

Route Weather Resilience and Climate Change Adaptation Plans

Scotland


Contents

Purpose of this document

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

Track washout at Dalguise, December 2006

Climate change presents us with an unprecedented challenge to understand how shifts in temperature and rainfall will impact our network and to identify the actions we can take to proactively increase our weather resilience.

In response to this challenge Scotland Route has developed a Weather Resilience and Climate Change Adaptation (WRCCA) plan which incorporates a number of programmes and initiatives designed to increase resilience of the railway in Scotland to effects of weather and climate change.

Scotland is no stranger to the best and worst of the weather. In recent years we experienced the prolonged spell of heavy snow fall in 2010/11 and the severe rain and wind in 2012 and 2013. Our ability to support the quality of rail service our customers expect is highly dependent on the capability of our assets to be resilient and our operational responses to weather events to minimise disruption.

Scotland Route has made significant investments in recent years to strengthen the railway network against the effects of the weather. Examples include over £5m improving the resilience of the railway to flooding risk at Dalmarnock, protecting Gourock from coastal impacts and undertaking extensive drainage and earthworks at Drem. In CP5 we are continuing to increase weather resilience through our investments, including drainage improvements, installation of remote condition monitoring, earthwork renewals and improving our real-time weather data.

We will do this in collaboration with our rail industry partners and other stakeholder organisations.

Alan Ross
Director Route Asset Management
September 2014

Executive summary

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

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

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

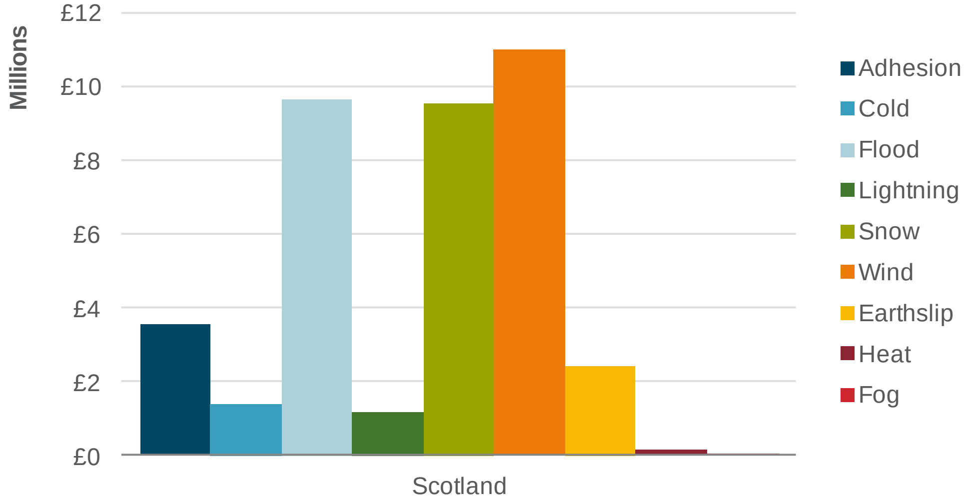


Figure 1 Scotland Route weather attributed Schedule 8 costs 2006/07-2013/14

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

- increase the understanding of climate change impacts on the Scotland Route
- improve the knowledge of weather impacts through identification of root causes and trends to support the identification of cost effective resilience measures
- develop and manage a Route Climate Change Adaptation Plan to inform current and future Control Period investment plans and work banks
- include climate change adaptation in Project Requirement Specifications for renewals and new works
- improve operational responses to extreme weather events
- support initiatives and demonstration projects aiming to deliver network-wide resilience improvements
- engage with key regional stakeholders to communicate the Scotland Route strategy, planned programmes of work and identified climate change adaptation actions, including the Scotland Environment Protection Agency and Transport Scotland.

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

- increase forecasting capability and real-time weather data
- engage with the Scottish Environment Protection Agency and Local Authorities to achieve sustainable solutions to reduce flood risk
- roll out strategic programmes of Remote Condition Monitoring for
  - high-risk earthworks
  - high-risk flooding sites
  - air conditioning in lineside buildings
  - points operating equipment
- engage with wider industry, including train operating companies, to minimise delay impacts.

Scotland 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 severe storm events demonstrated much of the network is resilient; however, asset failures such as flooding at Winchburgh and Dalguise, earthslips at Loch Treig and on the West Coast Main Line, the cyclone of 3 January 2013 and the high winds of 5 December 2013 when the Scotland network shut down due to severe high winds, reveal the vulnerability of the rail network and the impact these weaknesses in resilience can 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 performance cost attributed to Schedule 8 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, weather and seasonal events on average caused 12% of all delays experienced during this eight-year period.

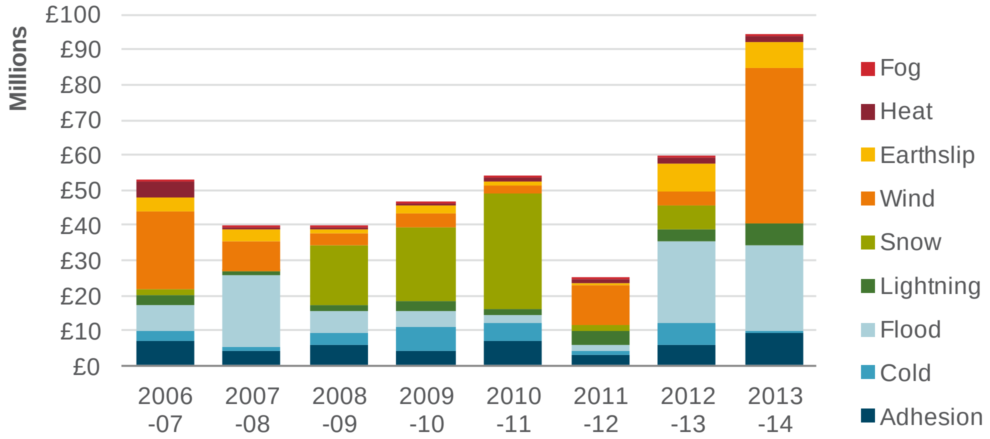


Figure 2 Whole network weather attributed Schedule 8 delay costs, 2006/07 to 2013/14

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

Historical temperature records indicate that a significant relatively recent shift in climate has occurred; Figure 3 clearly shows a rising trend in Scotland temperature over the past 40 years.

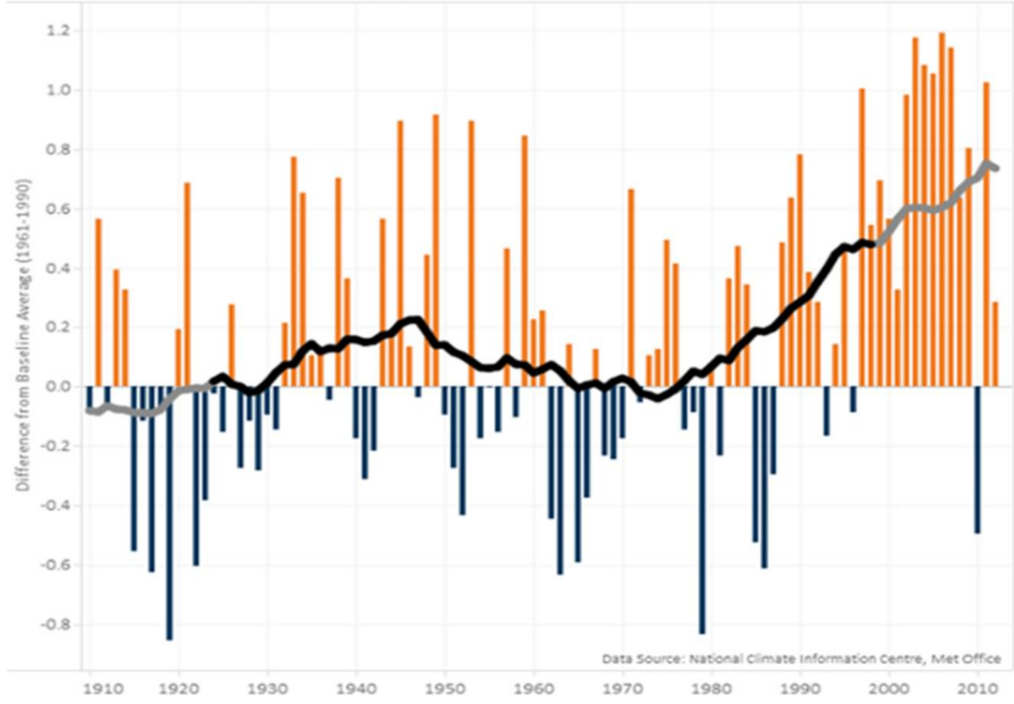


Figure 3 Annual mean temperature (°C) – Scotland[1]

[1] Reproduced with kind permission of Adaptation Scotland, original data source Met Office

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.

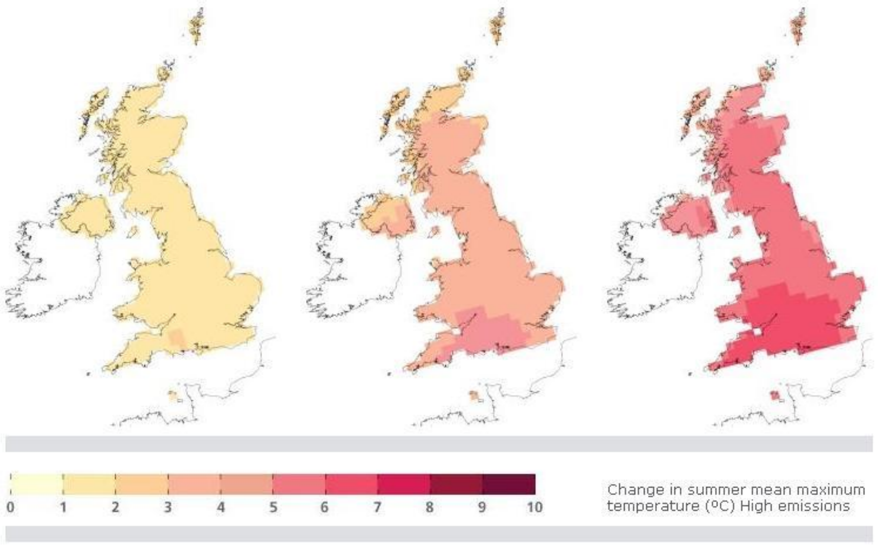


Figure 4 Change in summer mean maximum temperature (left 2020s, middle 2050s, right 2080s) (© UK Climate Projections, 2009)

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 the Scotland Route Weather Resilience and Climate Change plan uses the projections to support the prioritisation of weather resilience actions.

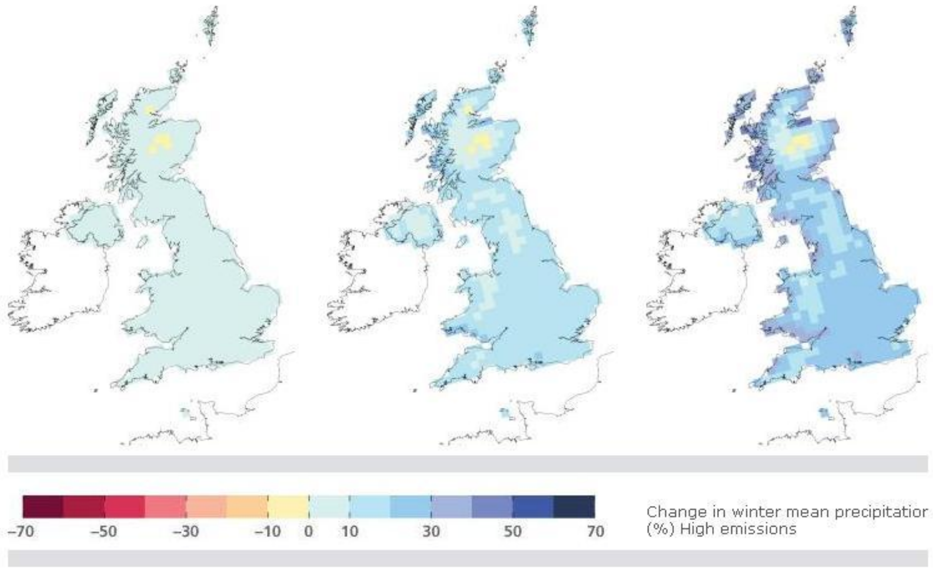


Figure 5 Change in winter mean precipitation (left 2020s, middle 2050s, right 2080s) (© UK Climate Projections, 2009)

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

Figure 6 Weather resilience and climate change adaptation framework

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

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

The following sections provide findings from the Scotland Route vulnerability and impact assessments, and details of the WRCCA actions; both completed and planned in Control Period 5, and potential additional actions, that aim to increase weather and climate change resilience.

