
Flooding	
Bridge scour	Consider investing in additional bridge scour prevention schemes
Aged drainage infrastructure	Consider investing in additional flood remediation schemes, including: • Quayward No. 4 • Holywell Phase 2 • Skiean • Taltreuddyn • Goodwick Siphon • Lower Heldre • Llanfallteg West • Clunderwen.
Earthworks	
Adverse weather sites	Review additional investment in earthwork sites
Earthworks natural slopes/third-party boundary	Review additional investment in natural slopes and third party boundary
Rock cutting freeze/thaw	Review additional investment in cuttings
Coastal and estuarine	
Sensitive coastal sites	Consider investing in additional coastal assets including: • Mostyn sea wall • Ferryside sea wall improvements and rock armour protection • Pwll sea wall • Tywyn (Sandilands) • Other high priority sites as revealed by the forthcoming CEAMP • Lord Vivian's embankment • Mostyn embankment • Conwy embankment • Penmaenbach west sea wall • Penmaenmawr armour stone • Avalance viaduct no133 • Near Glan Conwy • Conway Valley Line 1mile 1436yds – wall pitching and efences • Conway Valley Line 2miles 0534yds – wall pitching and defences.

Management and review

Corporate management and review

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

Key actions being taken within corporate functions include:

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

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

Wales Route management and review

Wales Route is committed to understanding the implications of weather resilience and climate change. This is particularly important for our coastal sites where we have commissioned a specialist to evaluate the whole of our coastline and quantify the risks. This will give us a strong basis to develop a strategy.

We have instigated a proactive management programme of works of our drainage assets, which is already seeing improved resilience of our drainage systems at previous flooding sites across the Wales Route. The recent full drainage asset survey will also help us to understand, and address, further areas of weakness.

Wales will continue to work with its external partners, including Natural Resources Wales, the Environment Agency and local authorities, to develop and implement holistic plans for weather resilience.[2]

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.

[2] Wales Coastal Flooding Review, April 2014, Recommendation 46

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