Earthworks and Drainage Weather Resilience

Targeted Assurance Review

25 May 2021

Contents

Acronyms and Abbreviations

CP6 – Control Period 6 (April 2019 to March 2024)

CP7 – Control Period 7 (April 2024 to March 2029)

DEAM – Director of Engineering and Asset Management

DU – Delivery Unit

EA – Environment Agency

LIDAR – Light Detection and Ranging (see definitions)

LLFA – Lead Local Flood Authority

NRW – Natural Resources Wales

ORR – Office of Rail and Road

PR23 – Periodic Review 2023 (ORR's review of Network Rail's 5-year plans for CP7)

RAM – Route Asset Manager (Note: in some Regions, this title is no longer used following Network Rail's national 'Putting Passengers First' re-organisation)

SEPA – Scottish Environmental Protection Agency

SM – Section Manager

TME – Track Maintenance Engineer

WRACCA – Weather Resilience And Climate Change Adaptation (which may refer either to a Plan or Strategy document, or to the central Network Rail team)

Definitions

LIDAR (2D)	A method for measuring distances, by directing a laser at an object and recording the time taken for the reflected light to return to a receiver. In "2D LIDAR" surveys, the laser scans back and forth horizontally (or vertically), measuring the distance to every point along the scan line.
Maintenance	Engineering work by Network Rail where: "The earthworks are maintained in a more or less steady state by carrying out regular or targeted cleaning of drainage, management of vegetation and vermin, and minor repairs." (definition from Network Rail's standard NR/L2/CIV/086).
Refurbishment	Engineering work by Network Rail where: "The likelihood of the earthworks failing is reduced by carrying out major repairs, local replacement, local reprofiling, or the installation of additional drainage works or local support." (definition from Network Rail's standard NR/L2/CIV/086).
Renewal	Engineering work by Network Rail where: "The likelihood of the earthworks failing is significantly reduced by carrying out major works that result in permanent changes to the asset. For example, full regrading, the installation of major retaining structures or other major support measures." (definition from Network Rail's standard NR/L2/CIV/086).
Weather Resilience	See section 3.1 for discussion on alternative definitions, but ORR's definition in this report is "more weather resilient" = sustainably reducing the risk of negative outcomes (safety, train performance, or economic) for railway end-users due to asset failures which happen as a result of the weather (allowing for future climate change)".
Wet-beds	A section of track where the ballast/sleepers become saturated through water contamination/leakage from either above or underground often resulting in a slight dip or reported "rough rides" in the track as trains pass over.

1. Executive Summary

‘Earthworks’ are the soil or rock slopes along the railway and ‘drainage’ is the system of pipes and ditches which carry water away from the railway. When these assets fail it is almost always triggered by the weather, so there is a need to make both the assets and operational systems more “resilient” to a range of weather conditions.

Following recent high-consequence incidents on the railway and national concerns about climate change, weather resilience is a priority for Network Rail, ORR and other stakeholders. However, Network Rail has a limited amount of funding to improve its weather resilience in CP6 and the Covid-19 pandemic may put even more pressure on funding for the next 5-year planning period (CP7) and beyond. It is therefore critical that all stakeholders understand options available to manage weather resilience, the implications for required levels of funding and the risks.

This level of detail was not included in Network Rail’s high-level plans, so ORR undertook this Targeted Assurance Review to collect specific examples of engineering solutions, innovations and other ways that Network Rail are trying to improve weather resilience. We have categorised these into eleven practical ‘levers’ to improve weather resilience and presented a framework which seeks to make CP7 funding discussions more transparent.

This report presents specific examples of good practice and it also presents examples to explain why these solutions cannot simply be copied and applied everywhere. A key finding was that improving weather resilience at a given location does not always require more funding – many of the examples presented here have the potential to save money, compared to traditional solutions. That is not to say that there is no requirement for funding to improve weather resilience, only that there are opportunities for efficiencies which Network Rail should be considering more widely.