Snow Avalanche near Tyndrum, February 2011

Scotland Route WRCCA strategy

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

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

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

Scotland Route strategy

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

- increase the understanding of climate change impacts on the Scotland Route
- improve the knowledge of weather impacts through identification of root causes and trends to support the identification of cost effective resilience measures
- develop and manage a Route Climate Change Adaptation Plan to inform current and future Control Period investment plans and work banks
- include climate change adaptation in Project Requirement Specifications for renewals and new works
- improve operational responses to extreme weather events
- support initiatives and demonstration projects aiming to deliver network-wide resilience improvements
- engage with key regional stakeholders to communicate the Scotland Route strategy, planned programmes of work and identified climate change adaptation actions, including the Scotland Environment Protection Agency and Transport Scotland.

Through these objectives, Network Rail's corporate commitments are applied in the context of Scotland 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 Scotland Route and the whole railway network.

Flooding at Dalmuir, November 2009

Scotland Route vulnerability assessment

This section provides the details of the general vulnerability of the rail network in Great Britain and Scotland 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 both today and potentially in future climates.

From this analysis it has been established that high temperatures have wider impacts across assets, low temperature affecting track asserts particularly points, 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.

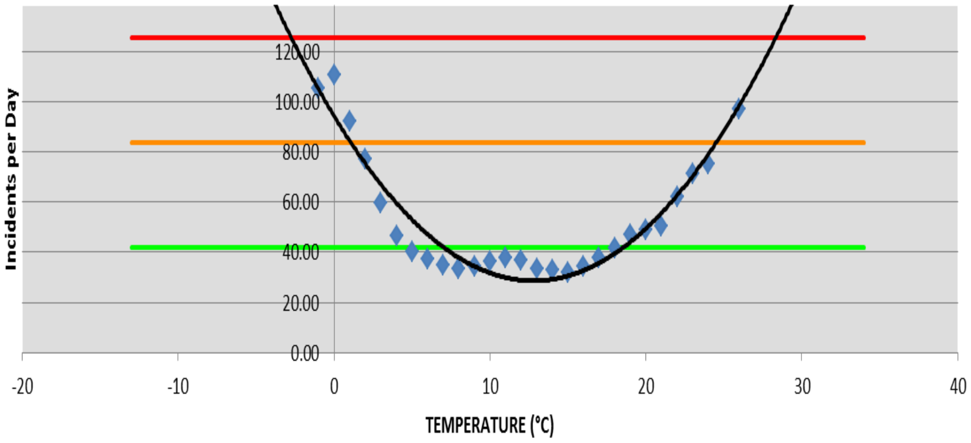


Figure 7 Example of asset failure and weather analysis

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 patrols 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 102 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.

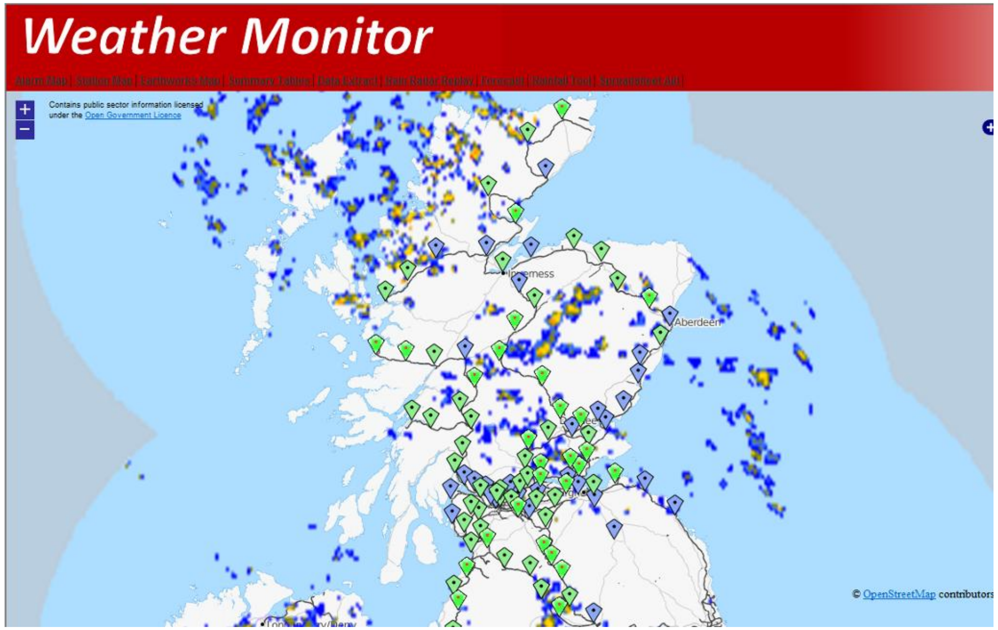


Figure 8 Scotland Route real-time weather monitor

For the management of operational flooding risk, Network Rail receives alerts through our Flood Warning database. 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.

Scotland Route weather stations

Improvements in our capability to receive weather forecasts and alerts in Scotland Route is being provided by the recently installed 102 weather stations, Figure 9, around the route on GSM-R Masts, lineside cabinets, lineside buildings and on the Forth Bridge and the Tay Bridge.

There were a number of drivers for this initiative:

- Office of Rail Regulation and Rail Accident Investigation Branch recommendations
- knowledge of vulnerable assets could be improved
- reduction of weather-related risk.

The aims of installing the weather stations were:

- improved asset resilience during poor weather conditions
- improved network performance
- improved safety
- improved stakeholder relations
- improved design of renewals/enhancements.

Computer analysis of trends and statistics enables decisions to be made based on scientific fact rather than experience or intuition. The weather stations will help develop accurate forecasting which allows proactive and risk-based decisions for network operations. However, in order to analyse data, we must first collect as much as we can.

Figure 9 One of the 102 weather stations deployed around Scotland Route

Improving our network-wide resilience

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

The WRCC programme is founded on a bow tie risk assessment of weather-related disruption, Figure 10 – 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.

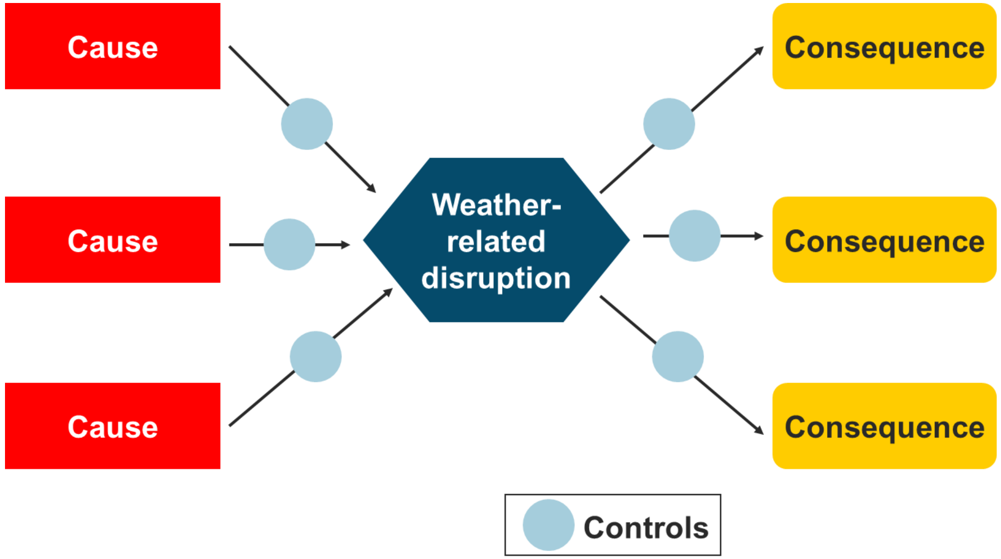


Figure 10 Bow tie risk assessment

The programme consists of six sub-programmes and their 23 constituent projects; these are described in Figure 11 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.

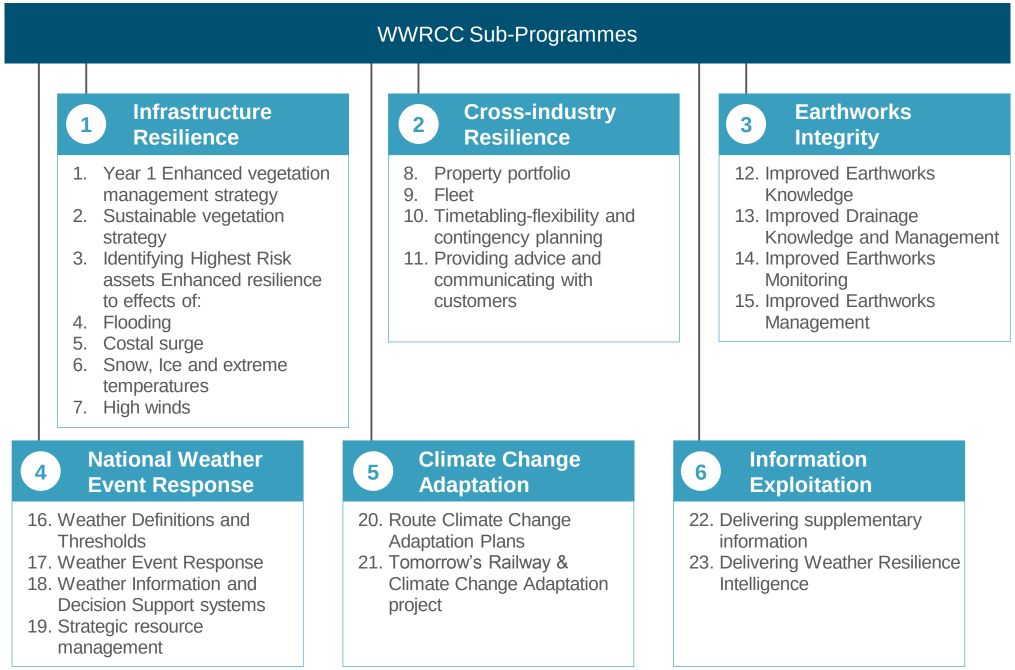


Figure 11 The constituent components of Network Rail's WRCC programme

The WRCC programme is currently supporting the delivery of:

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

Route weather vulnerability

The geography of Scotland is highly varied, from rural lowlands to barren uplands and from large cities to rural communities. The topography of Scotland is distinguished by the Highland Boundary Fault which traverses the Scottish mainland from Helensburgh to Stonehaven.

This fault line separates two distinctively different regions: namely the Highlands to the north and west and the lowlands to the south and east. The more rugged Highland region contains the majority of Scotland's mountainous terrain, which in itself is difficult to manage a large and exposed railway network, marry this with the abundance of rainfall we receive in Scotland and it makes for a challenging environment.

Wind remains the primary vulnerability within the route, accounting for 28 per cent of the route delay costs during 2006-2014. The vast majority of wind-related delay incidents are not wind gust affecting the OLE, more often than not its objects being blown on to the line and in some cases hitting the OLE and taking out a section.

In recent years we have had to deal with multiple third-party intrusion on OLE in periods of high winds with various articles blowing on to the line around Scotland Route, including trampolines, balloons, polythene sheets and garden sheds.

With further extension in the number of electrified routes in Scotland wind will continue to be our number one priority.

Scotland Route is also vulnerable to the effects of heavy rainfall with flooding accounting for 23.6 per cent of delay minutes 2006/07 to 2013/14.

Scotland Route has established plans to mitigate the effects of these weather impacts and continues to work proactively to further improve resilience.

Winter weather risk preparedness

Problems in Scotland Route are low adhesion to compacted snow and ice, icing of OLE, ice on inside of tunnels, snow in the points, landslips, flooding and strong winds.

Scotland Route has a procedure for proactively maintaining the infrastructure during winter months (Scotland Route: Winter Working Arrangements), which includes prompt reporting of infrastructure failures due to the weather conditions and coordinating local actions for maintenance staff reporting to sites. Improvement included the ability to remotely switch on 90 per cent of points heaters across the route without attending site and visiting the worst affected wire runs each morning during severe cold.

The Route also has four snowploughs, Figure 12, available along with two snow blowers, Figure 14, together with miniature snowploughs/route proving locos hired and stabled at various locations as dictated by the weather forecast.

Figure 12 Snowploughs are based at Slateford, Mossend, Inverness and Carlisle

The Snow Train or 'Winter Development Vehicle' as it is known, Figure 13, has been modified to carry the modules, generator and hot air blowers and a Mark 2 British Rail ex-Radio Survey Coach (with camera monitors, remote controls, GPS system installed etc). It was first introduced to the Route (and the company) in Winter 2011/12 at a cost of £1.4m.

It is used to melt snow from sets of points and has been used at Midcalder Jn, Lanark Jn and Law Jn. The train has the ability to sit over a set of points and blow warm air on to these, melting the snow and drying the points out. It also has steam lances and compressed air lances so the operators can clear the snow with more precision than the fixed hot air blower. It can be used on any line of Route within Scotland to clear/defrost points and can also be coupled with any of the snowploughs to provide a 'one stop shop' winter train.

Figure 13 Winter train located at Slateford

Winter preparedness for staff

The 2009/10, 2010/11 and 2013/14 winter seasons posed some of the most severe winter conditions for Scotland Route staff to work in. This included difficulty for signallers getting to work, maintenance staff responding to incidents and staff working in sub-zero temperatures for long hours over a period of up to four months to assist in keeping the railway running.

As a result, several actions have been put in place to ensure if there is a severe winter the Route will be better equipped to deal with staff and welfare issues. Staff working in any winter conditions should always report at regular intervals to Scotland Infrastructure Control Centre (ICC) especially when working alone at remote locations.

In particular, arrangements have been put in place for both lone workers on the railway and signallers working in remote areas as the safety risks faced by lone workers on the railway increases significantly during the winter season, especially during severe weather conditions.

Figure 14 Two snow blowers are located at Kilmarnock and Inverness

Summer weather risk preparedness
Scotland Route doesn't suffer from a lot of heat-related problems; however we still take actions to ensure that potential problems do not arise.

The onset of summer brings with it a number of risks to the effective operation of the rail network. The main risks are:

- expansion of point work causing detection failures
- closure of Intermediate Block Joints (IBJ) causing track circuit failures
- air conditioning failure
- heat effect on overhead line equipment
- flooding
- lightning strikes on the infrastructure
- rail buckles due to high temperatures
- staff working in outside locations experiencing sun exposure.

Scotland Route has a procedure (Scotland Route Summer Work Arrangements) for proactively maintaining the infrastructure during summer and periods of hot weather; this is documented and reviewed annually.

Scotland Route also priorities low CRT sites to ensure as few locations as possible on main running lines require a CRT imposed on the hottest of days and weekly progress report on summer preparedness (plate oiling, fish plate adjusting, CRTs, etc) is sent to relevant parties to highlight any issues. The painting of rails white is a mitigation action to reduce high temperature effects on points, Figure 15.

All of these actions help to ensure if the temperature does increase to a particular dangerous level the Scotland route has already mitigated some of the potential issues.

Figure 15 Rails painted white to reduce heat effects on points, Glasgow Central Station

Future climate change vulnerability

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

The UK Climate Change Projections (UKCP09) provides regional climate change projections across 13 administrative regions in Great Britain, Figure 16. Scotland Route is divided into three regions – Western Scotland, Eastern Scotland and Northern Scotland. Projections for these are considered to be representative of the future climate changes within the Route.

Figure 16 UKCP09 administrative regions

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

Mean daily maximum temperature change

Mean daily maximum temperatures for all parts of Scotland are projected to increase throughout the year, with greater increases expected in the summer months.

In Eastern Scotland the average maximum daily temperature in July is expected to increase by 2.6°C, reaching 19.6°C by the 2050s, and by 4.3°C, reaching 21.3°C by the 2080s. Average maximum daily temperature in January is expected to increase by 1.8°C, reaching 6.1°C by the 2050s, and by 2.5°C, reaching 6.8°C by the 2080s, Figure 17.

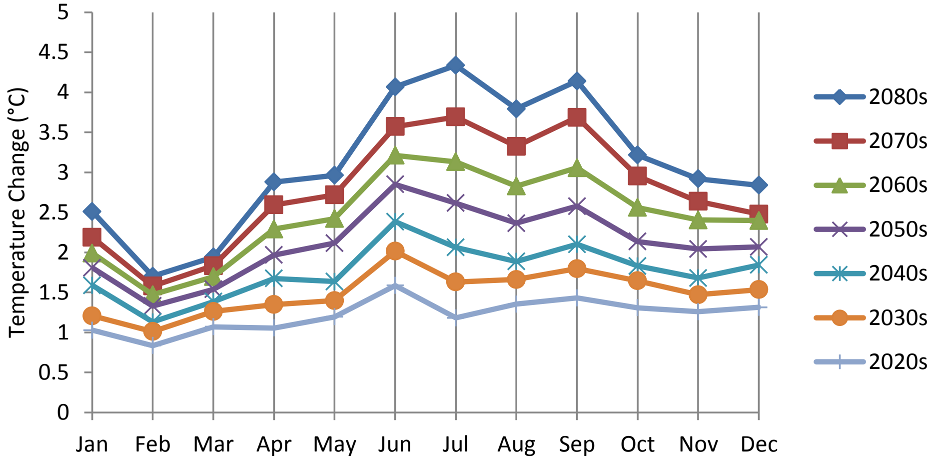


Figure 17 Scotland East, mean max temperature change (50th percentile)

The average maximum daily temperature in Northern Scotland in July is expected to increase by 2.1°C, reaching 17.6°C by the 2050s, and by 3.5°C, reaching 19°C by the 2080s. Average maximum daily temperature in January is expected to increase by 1.7°C, reaching 6.3°C by the 2050s, and by 2.3°C, reaching 6.9°C by the 2080s, Figure 18.

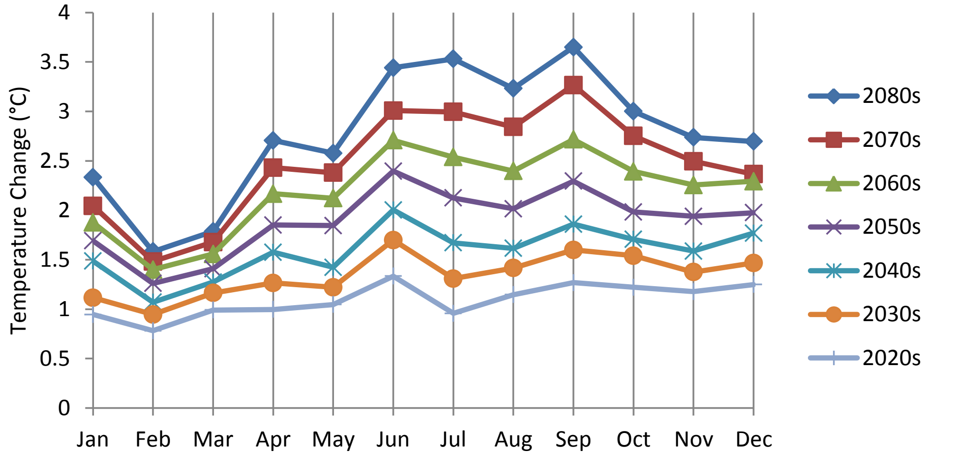


Figure 18 Scotland North, mean max temperature change (50th percentile)

The average maximum daily temperature in Western Scotland in July is expected to increase by 2.2°C, reaching 19°C by the 2050s, and by 3.7°C, reaching 20.5°C by the 2080s. Average maximum daily temperature in January is expected to increase by 1.9°C, reaching 7.2°C by the 2050s, and by 2.8°C, reaching 8.1°C by the 2080s, Figure 19.

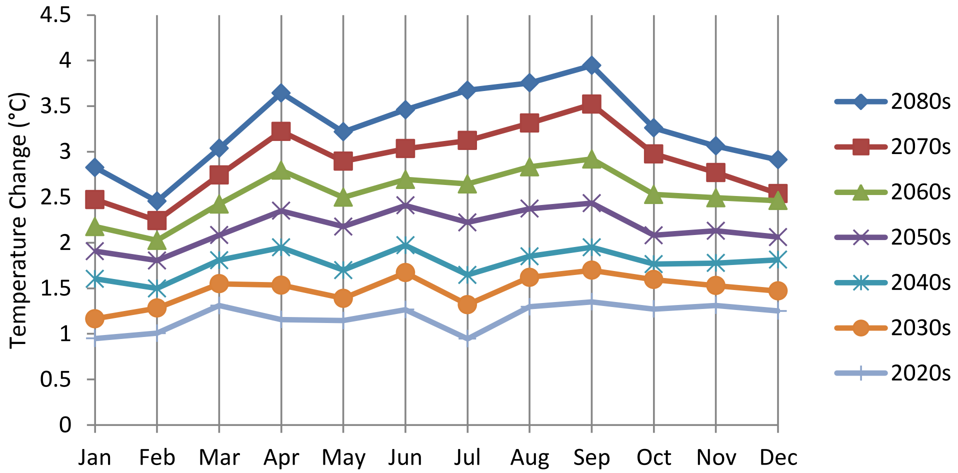


Figure 19 Scotland West, mean max temperature change (50th percentile)

Mean daily minimum temperature change

The mean daily minimum temperatures for all parts of Scotland are also projected to increase throughout the year.

In Eastern Scotland the average minimum daily temperature in July is projected to increase by 2.6°C, reaching 11.7°C by 2050s, and by 4.2°C reaching 13.3°C by the 2080s. Average minimum daily temperature in January is projected to increase by 1.9°C, reaching 1.2°C by 2050s, and by 2.6°C, reaching 1.9°C by 2080s, Figure 20.

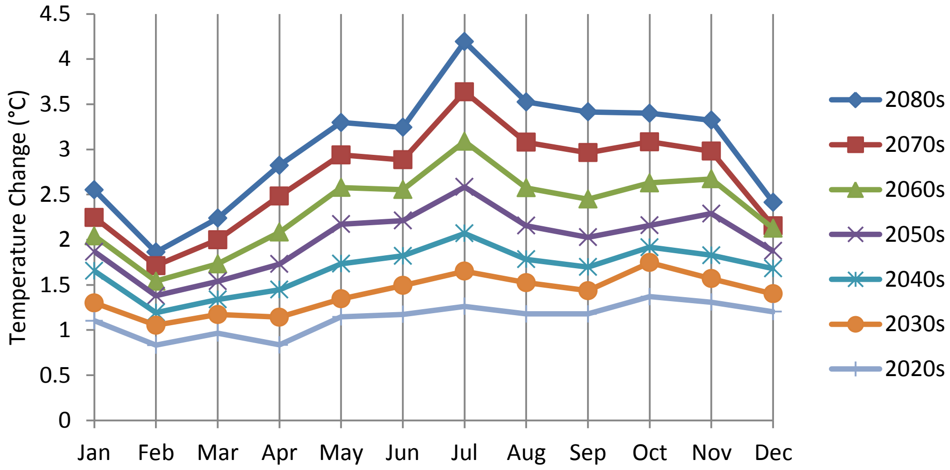


Figure 20 Scotland East, mean min temperature change (50th percentile)

In Northern Scotland the average minimum daily temperature in July is projected to increase by 2.3°C, reaching 11.3°C by 2050s, and by 3.8°C reaching 12.8°C by the 2080s. Average minimum daily temperature in January is projected to increase by 1.8°C, reaching 1.7°C by 2050s, and by 2.4°C, reaching 2.3°C by 2080s, Figure 21.