While we identified numerous examples of good practice, Regions were not always aware of good practices in other Regions. We found that there was no clear definition of weather resilience, nor a framework to explain the options available for Regions or projects to improve it. We identified three recommendations:

1. WRACCA team to identify examples of best practice; and Network Technical Heads (earthworks & drainage) to demonstrate sharing between the Regions.
2. Regions (DEAMs) to provide clarification on how they plan to improve weather resilience in CP7, in each of the areas described in this report.
3. Regions (DEAMs) to develop plans and guidance to give delivery teams clear line-of-sight to Regional weather resilience strategy.

This additional transparency around weather resilience will ensure that the effectiveness and efficiency of Network Rail’s plans are clear at our PR23 Periodic Review.

2. Introduction

2.1 Background

Almost all failures of Network Rail's earthworks or drainage assets are triggered by the weather. Most commonly this is intense or prolonged rainfall which saturates the ground, weakening soils and rocks and leads to landslips; or causes natural and engineered drainage systems to overflow – which then floods or washes soil onto the tracks.

Landslips and flooding events do not occur uniformly over the year – most of the incidents in a year are concentrated in just a handful of days, during the most severe weather. So, even a marginal increase in the number of stormy days each year can have a significant impact on rail infrastructure.

Earthworks and drainage assets are already starting to see the impacts of climate change. Winter "frontal" storms (large, slow moving weather patterns) have historically caused the largest numbers of landslips and flooding incidents; and these storms are becoming more frequent and more severe. The impact from "convective" storms is also increasing. These are sudden, intense thunderstorms in the summer, which are harder to predict and react to. There are also increasing risks from extreme hot weather, rapid changes between hot and wet, unseasonal snow and high winds.

To manage this challenge, in the next 5-year Control Period (CP7) Network Rail will need to concentrate significant effort and resources in earthworks and drainage. However, due to the impacts of the Covid-19 pandemic on the UK economy, there is likely to be an unprecedented level of competition for funding – competition between different assets and Regions within Network Rail; and, competition between railway funding and other public funding, such as healthcare.

Given this, Network Rail, ORR and other stakeholders will all need to be clear about what choices are available to Network Rail to manage weather resilience – and what those choices mean in terms of cost and risk.

In 2020 Network Rail published a series of WRACCA plans, outlining their national and route-level strategies to improve resilience. These noted the challenges faced by earthworks and drainage and set out high-level actions to spend significant amounts of funding to improve resilience, but they did not explain the specifics of how this would be done, in terms of engineering solutions or asset management decisions.

2.2 Purpose

This TAR's purpose was to collect and assess examples of engineering solutions and decisions, which Network Rail are currently using to improve weather resilience:

(1) To give ORR assurance that Network Rail are following best practice in how they currently manage their infrastructure; and,

(2) To understand what choices are available to improve weather resilience and any constraints on these choices.

These will then help to inform our discussions with Network Rail and funders about plans for CP7.

2.3 Scope and objectives

(a) Scope

This TAR covers any aspects of Network Rail's earthworks and drainage, relating to weather resilience and climate change. This includes national policies and strategies; Region-level asset management decisions; how renewals, refurbishments and maintenance are delivered; and the supply chain.

This TAR covers all five of Network Rail's Regions, as well as Central functions.

(a) Objectives

(1) To collect practical examples, showing best practice and constraints, from Network Rail's current activities in CP6.

(2) To create a framework for discussing weather resilience choices in CP7.

2.4 Methodical Approach

Phase 1 of this TAR was a written questionnaire to RAMs, Network Technical Heads (earthworks and drainage) and the Weather Resilience and Climate Change Adaptation Strategy Manager. The questions and a summary of the responses is provided in Appendix A.

Informed by these responses, Phase 2 involved interviewing staff from Network Rail and their supply chain. A feature of this TAR was asking for examples of engineering solutions, decisions or conversations around weather resilience. These questions were combined with questions for two other TARs[1,2], to make the best possible use of people's time. In total we interviewed 101 people, summarised in Figure 1.