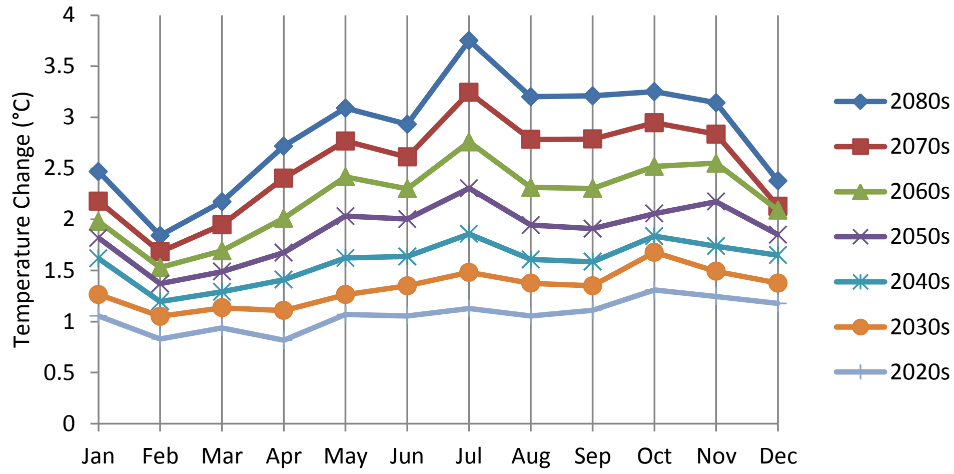


Figure 21 Scotland North, mean min temperature change (50th percentile)

In Western Scotland the average minimum daily temperature in July is projected to increase by 2.4°C, reaching 12.2°C by 2050s, and by 3.8°C reaching 13.7°C by the 2080s. Average minimum daily temperature in January is projected to increase by 2.4°C, reaching 2.9°C by 2050s, and by 3.5°C, reaching 4°C by 2080s, Figure 22.

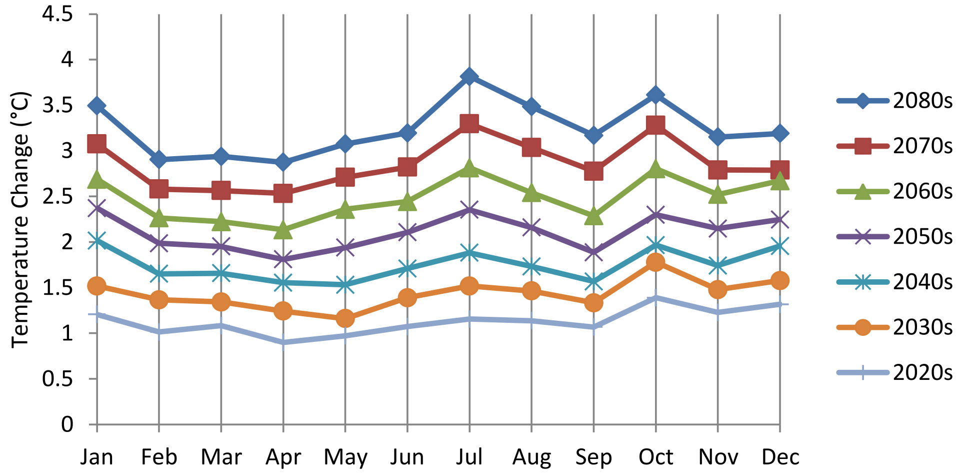


Figure 22 Scotland West, mean min temperature change (50th percentile)

Mean daily precipitation

Projections for mean daily precipitation for all parts of Scotland show a significant increase in the winter months and a decrease in summer months.

In Eastern Scotland the greatest increase in daily precipitation is expected to occur in November. Precipitation is projected to increase by 15 per cent, reaching 4.2mm per day by the 2050s, and by 23 per cent, reaching 4.5mm per day by the 2080s. The month with the greatest decrease in precipitation is likely to be June, when daily precipitation is projected to decrease by 17 per cent by the 2050s, to 1.9mm per day, and by 25 per cent, to 1.7mm per day by the 2080s, Figure 23.

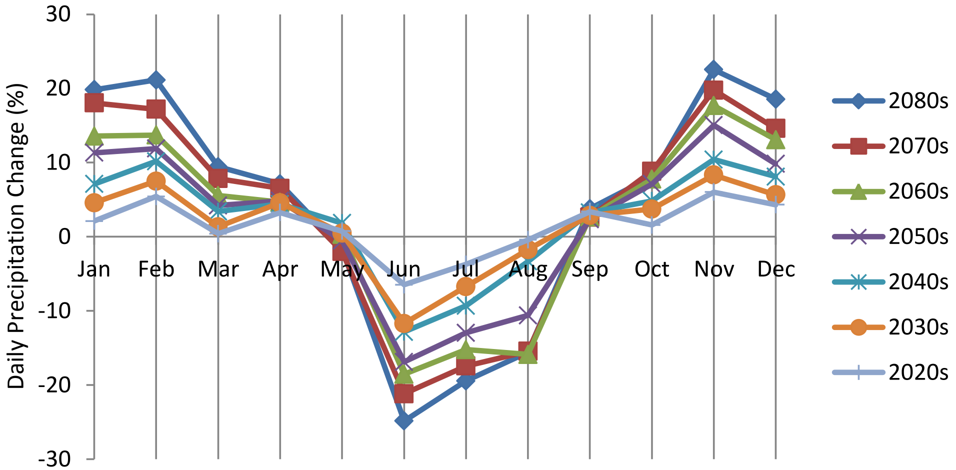


Figure 23 Scotland East, mean daily precipitation change (50th percentile)

In Northern Scotland the greatest increase in precipitation is expected to occur in December. The mean daily precipitation is projected to increase by 20 per cent, reaching 7mm per day by the 2050s, and by 40 per cent, reaching 8.1mm per day by the 2080s. The greatest reduction is likely to occur in August, when the mean daily precipitation is projected to decrease by 7 per cent by the 2050s, to 3.1mm per day, and by 11 per cent, to 2.9mm per day by the 2080s, Figure 24.

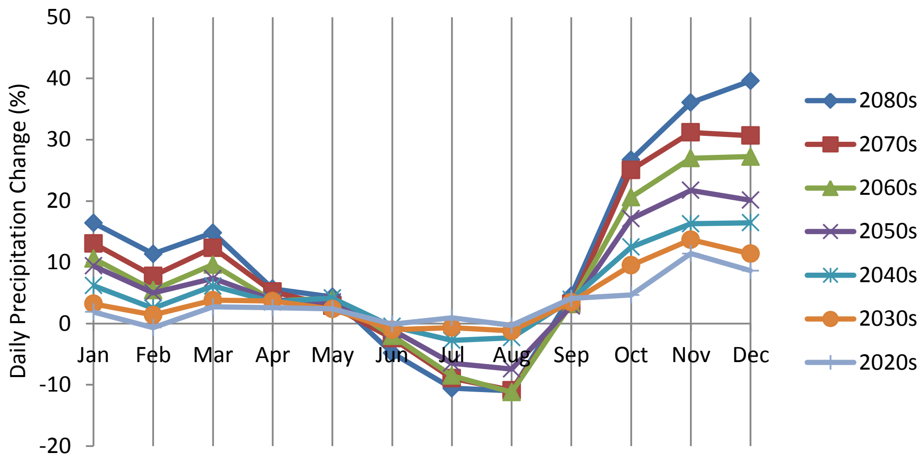


Figure 24 Scotland North, mean daily precipitation change (50th percentile)

In Western Scotland the greatest increase in precipitation is expected to occur in December. The mean daily precipitation is projected to increase by 20 per cent, reaching 7.3mm per day by the 2050s, and by 40 per cent, reaching 8.5mm per day by the 2080s. Similar to Eastern Scotland, here the greatest reduction is also likely to occur in June, when the mean daily precipitation is projected to decrease by 16 per cent by the 2050s, to 2.4mm per day, and by 24 per cent, to 2.2mm per day by the 2080s, Figure 25.

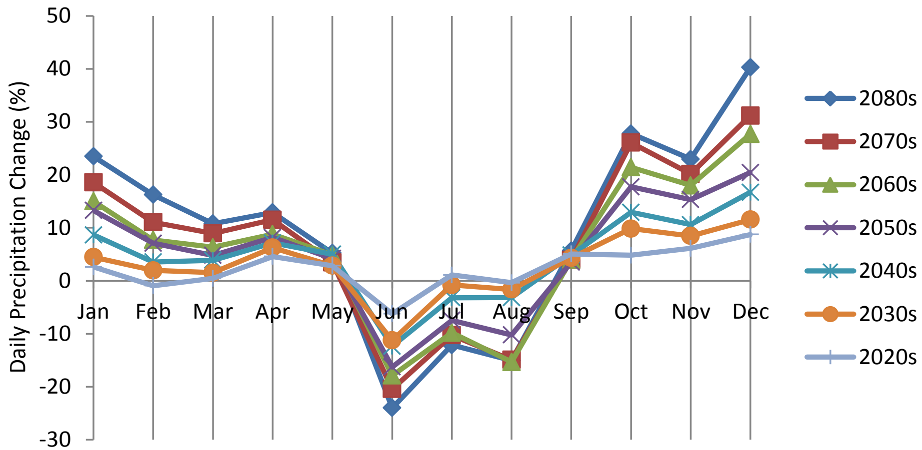


Figure 25 Scotland West, mean daily precipitation change (50th percentile)

Sea level rise

Sea level rise for the Scotland Route coastal and estuarine assets can be represented by the projections for the Queensferry area. For the high emissions scenario, the projections for the 50th percentile for 2050 are 0.176m and 0.413m by the end of century (the rise is unlikely to be higher than 0.319m and 0.735m respectively), Figure 26.

The increase in sea level will have to be considered in any future design.

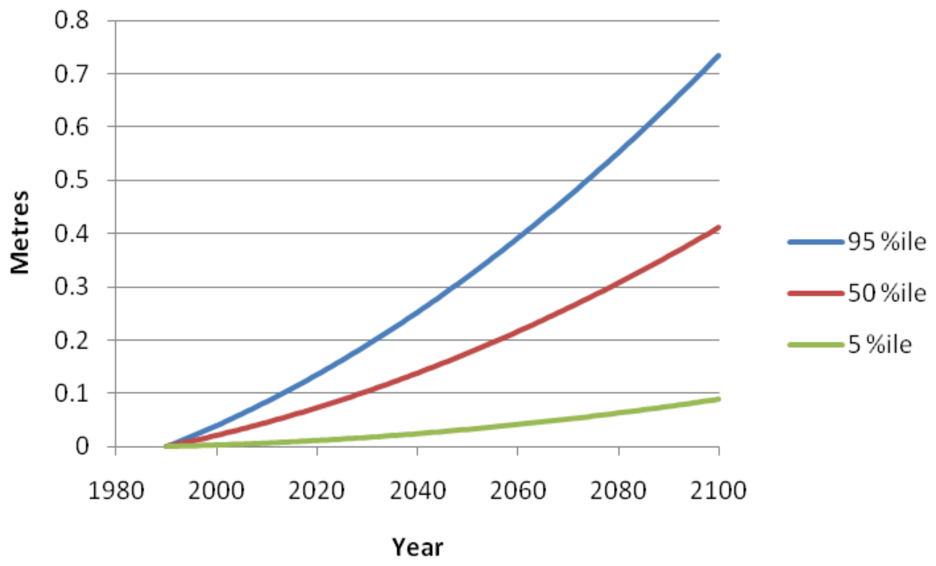


Figure 26 UKCP09 sea level rise projections for Queensferry area

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

Scotland Route impact assessment

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

Performance impacts

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

Schedule 8 costs for the past eight financial years for the Scotland Route has been analysed to provide an assessment of weather impacts, Figure 27.

- ‘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.

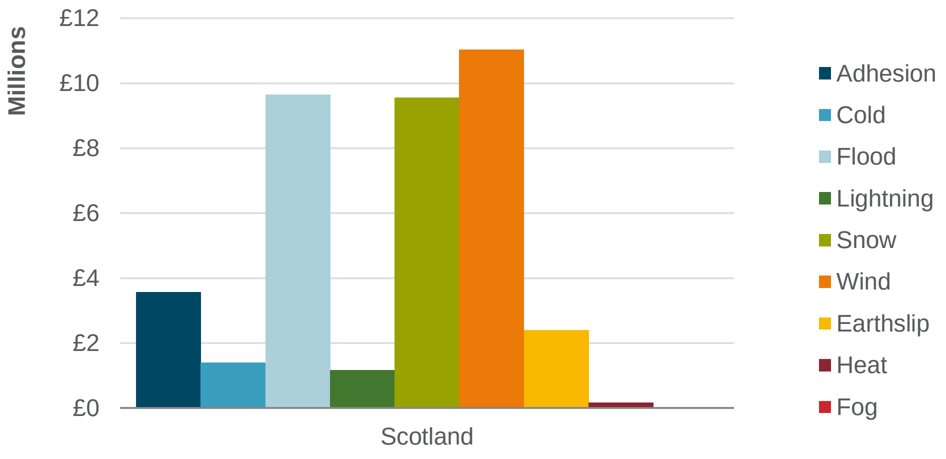


Figure 27 Scotland Route weather attributed Schedule 8 costs 2006/07-2013/14

Over the past eight years, the average annual performance cost to the Scotland route, as a result of weather-related events, has been almost £5m.

The analysis shows that wind, flooding and snow have been the most significant weather impacts for the Route. Climate modelling cannot provide strong projections for future changes to wind speeds, though; increased storm frequency is generally projected and may increase the risk of wind-related incidents on the Route.

Table 1 Prioritisation of weather-related impacts on Scotland Route

Weather-related impact	Schedule 8 costs[1]	Projected future impacts	Prioritisation
Wind	£0.99m	Wind changes difficult to project however generally projected to increase	High
Flooding	£0.91m	Up to 25 per cent increase in February mean daily precipitation[2]	High
Snow	£0.98m	Up to 3°C increase in January mean daily minimum temperature[1]	Medium
Adhesion	£0.16m	Complex relationship between adhesion issues and future climate change.	Medium
Earthslips	£0.25m	Up to 25 per cent increase in February mean daily precipitation[1]	Medium
Heat	£0.02m	Up to 3.1°C increase in July mean daily maximum temperature[2]	Medium
Sea level rise	Not recorded	0.18m increase in sea level rise[3]	Medium
Cold	£0.22m	Up to 3°C increase in January mean daily minimum temperature[2]	Low
Lightning	£0.20m	Storm changes difficult to project however generally projected to increase	Low
Fog	2 mins delay	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

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

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 the Scotland Route over the coming decades.

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

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.

Tree on the line affecting OLE, Ardoch, January 2013, following a cyclone

Identification of higher risk locations

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

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

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

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

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

Wind impact assessment

Based on 2006/07 to 2013/14 data, wind-related delays total 56,106 minutes per year, costing £0.99m per year in Schedule 8 costs. This is 28.5 per cent of weather-related delay minutes.

The following table is a list of our top ten most costly sites and the number of incidents we responded to over period 2006/07-2013/14 as a direct result of high winds.

Location	No. of incidents
Rutherglen East Jn	4
Drem to Dunbar	14
Lockerbie to Gretna Jn	1
Saltcoats	21
Anniesland	2
Winchburgh Jn	5
Gourock Station	1
Craigendoran Jn	7
Gailes	7
Dyce	4

Wind affects performance directly in that blanket speed restrictions are imposed when thresholds are reached. Scotland Route has a High Wind Procedure involving live feeds from weather stations and predefined trigger levels for wind gusts of 60mph+ or mean speed of 47mph+.

Wind also affects performance indirectly, primarily as a result of damaging lineside trees which then fall or drop branches on or near the line. Wind also moves other debris on to the line from the line side environment, frequently from neighbouring sites, recent examples include trampolines, balloons, polythene sheets and garden sheds, Figure 28.

High winds can also lead to significant waves to form even in waters protected from the open sea, these can cause power trips in OLE areas and damage to the infrastructure.

A recent example of the effects of wind on Scotland route occurred on 4 December 2013. An advanced weather warning was issued to media outlets in Scotland, stating that on the morning of 5 December, due to forecast high winds, the rail network would be closed for much of the day. On one particular part of the rail network in Markinch, Fife, over 60 large trees fell on the railway completely blocking the line until operatives could get on site and clear the debris. The rail network started to re-open in the early afternoon in some parts of the Route.

Closing the rail network for that one day due to high winds cost Network Rail over £1m in delay attribution cost.

Figure 28 Hay bales on line just North of Newtonhill, Aberdeenshire, December 2013

Vegetation

The Route has commenced a proactive strategy to remove high-risk trees which are capable of landing on the track if they fall. Clearing trees in danger of falling on or near the line is an enormous undertaking with some trees protected and other trees forming an important visual screen to our infrastructure.

A LIDAR (Light Detection and Ranging) survey was undertaken in July 2012 to identify trees that were at risk of falling on to our infrastructure. It also provided data on the height of the tree and where the trees are growing, for example an embankment or cuttings. A further LIDAR survey is been undertaken this year which will also give us increased details of the trees that are remaining, the results from this survey, available in Spring 2015, will be used by the Route to target the areas at which the railway appears to be vulnerable.

Where it is not possible to remove a tree completely, work is undertaken to reduce the crown size.

In addition, improvements to Asset Resilience and Vegetation Management will include:

- development of vegetation encroachment risk model and risk-based prioritised vegetation management plans are now in place
- enhanced management process for trees in high winds introduced in the Route underpinned by real time weather stations.

Figure 29 High winds cause considerable damage to trains, Dunkeld and Burnam

Flooding impact assessment

Based on 2006/07 to 2013/14 data, flood-related delays total 46,444 minutes per year on average, costing £0.91m per year in Schedule 8 costs. This is 23.6 per cent of weather-related delay minutes.

Scotland has experienced high levels of rainfall since the start of 2008, three of the top 10 rainfall years in the last 100 years have occurred since then.

Average annual rainfall in Scotland, since records began in 1910 is 1433mm but both 2011/12 and 2013/14 were well above that level.

2011/12 saw 1827mm, the third wettest since 1910, with 2013/14 at 1738mm.

The calendar year 2011 was the wettest year of the last 100 with 2008 in fourth place and 2009 in eighth place.

Water Management Group

Since 2008 Scotland Route has held a period end Water Management Group to look at flood sites and to plan actions to mitigate flooding. This group has led to the mitigation of minor and major flood sites within the Route.

The following table is a list of sites which, in recent years, have been greatly affected by flooding and work done to mitigate against any future flooding at the sites and reduce the number of delay minutes to passengers.

Sites	Action details	When
Dalmuir	Mitigated through minor works and sewer repairs by Scottish Water. Future works to increase resilience is planned during CP5	Ongoing
Glasgow Queen Street	Mitigated through a number of minor improvements together with enhanced inspection and maintenance	Completed
Princes St. Gardens	Flooding in Princes St. Gardens was remediated by a major works scheme to gather and pump the water away	Completed
Penmanshiel	Flood site at Penmanshiel siphon. Initial remediation through enhanced inspection and cleaning. A major works scheme to raise the wall heads of siphon chamber and install new screens has being completed. Further enhancement to provide an attenuation pond is planned during CP5	Ongoing
Dalmarnock Station	Flood site at Dalmarnock Station remediated through major works by providing an attenuation system	Completed
Plean	Flood site at Plean/Cowie remediated by a major works scheme with new culvert	Completed
Winchburgh Jn	Five flood sites in the greater Winchburgh area over 4 miles of track. First Phase mitigation completed by replacing pipes which were under capacity in Craigton cutting and renewing pipe work at Winchburgh Junction. A second phase to replace the Underbridge at Niddrie Burn, works at Swine Burn Pumping Station and install new track drainage is planned during CP5	Ongoing
Wallyford	Flood site at Wallyford where a culvert screen blocked and flows went on to the track. New more resilience screen designed and installed	Completed
Drem	Flood site at Drem station which has been remediated under a Business Plan with a new pipe work and an attenuation pond	Completed
Lochwinnoch	Minor works completed at Milliken Park and Lochwinnoch Station. Enhanced inspection and maintenance ongoing with further minor works planned during CP5	Ongoing

Figure 30 Flooding at Bishopton, August 2012

Increasingly frequent and intense storms may have the effect of overwhelming the existing drainage networks. This in turn could lead to service disruption and accelerated degradation of other assets that depend on good drainage, for example geotechnical assets and the track formation.

A recent example of this was 12 August 2014, at Kingussie when heavy rainfall caused local rivers to flood and drainage systems to become overwhelmed. Restoration of services took three days whilst recovery operations took place to reinstate ballast washouts and clear flood debris from the line. This one event caused 761 delay minutes and cost over £150,000 in delay attribution costs.

Track assets

Flooding can greatly affect the Track and its formation. There are a number of investigations Scotland Route is proposing to undertake in order to better understand the impact of flooding on the Track system:

- ballast retention – in areas of high flood potential investigate means of ballast retention to avoid loss of track formation as a result of wash out or scour
- investigate use of bituminous paving materials on sub grade to improve water run off and avoid scour or earthworks failure
- ballast cleaning/replacement – model the probability of increased ballast fouling as a result of regular flooding or increased rainfall, leading to reduced ballast life. In critical locations outline what ballast replacement frequencies or methodology should be adopted.

Structures assets

The topography of the Route, with steep-sided mountainous terrain and high rainfall, together with other significant precursors such as seasonal snow melt and sudden release of water from hydroelectric scheme dams means that our assets are particularly susceptible to severe localised weather events, as well as wider floodplain events.

Scotland Route contains a larger proportion of small diameter culverts on steep sidelong ground than other routes. As a result, the route has an increased work bank of culvert repairs identified in addition to those identified by the Network Rail Structures Policy.

The West Highland Line is a section of route with a significant number of such assets in poor condition, and at risk of increased frequency of severe weather events. A specific asset strategy has been developed and a remediation programme has commenced continuing through to the end of CP6.

Due to their small size, culverts can also present constraints in flow capacity when considered as part of an overall drainage system. During periods of exceptional rainfall this can lead to overtopping of these assets or flooding of adjacent land.

Two culverts with multiple historic instances of flooding have been identified by the Route Water Management Group for replacement. For example, the replacement of the culvert crossing Keppen Burn, Figure 31, on the Kilwinning Jn to Largs Line at Fairlie is being jointly developed with Transport Scotland (Trunk Roads Directorate) and North Ayrshire Council to provide the optimum solution.

Figure 31 Keppen Burn – downstream elevation

Underbridges
Underbridges historically experience scour and overtopping, which present a risk to the operation of the railway.

We have an established programme to calculate the risk of scour damaging underbridges. This programme is used to prioritise mitigation measures including physical works (scour protection) and operational instructions.

The Route currently has 41 structures classified as higher risk. In addition, a further 72 structures have the potential to fall into the higher-risk category on the conclusion of more detailed assessment.

The Route currently has plans to remediate 20 higher-risk sites in CP5. To further improve weather resilience an additional 12 sites have been identified.

To address the risk of overtopping at two historically at risk sites, schemes to improve the flow capacity are proposed.

The replacement of the underbridge crossing the Niddrie Burn, Figure 32, on the Edinburgh Waverley to Glasgow Queen Street Line would benefit from additional investment.

By replacing the existing two-span structure by a single-span structure, the flow capacity can be increased to reduce the frequency of flooding and to be able to accommodate additional pumped flows from the upgraded track/tunnel drainage system. The opportunity to carry out this work is available in 2015/16 during the blockade to carry out work in Winchburgh Tunnel as part of the Edinburgh to Glasgow Improvement Programme (EGIP) Enhancement Scheme.

Figure 32 Niddrie Burn – downstream elevation

At Wamphray on the West Coast Main Line flow capacity is being increased by lowering the river bed (renewal of existing concrete weir), this scheme is also replacing damaged scour protection.