Figure 1 – Map showing locations of projects or staff interviewed for this TAR

[1] Earthworks Cost and Volume Transparency TAR: https://www.orr.gov.uk/media/22458

[2] Drainage Maintenance TAR: https://www.orr.gov.uk/media/22459

3. Findings

3.1 Definitions and Regional differences

Our key finding from Phase 1 was that Network Rail's approach to weather resilience has evolved separately in each of the Regions, based on local geography, geology, types of railway infrastructure and historical issues around funding and priorities. While it is important for the Regions to be adapting to unique local issues and local end-users' priorities, there is a risk of avoidable failures, inefficient solutions and duplication of work if good practices are not shared Nationally.

Across our interviews, the phrase 'weather resilience' meant very different things to different people. Some teams saw 'weather resilience' and 'climate change adaptation' as two completely separate issues. Most teams combined the two together into 'weather resilience'. While some said that everything they do in earthworks and drainage is so closely related to the weather, that they do not talk about 'weather resilience' as a specific issue at all – it is just business-as-usual.

Network Rail's central Weather Resilience and Climate Change Adaptation team referenced the United Nations definition of resilience[3] as:

> *The ability of a **system**, **community** or **society** exposed to hazards to **resist**, **absorb**, **accommodate**, **adapt to**, **transform** and **recover from** the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.*

The Network Rail central Technical Authority teams, specialising in earthworks and drainage, regularly use the Cabinet Office definition of infrastructure resilience[4] in their strategies and presentations. This is split into four components as shown in Figure 2. In the Regions, roughly one third of the earthworks and drainage teams were using this Cabinet Office definition. Another third used a simpler version of this, mentioning 'resistance' (are assets strong enough to withstand the weather?) and 'response' (if there is a landslip or a flood, can trains be stopped before they hit it?). The remaining third focussed on 'resistance', i.e. stopping assets from failing.

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[3] Resilience | UNDRR

[4] Public_Summary_of_Sector_Security_and_Resilience_Plans_2017__FINAL_pdf___002_.pdf (publishing.service.gov.uk)

Figure 2 – Cabinet Office definition of infrastructure Resilience (from [4])

While both the United Nations and the Cabinet Office definitions are a useful reminder of the key elements to consider, in this TAR we sought to understand all the practical choices which Network Rail can make to manage resilience to the weather. In the following sections we will include some of the terms from these definitions, but we also add additional, more specific breakdowns.

For the purposes of this report, we will use the following meaning of weather resilience, which reflects our role as the rail regulator:

> *"more weather resilient"* = ***sustainably reducing the risk of negative outcomes (safety, train performance, or economic) for railway end-users*** *due to* ***asset failures*** *which happen as a result of* ***the weather (allowing for future climate change)****".*

It is important to note that wherever we use the term 'weather resilience' in this report, we are also considering future climate change. We expect the railway to be made more resilient to observed weather conditions today and also to plan for and adapt to changing weather conditions.

We will describe in this report how weather resilience involves preventing assets from failing, but it also involves operational measures to protect end-users from negative outcomes, if assets do fail.

3.2. 'Levers' within Network Rail's control, to improve weather resilience

We identified eleven distinct areas, where a Network Rail team made a clear decision to do one thing differently, in order to improve weather resilience. These are referred to here as 'levers', as they represent something Network Rail can change, with predictable results (good or bad). The eleven levers are shown in Figure 3.

We found that the Regions and central teams are putting significant effort and resources into improving weather resilience and we found examples of good decision making and innovative ideas in every Region. All of the Regions discussed some of the eleven levers, but no Regions could clearly explain their approach to all eleven.

For each lever, we have presented examples of ‘best practice’, where Network Rail made a change and there was some indication of a positive impact. It is important to note that these changes did not always require Network Rail to spend more. In many cases Network Rail actually made significant savings, while improving weather resilience.

We have also set out examples of constraints – highlighting why this ‘best practice’ cannot simply be copied and used everywhere. In some cases this is because it would not be cost effective, but it might also be physically impractical, wasteful or actually counterproductive in some situations. In some of these cases, simply providing more funding would not solve the problem and what is needed within the Regions is more awareness of the available options and their impacts on resilience, so that they can make better informed decisions.

In general, we expect each Regions to be able to discuss these eleven levers as follows:

“In this area, we are currently doing …”

“To improve our resilience, in CP7 we are planning to change …”

“To deal with funding challenges in CP7, we may need to consider changing …”

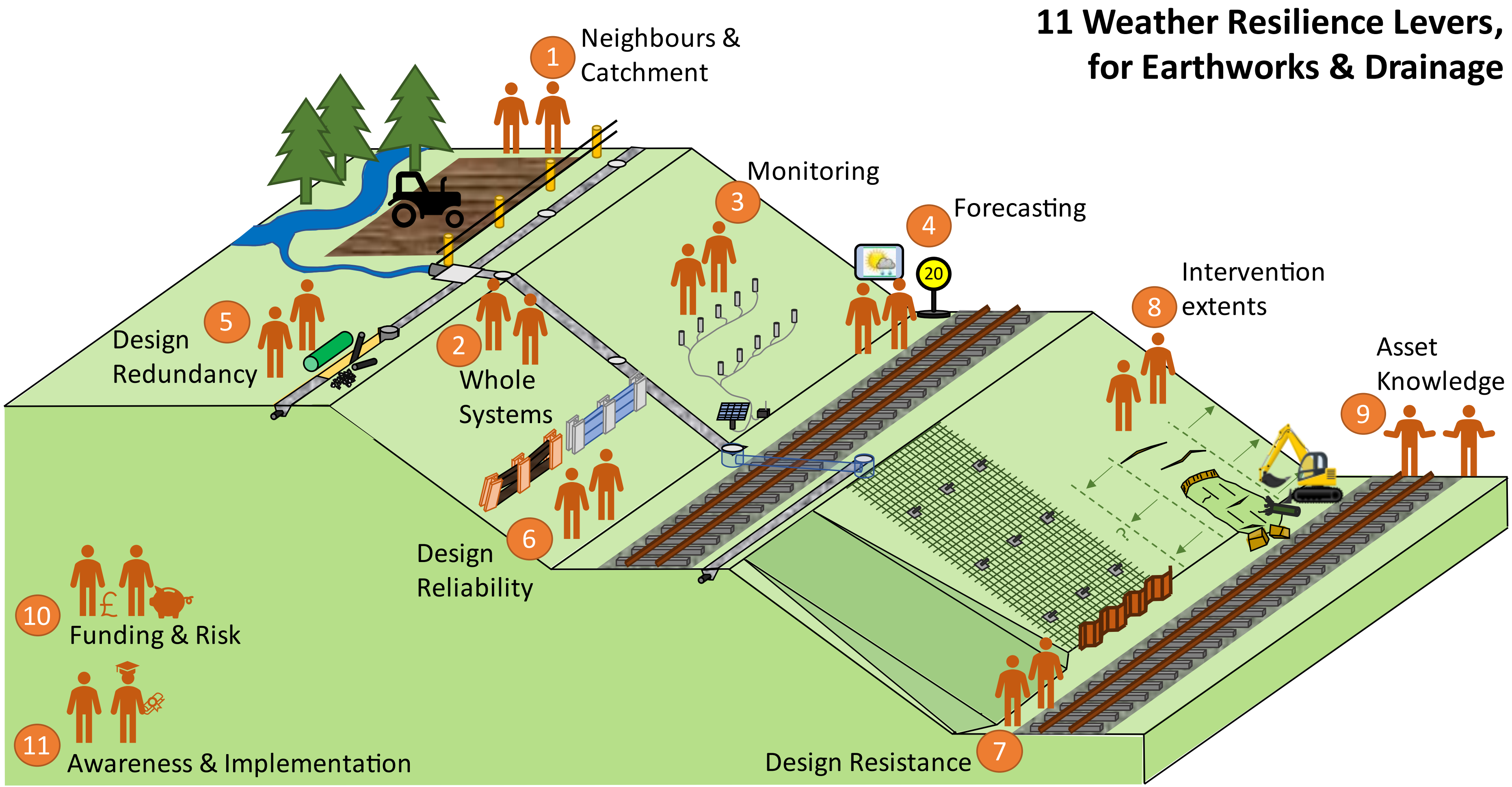
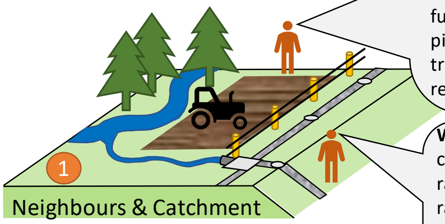