Where full renewal of a bridge or culvert cannot be achieved, Scotland Route has explored a number of alternative options to improve resilience to flooding. One example is at the bridges crossing the Gynack and Balavil Burns near Kingussie on the Highland line, Figure 33. These bridges have special operating instructions to allow trains to continue to run safely when river levels are high and have scour protection and holding down arrangements installed to prevent them being washed away.

Figure 33 Gynack Burn, Kingussie – August 2014

Potentially vulnerable areas

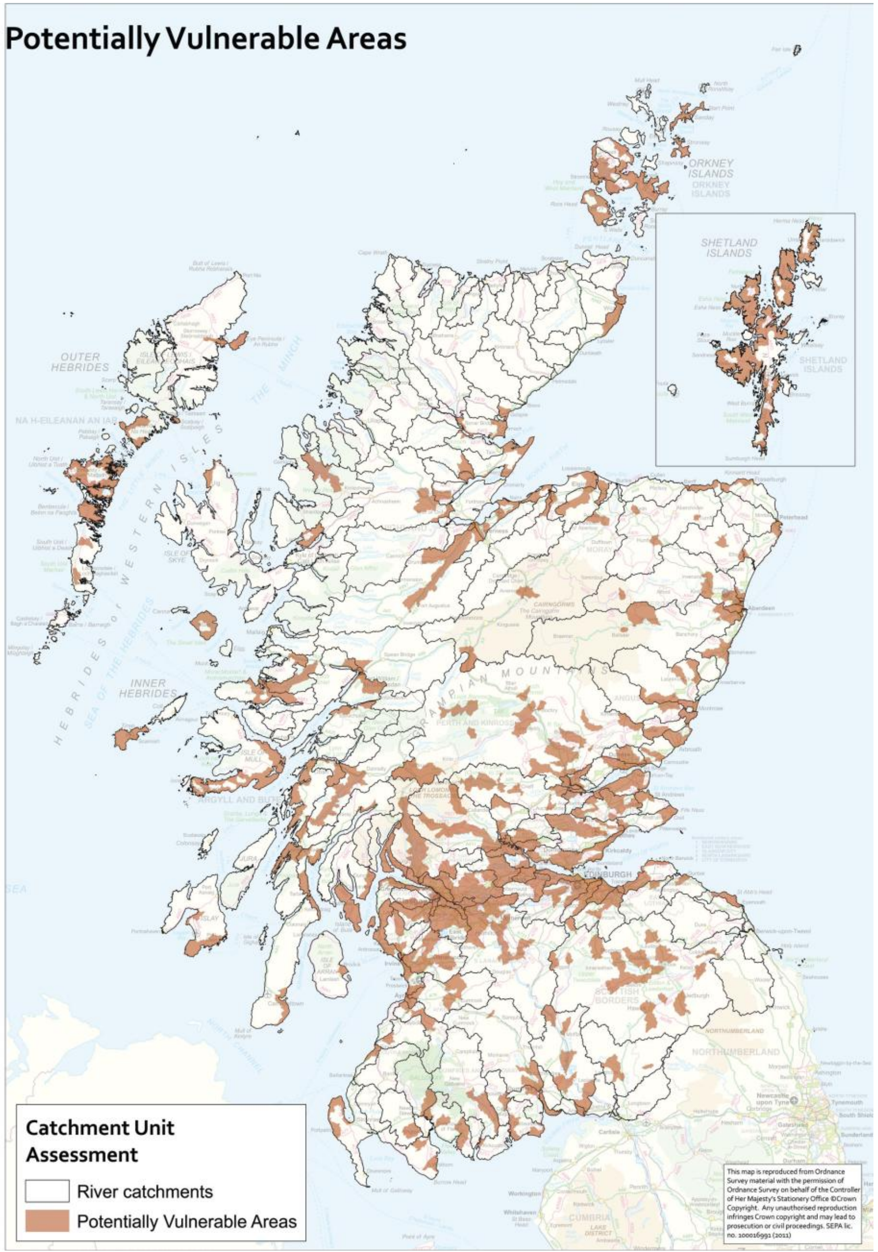
Scotland is developing its first Flood Risk Management Strategies, to be published by Scottish Environment Protection Agency (SEPA) in 2015, and Local Flood Risk Management Plans, published by Local Authorities in 2016.

SEPA's approach to Flood Risk Management Planning is underpinned by the National Flood Risk Assessment. This provided the first national picture of flood risk which looked at flooding from rivers, the sea and heavy rainfall in urban areas. It identified 243 areas, called Potentially Vulnerable Areas (PVAs), which contain the greatest risks from flooding in Scotland.

Scotland Route has one or more railways in 131 of these PVAs and will undertake a study of each PVA to determine the risk to the railway. The 131 PVAs will be ranked based on the level of risk to support long-term strategic flood resilience actions.

Scotland Route, along with all other Routes, is developing Drainage Management Plans during CP5 to align with the above.

A high-level strategy has been developed for the production of these plans and a pilot study has been undertaken on part of the Edinburgh to Glasgow main line, between Polmont and Haymarket West Junction.



Sea level rise impact assessment

The following table is a list of sites where we have been affected by coastal impacts in the past and the work we have done to make the assets more resilient in the coming years.

Sites	Action details	When
Kinfauns, River Tay	Installation of rock armour to reduce risk of scour and erosion to embankment which may affect its stability.	Completed
Gourock Station	Voiding is occurring in sea wall due to 'plucking' of concrete repairs. Remediate by placing rock armour along length to protect sea wall face.	Completed
Langbank Coastal Defence	Place suitable rock armour protection to toe of embankment, including carrying out all ancillary excavations and preparation to receive the rock armour. Preparatory work to include cropping of selected trees.	Ongoing
Saltcoats	Promenade and seawall refurbishment. Inclusion of scour/erosion protection to toe of wall. Additional sheet piling, large rock armour, accropode or similar to be considered.	Ongoing
Burntisland	Remedial works to embankment completed as interim mitigation. Further major works planned during CP5	Ongoing
Kincardine on Forth	Prioritised repairs to worst areas of defence with rock armour	Completed
Culross	Remedial works sufficient to ensure satisfactory service of the asset over a 60-year design life	Ongoing
Inverness-Muir of Ord	Rock Armour protection	Ongoing
Tain-Ardgay	Rock Armour protection	Ongoing
Craigendoran	Remedial works to areas of scour and erosion.	Ongoing
Stranraer Harbour	Rock Armour Protection	Planned

Sea level increase will not have a day-to-day impact in the short to medium term. Minor coastal storms will have an ever greater impact and over time the proportion of the tidal cycle that coastal gravity drainage systems are able to discharge over will reduce.

A particular coastal erosion location in Scotland Route is on the East Coast Main Line, just north of the border at Meg's Dub, Lamberton Beach, adjacent to the A1 Trunk Road. Here the cliff face is being scoured away and starting to encroach towards the railway.

To better understand the rate of erosion we have completed a study that illustrates the impact and options available. We are in the process of evaluation the options in conjunction with Transport Scotland and other stakeholders.

Coastal and estuarine defences
The Route manages 138 coastal and estuarine defence assets, a significant proportion of the national portfolio, as many lines were built along the coast to avoid upland terrain. The baseline programme of works for CP5 was based on specific work to key assets, and also a review of risks by geographic/line of route groupings of assets. The former included a scheme to carry out substantial repairs to Saltcoats Seawall, Figure 34. This mass concrete wall on the Kilwinning Jn to Largs Line suffered significant damage during the winter storms of 2012 and 2013.

In areas where track is subjected to greater levels of salt water exposure there is an increased risk of corrosion. Coated rail can be installed alongside non-corrosive fastenings to increase resilience to the coastal impacts.

Figure 34 Saltcoats Seawall, January 2014

OLE assets
OLE assets are susceptible to the effects of sea spray. Scotland Route currently has a limited number of locations which are vulnerable, Saltcoats, Craigendorand and Ardrossan. At Saltcoats there is a history of performance incidents due to sea spray shorting out the OLE and there have been 39 incidents in the past eight years of the line being closed due to this issue. During development of the wall repairs scheme it has been identified that the effects of sea spray could be reduced by incorporating a wave return wall into the promenade parapet at an additional cost of £1.25m, including OLE work to further reduce impact.

Scotland Route has asset management plans for ongoing maintenance and repair of the remaining coastal defence portfolio. Work has been identified at a number of key locations, for example, the North bank of the Firth of Forth, Figure 35. This group of assets has increased criticality following the introduction of coal flows serving Longannet Power Station.

Figure 35 Kincardine on Forth – typical coastal defects

Earthslip impact assessment

Based on 2006/07 to 2013/14 data, earthslip-related delays total 9,654 minutes per year on average, costing £0.25m per year in Schedule 8 costs. This is 4.9 per cent of weather-related delay minutes.

The following table is a list of sites which in recent years have been greatly affected by earthslips, within the table we have outlined what work was carried out at each site and if completed or ongoing.

Sites	Action details	When
Fishers' Wood	Earthslip was remediated.	Completed
Helmsdale	Works completed to reinstate slope. Future work to make the slope more resilient is planned during CP5.	Ongoing
Carmont	Remediation of cutting slope following emergency, after mudslide due to flooding.	Completed
Arrochar	Embankment slip was repaired with stone.	Completed
Aberdeen to Stonehaven	Minor works completed to reopen the line and followed by further minor repairs on 20 no. sites	Completed
East Linton	Earthslip was remediated.	Completed
Dumfries	Landslip and embankment failure. Gabion Baskets were installed and the embankment was regraded.	Completed
Slochd	Storm weather conditions in October 2009 resulted in a number of reactive repairs at various locations which have all been remediated.	Completed

Managing high-risk earthworks in heavy rainfall

Scotland Route maintains a live risk assessment of earthworks which it uses to produce a list of cuttings and embankments which are vulnerable to heavy rainfall. Earthwork assets vulnerability is likely to increase in periods of severe rainfall and so a weather alert system is used to trigger the implementation of robust short-term control measures at high-risk earthwork locations, involving regular inspection during the weather alert.

Network Rail uses the Met Office assessment of risk to infrastructure with warning thresholds of amber and red as triggers for action. A forecast for each high-risk site on the asset list will be sent to Scotland Route Control Centre 48 hours in advance. These forecasts are updated every six hours to ensure ongoing accuracy.

Upon receiving a weather forecast that's predicts an amber or red rainfall weather event for one of more high-risk sites, an Extreme Weather Action Team (EWAT) will be called. During the extreme weather event, resource requirements and the approach to be taken to the specific weather event will be agreed by the EWAT.

Under the high-risk earthworks procedure an enhanced patrolling and monitoring regime is implemented for earthworks deemed as 'high risk' when >25mm of rainfall over a 24-hour period.

Intense rain and flooding can cause the failure of geotechnical assets via a number of mechanisms each with a different suit 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 slope face drainage and stabilisation
- failure due to wet cutting toe, often accompanied with track quality problems. Mitigated by improved cutting and track drainage
- embankment failure due to saturation during rainfall events. These are very difficult to protect against, often an engineered solution is required to restore support
- 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. Mitigated by installing scour protection.

Physical mitigations to reduce the risk of rock fall include vegetation management, removal of loose or potentially loose material (descaling) and rock netting.

Earthslips and rock falls do not always occur on assets that Network Rail control. Scotland Route has a high number of rural lines which pass through mountainous terrain and where the land on either side of the railway is on naturally occurring sloping ground (natural slopes).

Where natural slopes present a risk from earthslip or rock fall Scotland Route has and will continue to make contact with third-party landowners in order to better ascertain what work they plan to undertake close to the railway boundary. Any drainage or vegetation management work undertaken will be discussed at ongoing meetings with local protocols put in place to prevent any negative impact to the railway which would compromise passenger safety.

In addition to this, Scotland Route is exploring the use of new technology to proactively alert instances of earthslip and rock fall in remote locations. Distributed Acoustic Sensing (DAS) technology is now being used as a detection system in an innovative trial which is proving successful. Work on this system will continue through CP5 with the potential for a wider deployment being considered.

We will continue to investigate other new and developing technology which would make the railway more weather resilient. The Route is currently evaluating through a proof of concept study the potential to utilise satellite imaging to help predict movement in natural slopes that neighbour the rail network.

Figure 36 Rock fall on line due to earthslip from flooding, Falls of Cruachan, June 2012

Snow impact assessment

Based on 2006/7 to 2013/14 data, snow-related delays total 55,335 minutes per year on average, costing £0.98m per year in Schedule 8 costs. This is 28.11 per cent of weather-related delay minutes.

The table below shows a list of sites within Scotland Route most affected due to snowfall, and the number of incidents responded to over the past eight years.

Location	No. of incidents
Beattock Summit	16
Law Jn	15
Rutherglen East Jn	14
Inverness to Aviemore	27
Newton	13
Dalwhinnie to Pitlochry	14
Blackford	5
Newbridge Jn	2
Carstairs East Jn	13
Glasgow Central	15

Snow is frequent in much of the Scotland Route and the very significant delay minutes are due to the widespread nature of this problem when it does occur and the fact that in very heavy snowfall it can prevent trains from running.

Although the number of cold and snowfall events is likely to fall in future years, and the season where there is a snow risk is likely to shorten, snowfall events may increase in intensity.

The primary mitigation for snow and cold is good forecasting allowing robust emergency timetables to be implemented and the targeted use of Multi-Purpose Vehicles (MPVs) to de-ice key routes. An increased robustness in these capabilities could improve preparation for well-forecast snow and speed up recovery following ice or snowfall.

Scotland Route has a number of other mitigations for improving response to snow events including, a procedure for proactively maintaining the infrastructure during winter months, four snowploughs available along with two snow blowers together with miniature snowploughs and route proving locos hired and stabled at various locations as dictated by the weather forecast.

Scotland Route also has The Snow Train or ‘Winter Development Vehicle’. It is used to melt snow from sets of points. It also has steam lances and compressed air lances so the operators can clear the snow with more precision than the fixed hot air blower.

Figure 37 Two trains caught in heavy snow Carrbridge, March 2010

Cold impact assessment

Based on 2006/07 to 2013/14 data, cold-related delays total 12,864 minutes per year on average, costing £0.22 per year in Schedule 8 costs. This is 6.5 per cent of weather-related delay minutes.

The table below shows a list of sites within Scotland Route most affected by cold, and the number of incidents responded to over the past eight years.

Location	No. of incidents
Bowling	1
Motherwell	9
Carstairs	5
Rutherglen East Jn	2
Lenzie	2
Lugton	4
Edinburgh	4
Bellgrove	2
Aberdeen	3
Aberdour	1

Overall the risk of significant delays due to cold and snow is a reducing problem and significant investment in expensive mitigations should probably not be a priority and moderate investments in better procedures and relatively short-term investments such as more MPV capacity etc should however be assessed.

We have a number of teams which make icicles patrols during times of very cold weather.

Points assets

One of Scotland Route's primary weaknesses against cold weather is the failure of points. There are several failure modes for points: compacted snow between the switch rail and the stock rail; frozen point ends due to failed points heating; and frozen points operating equipment (POE).

With potentially less frequent, more severe cold and snow events, it is imperative that points are reliable in order to maintain an operational railway. Reliability is currently monitored, the root cause of failures is established to improve asset knowledge and there is an appropriate action plan:

- to reduce the number of incidents associated with frozen POE, the Route is increasing the number of POEs that have internal heating, with increased capacity for heat retention within the points heaters and rail
- snow compacted into point end will continue to be cleared by maintenance when snowfall is predicted to overwhelm the points heating capability
- points heating may fail for a number of reasons, however the majority of our installations are monitored remotely which provides alarms and allows prompt interventions
- every main line point end is fitted with Remote Condition Monitoring (RCM).

Figure 38 Heavy snow at Corrour, West Highland Line, February 2014

Signalling assets

One of the route's major signalling weaknesses against cold weather is manual signalling and points rodding. This equipment is prone to freezing which can cause long delays, and the Route has completed a renewal programme.

Structures assets

There have been incidents in the past eight years of icicles in tunnels and on bridges that have caused delays, primarily posing a danger of damage to the train. These have been removed by maintenance on a case by case basis in the past but with the addition of the Winter Development Vehicle future work is likely to be less time consuming and reduces the risk to operatives.

No one structure is particularly vulnerable currently and therefore proactive resilience is currently difficult to target.

With an increase in winter temperature, icicles are unlikely to increase in regularity. However, extreme cold events are predicted and so wet tunnels and structures, such as Haymarket Tunnel and Queen Street Lower, will be a continual vulnerability. Scotland Route has a programme of ice management removal undertaken throughout high-risk days. Areas with OLE are particularly vulnerable to the impact of icicle formation and prioritised accordingly.

For tunnel structures in addition to the risk of icicles, ice can build up at track level and can also cause damage to tunnel lining. Scotland Route is undertaking a programme of rock stabilisation works in 12 unlined rock tunnels. This is driven by Unlined Tunnel Geological Risk Assessment (UTGRA) recommendations on each structure, which was informed by a review of the deterioration in rock condition over time due to freeze/thaw damage.

It is proposed to replace the drip shield structure at the west portal of Bishopton Tunnel, Figure 39. The current arrangement has proved to be susceptible to ice build up and there is the potential that structural failure could result from severe ice jacking.

During the cold winter months of 2009/10 and 2012/12 there was a significant effect on station platforms with frost heave causing the platform and copping at the platform edge to become uneven and dangerous for station users. All these sites have been remediated.

Earthworks assets

Freeze-thaw action affects rock slopes, particularly those with heavily jointed configurations. Mitigation includes enhanced examination for vulnerable assets and a programme of targeted rock scaling, bolting and rock fall netting.

Figure 39 Icicles at Bishopton, December 2010

Adhesion impact assessment

Based on 2006/07 to 2013/14 data, adhesion-related delays total 8,772 minutes per year on average, costing £0.16m per year in Schedule 8 costs. This is 4.5 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 rail head treatment. The weather that causes the greatest adhesion problems are still and cold mornings and evenings which promote heavy dew and if combined with leaf fall the railhead can become contaminated.

The table below shows a list of sites and actions taken at those locations to address any adhesion issues.

Site	Action details
Inverness : Aviemore	Traction Gel Applicator installed between Inverness and Culloden. Rail Head Treatment Train runs increased on this section
Kirkcaldy : Inverkeithing	Vegetation clearance and special attention paid by Leaf Fall teams and Station Maintenance Teams to Dalgety Bay
Newton : Hamilton Central	Additional works carried out during the autumn season to mitigate leaf fall. Vegetation clearance
Falkland S.S. : Mauchline	Three new Traction Gel Applicators installed. Rail Head Treatment increased. Vegetation clearance
Usan : Carnoustie	Rail Head Treatment increased at Carnoustie
Dalmuir	Vegetation clearance
Dalwhinnie : Pitlochry	Additional mitigation works carried out and adhesion modifier laid on the rail throughout the section

The primary mitigation is tree removal in areas where the problem is persistent followed up with a programme of railhead treatment, including rail cleaning to remove contamination and application of adhesion gel. Increased Multi Purpose Vehicle (MPV) capacity can assist with both rail head treatments. Plans to reduce the vegetation cover on the route will improve matters also.

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.

Scotland Route has implemented risk-based models to prioritise the removal of lineside vegetation. This will assist in reducing adhesion issues Route wide.

Lightning impact assessment

Based on 2006/07 to 2013/14 data, lightning-related delays total 6,895 minutes per year on average, costing £0.20m per year in Schedule 8 costs. This is 3.5 per cent of weather-related delay minutes.

Where possible the Route has implemented measures to reduce the impact of lightning on signalling and control systems. The ability to completely reduce the impact is however not possible, particularly on older generations of equipment.

As signalling systems are replaced over time, new systems will be specified with a greater degree of resilience including the provision of lightning surge arrestors. Current mitigation is to ensure a good stock of vulnerable equipment spares are held to ensure service recovery is swift.

The table below shows locations around Scotland Route which have been affected by lightning strikes and the actions taken at these locations to make our assets more resilient to future strikes.

Site	Action details
Highline Line (Dalwhinnie, Blair Athol, Slochd, Aviemore) Easy Coast North Line, (Laurencekirk, Aberdeen) Scottish Central Main Line, (Blackford)	These locations are Block Control areas. All utilise line pairs or occasionally Earth returns for the Block Control circuits and are susceptible to induced voltages causing equipment damage. These circuits are sensitive to Earth-related faults and are primarily protected by in-line fusing. System rectification time is usually primarily directly related to staff deployment and failure point identification followed by service recovery as many are on single lines
East Coast Main line, (Reston)	Reston has a Frequency Division Multiplex (FDM) transmission system and a significant delay incident occurred due to a large volume of FDM equipment damage following a direct strike. This system uses a sectionalised cable pair and due to the sensitivity to Earth faults, the primary protection method is in-line fusing
West Coast Main line, (Lockerbie)	The failure at Lockerbie was due to line fuses failing which would have an impact on the signals affecting Cove MCB. The legacy TDM transmission has since been replaced by a point-to-point digital system over Fixed Telecoms Network (FTN) which has alleviated this issue

Heat impact assessment

Based on 2006/07 to 2013/14 data, heat-related delays total 723 minutes per year on average, costing £0.02m per year in Schedule 8 costs. This is 0.37 per cent of weather-related delay minutes.

The following table shows the areas which have been affected by Heat, in some cases more than once, over the period 2006/07 to 2013/14.

Location	No. of incidents
Longniddry	2
Carstairs	1
Lenzie	3
Drem to Dunbar	2
Carrbridge	3
Law Jn	2
Reston to Grantshouse	1
Midcalder Jn	1
Laurencekirk	2
Carmuirs	1

There are several assets that are vulnerable to the effects of heat. There are proactive measures in place currently to reduce the impact of heat on the railway system and consideration has been given to the opportunities available to mitigate an increase in impact as temperature increases.

Points

Currently, in conjunction with the Critical Rail Temperature (CRT) mitigations, the operations of points is minimised during hot weather to reduce the risk of failure. The movement is particularly restricted on Key Route Strategies (KRS) to enable flowing traffic. The mitigations stated above are also being considered for points and the immediately adjacent sections to reduce the need for restricted points operations.

At Haymarket East Jn, in order to keep the rails cool, there is a sprinkler system in place which automatically detects the rail temperature and activates before a problem occurs.

Signalling assets

Electrical equipment in lineside buildings can be severely affected by high temperatures. Currently the Relocatable Equipment Buildings (REBs) are air conditioned and are able to maintain constant temperature conditions.

With an increase in temperature and more heat-generating technology in lineside REBs, it is likely that the air conditioning requirements will increase. Remote condition monitoring is currently installed and operated, and will be extended to more critical sites during CP5. Air conditioning is to be a more valued asset within the route, as it is noted that it is critical to the performance of the signalling assets.

Lineside location cabinets are also susceptible to failures due to overheating. To reduce the failure frequency location cabinets are being painted white in an effort to reduce the effect of direct sunlight and heat on the cabinet.

Electrification and plant assets

Currently, E&P assets are not largely affected by high ambient temperatures. Some batteries and equipment in lineside buildings can have a reduced life span if they are kept at high temperatures for a long period of time. However, this is not significant across the life span of the asset.

At one location on the network, at Finnieston, the OLE equipment is of fixed termination meaning it is susceptible to sag during hot weather. Mitigation to convert this to a more resilient design (auto tension equipment) has been identified as part of this plan.

Track assets

Track assets are vulnerable to the effects of increased temperatures. Mitigation is provided as part of routine maintenance. Track maintenance teams put significant resource into managing the track asset in a way that limits the number and length of speeds restrictions required due to heat to manage safety. They are largely successful and the current impact is relatively small as a result.

Mitigation actions have been to:

- paint rails white to lower the temperature of the rails
- prioritising low CRT sites to ensure as few locations as possible on main running lines require a CRT imposed on the hottest of days
- stress the track to ensure its robustness during hot weather.

In addition to the above mitigations, further work has been identified which would increase knowledge and understanding of the effects of heat on track assets and could be used to target future mitigation. These include:

- a study to understand impact of temperature increases on optimal stressing regime. Investigate whether an increased Stress Free Temperature provides more robust track asset performance.
- model impacts of expected durations of hotter and colder temperatures. Review the extents and compare them to current levels. Understand the impact on Track Machine (Tamping and Stone blowing) productivity.
- temperature rate of change – break potential and monitoring of defect growth. Identify if any proposed changes to the rate of temperature change will impact upon the rate of defect propagation.
- extreme temperature – Insulated Block Joint (IBJ) usage. Understand if extremes are likely to result in increased risk of failure at an IBJ due to 'pulling apart' or crushing due to higher forces and stresses in the rail. Consider whether alternative designs (such as the scarf type) should be considered on specific locations.

Earthworks assets

South facing Rock Slopes and Soil/Rock Slopes are also becoming more vulnerable to rock fall due to the drying effects from the increase in temperature. Targeted programmes of rock fall netting have been completed with further sites planned during CP5, Figure 40. Additional mitigation is being trialled in the form of rock fall detection using Distributed Acoustic Sensing technology and the potential use in the longer term of satellite technology.

Figure 40 Rock fall netting near Bridge of Allan, May 2014

Fog impact assessment

The historical impact of fog on railway operations in Scotland is low.

Based on 2006/07 to 2013/14 data, fog-related delays total two minutes of delay per year. This is 0.07 per cent of weather-related delay minutes.

Fog risk is expected to decrease as temperatures rise; current controls are adequate for future management of fog.

Scotland 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 Scotland 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
Risk to staff from extreme weather conditions	Staff trained to use and supplied with appropriate equipment, e.g. life vests for flooding events, seasonal PPE, offices and depots temperature controlled	Ongoing
Weather information		
The provision of only cyclical forecasts (e.g. daily general forecast) limits the prediction of weather impacts on vulnerable assets	Use real-time weather data. Also radar services provided by weather services contractor to confirm actual weather conditions and assess asset vulnerability	New contract in place; 2015
Flooding		
Safety risk to staff responding to flooding sites and assessing the condition of the railway	Install Remote Condition Monitoring on the most frequently monitored 50 per cent of bridge structures in the 'flood plan'	End Y2 CP5
	Provision of water safety equipment (lifejackets, lifesaving rings) at repeat flood sites which require staff attendance	End 2014
	Staff who respond to flooding and assess flood risk to receive Water Awareness Training	Ongoing
Level of engagement with flood risk management authorities has to support effective discussions	Continue to liaise with and build on relationships with SEPA and Local Authorities through various local and Scotland wide Liaison Groups on flood risk management to share information and resolve issues, as in Scotland it is the local authority who has responsibility for flooding. Engage with Local flood resilience forums	Ongoing
Major repeat flood sites	Continue to investigate a resolve and undertake any Flood Risk Assessments identified to guide mitigation by Major/Minor Projects. Deliver the major projects previously identified	Throughout CP5
New flood sites:	Review new flood sites, identified at Water Management Group and prioritise them for investigation, design, development and remedial works	Throughout CP5
	Install any Remote Condition Monitoring identified, as prioritised by the route	Throughout CP5
Potentially Vulnerable Areas	Analyse PVAs Identified by SEPA and determine the risk to the railway and prioritise mitigation actions	End 2015
Coastal and estuarine		
Potentially vulnerable areas	From analysis of PVA determine any Coastal and Estuarine locations at risk and prioritise mitigation actions	Ongoing
Saltcoats Sea Wall	Develop proposals for increasing the resilience of the coastal railway at Saltcoats to include sea wall and OLE	End 2016
	Seek funding for a rolling programme of resilience improvement work for other at risk defences	From 2015 (mid CP5) to end CP6
Signalling	Relocate high-risk signalling equipment into storm resilient cases and buildings	From 2015 (mid CP5) to end CP6
Other route sections at increased risk of flooding following sea level rise due to climate change	Develop from PVA and sea level rise predictions, a Route Coastal, Estuarine and River Defence (CERD) plan which details vulnerable coastal assets and their management plan	From 2015 (mid CP5) to end CP6

Vulnerability	Action to be taken	By when
Earthworks		
A number of high-risk earthworks presently require proactive safety management in heavy rainfall	Actively monitor our rainfall data to implement the Adverse Weather Earthworks Plan and ensure safety. Continuously revise the plan to take into account earthwork condition	Operational measures ongoing
	Remediate the highest-risk earthworks as planned within the renewals work bank	End of CP5 Year 2
Failure precursors at earthwork sites are not directly monitored	Install Remote Condition Monitoring on select high-risk earthworks	Start Autumn 2014
Residual risk sites which require remediation	Target adverse weather sites in the Civils Adjustment Mechanism submission, for remediation in Years 3-5 CP5	Funding submission ongoing, to be complete End Q1 2015
	Remediate further high-risk condition earthworks.	Works in Years 3-5 CP5
Wind		
Detailed tree asset knowledge (location, size) is limited.	Review and catalogue the results of the national LIDAR survey of 2014 and compare with Scotland Route survey of 2012	End Q1 2015
	High-risk tree removal	Ongoing
On electrified routes, 'tree on line' incidents will cause greater disruption than non-electrified routes.	Future OLE Designs to have Improved design parameters for wind loading compared to previous high-speed overhead line systems	Ongoing
Edinburgh to Glasgow Main Line will be Electrified in 2016	Vegetation clearance ongoing within Electrification Programme	End 2016
	Maintain new reduced levels of vegetation	Ongoing
Adhesion		
Continued vegetation growth increases the volume of leaf fall and worsens adhesion	Delivery of de-vegetation (risk based) programme	Ongoing
Adhesion issues continue to cause a number of delay minutes	Continue to manage adhesion issues and amend the 'Autumn plan' of rail treatment as required	Ongoing through Autumn seasons
Cold and snow		
Only a limited number of points operating equipment (POE) have internal heating	Increase the number of points operating equipment with internal heating as part of the renewals process	End CP5
System failure occurs when points heating strips become detached, but this is not detected by Remote Condition Monitoring (which monitors the electrical properties of the points heating)	Use train-borne monitoring where possible. Review inspection frequencies during Winter preparation	November 2014
Overhead line and Tunnel icicles can form, affecting performance of the first trains each day	Run a maintenance train ahead of the first passenger trains to clear icicles, or other mitigation, as necessary	End 2016
High temperatures		
Speed restrictions are imposed earlier than required, as actual site conditions are not known. Remote Condition Monitoring is not widespread	Install Remote Condition Monitoring of rail temperature on some of the high-risk, highest delay impact locations	End 2015
Lightning		
The Highland Line is particularly vulnerable to lightning strikes due to its geology	Undertake a study to investigate causes and determine any mitigation	Renewal proposed for 2018
	Replace track circuits with Axle Counters	

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

Table 3 Potential additional WRCCA actions requiring further evaluation

Vulnerability	Action to be evaluated
All impacts	
Weather stations	More robust IT architecture to support better real time data retrieval and analysis
	Communications migration from 3rd party mobile provider to in-house Network Rail telecoms (FTN-X), thus enabling true real time data retrieval
	Reliability improvements to individual weather station sites
Flooding	
Underbridges	Continued scour protection at 12 number underbridges that have being identified around the Scotland route as potential Scour Sites
Culverts/earthworks	Continued protection and improvement around the Scotland Route of Culverts, to protect against track washout and land slips
Flash floods	Improvement to specific location around Scotland Route to further improve the resilience of Track washout due to flash floods
Level crossings	Improvement to specific level crossings around Scotland Route to further improve flooding resilience
Low lying locations	Improvement to specific location around Scotland Route to further improve the resilience of Track washout in low-lying locations
Track	Ballast retention – In areas of high flood potential investigate means of ballast retention to avoid loss of track formation as a result of wash out or scour
	Investigate use of bituminous paving materials on sub grade to improve water run off and avoid scour or earthworks failure
	Ballast cleaning/replacement – model the probability of increased ballast fouling as a result of regular flooding or increased rainfall. In critical locations outline what ballast replacement frequencies or methodology should be adopted
	Sleeper Failure – Model the increase in sleeper failure where 'Alkali/Silica Reaction' (ASR) is known to occur in concrete types. Include guidance to the relevant Asset Management teams on recommended replacement timescales

Vulnerability	Action to be evaluated
High temperatures	
Track signalling, electrification and plant, and telecoms	Improved resilience to heat within lineside building around Scotland Route to further prevent problems with signalling equipment failure.
Track	A study to understand impact of temperature increases on optimal stressing regime. Investigate whether an increased stress-free temperature provides more robust track asset performance.
	Model impacts of expected durations of hotter and colder temperatures. Review the extents and compare them to current levels. Understand the impact on track machine (tamping and stone blowing) productivity.
	Temperature rate of change – break potential and monitoring of defect growth. Identify if any proposed changes to the rate of temperature change will impact upon the rate of defect propagation.
	Extreme temperature – Insulated Block Joint (IBJ) usage. Understand if extremes are likely to result in increased risk of failure at an IBJ due to 'pulling apart' or crushing due to higher forces and stresses in the rail. Consider whether alternative designs (such as the scarf type) should be considered on specific locations.
Coastal and estuarine	
Coastal and estuarine defences	Continued protection around the Scotland Route of coastal defences, to protect against track washout and scour
Track	Wave height – avoiding rail corrosion. If the rail is likely to be subject to greater levels of salt water exposure then make recommendations where coated rail is to be used and when it is to be installed
	Wave height – robust components. If the track is likely to be subject to greater levels of salt water exposure then identify when to implement non-corrosive fastenings to enable maintenance

Vulnerability	Action to be evaluated
Earthworks	
Adverse weather sites	Continued and improved resilience to earth slips at adverse weather sites around Scotland Route
Natural slopes and third party boundary	Continued and improved resilience to earth slips and rock falls at natural slopes and third-party boundary locations around Scotland Route
Rock cuttings	Continued and improved resilience to rock falls within rock cutting due to freeze thaw actions
South facing slopes	Continued and improved resilience to boulder encroachment at south facing slopes
Fiber optic cabling	Installation of fiber optic cabling along parts of the route to aid in the detection of earthslips and rock falls and improve the response time of on call staff in locating the site
Vegetation management	Significant de-vegetation to enable earth works inspection to be undertaken or completed
Wind	
Circuit breaker trips	Continued protection and improvement of OLE at Saltcoats with possible installation of circuit breaker trips, in conjunction with sea wall modifications
Circuit breaker trips	Continued protection and improvement of OLE at Craigendoran with possible installation of circuit breaker trips
De-wirement	Continued protection and improvement of OLE from Hyndland to Finnieston with possible installation of improved de-wirement protection measures
Cold and snow	
Track signalling	Improved resilience to snow on the track signalling equipment on the Highland line
Station platforms	During cold winter months there can be a significant effect on station platforms with frost heave causing the platform and copping at the platform edge to become uneven and dangerous for station users. Review of investment needed to renew platform edges
Adhesion	
Vegetation management	Review enhancement of de-vegetation programme of works
Lightning	
Telecoms	Lightning strikes are accountable for 30 per cent of all level crossing Telecoms failures, improved resilience of the LC Telephones leads to no disruption after a lightning strike
Track signalling	Improved resilience to lightning strikes on the track signalling equipment on the Highland line

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.

Scotland Route management and review

Scotland Route is already committed to managing and reviewing the implementation of weather-related resilience actions and has several forums in which risks are identified and tracked.

The principal forums are:

- Route Infrastructure Reliability Group (each period)
- Asset Stewardship Group with TOCs, FOCs and other stakeholders (each period)
- Review of Flooding Resilience Actions at Water Management Group (each period)
- Joint Performance Improvement Plan (each period)
- Actions from route reports and the above forums are tracked regularly to measure the effectiveness of the resilience actions.

The Director Route Asset Management will undertake a six-monthly review of progress. The six-monthly Scotland Route reviews of seasonal preparedness plans will continue to ensure that all preparatory work has been completed.

Review of Route WRCCA plan actions

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

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

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

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

Network Rail
Buchanan House
58 Port Dundas Road
Glasgow
G4 0LQ

networkrail.co.uk