Figure 3 – summary of eleven Network Rail levers, to manage weather resilience for earthworks and drainage

3.2.1 Neighbours and Catchment



Eden Rivers scheme, Cumbria, Northwest & Central Region: Network Rail contributed funding towards a project by the Environment Agency and a local trust, returning the river Leith to its natural course where it had been straightened. This significantly reduced the risk of erosion and flooding of the railway, along the busy West Coast Mainline, as well as providing new wildlife habitats and benefits for the landowner (a sheep and cow farmer). Network Rail's funding contribution was 90% less than what it would have cost to achieve the same reduction in flood and erosion risk, by re-engineering the railway.

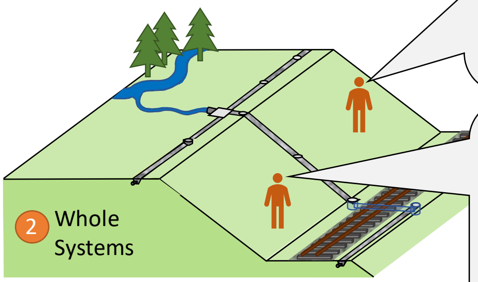
Leeds Flood Alleviation scheme, Eastern Region: Network Rail contributed around 10% of the total funding towards Leeds City Council and Environment Agency project to install a flood barrier (sheet-piled wall and clay bund) between a river and the railway – but also includes planting 300,000 new trees and restoring moorland to capture water further up the river catchment. The scheme will reduce the risk of railway flooding from an 87% chance in any given year, to 0.5%.

Washout near Corby, Eastern Region, in June 2019: Over several years, there had been multiple changes in land use and how flood-water was managed by 3rd parties, on land upstream from the railway. This resulted in water overtopping a flood pond and washing large amounts of soil from a railway cutting onto the track, trapping a train and stranding passengers for nearly 8 hours – on a day when the weather was considered to be 'normal'. Network Rail are identifying sites where there are 'known' risks from neighbouring land and they are trying to work with neighbours to understand changes and new risks, but Network Rail do not have the resources or the authority to manage the whole catchment.

A key challenge is that whilst Network Rail can try to engage with 3rd party neighbours and can look for opportunities to work together, they have limited ability to force neighbours to change their practices (other than seeking compensation after an incident). There is currently no requirement for neighbours to inform Network Rail of all changes to land use or water management.

However, there are already actions which ORR would expect all Regions to be taking, including regular dialogue with Lead Local Flood Authorities (who are responsible for monitoring flood risks throughout the catchment) and also with environmental regulators (NRW, SEPA and EA), to seek opportunities for collaborative projects which make the railway more weather resilient.

3.2.2 Whole Systems



Research project with University of Southampton, Southern Region: The project is looking for innovative solutions to reduce track movements due to desiccation (drying and shrinking of clay embankments in hot weather). E.g. replacing the top section of embankments with engineered fill at hard spots near bridges. This brings together understanding of earthworks, structures and track tolerances.

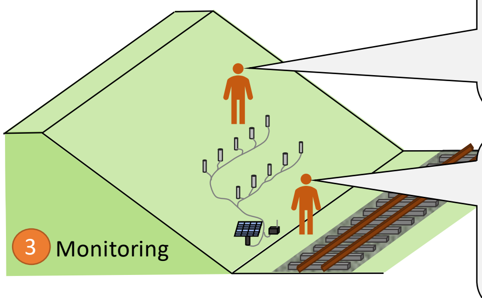
Following a freight train derailment at Willesden, Northwest & Central Region, in May 2019: Network Rail have carried out an R&D project to see how track geometry measurements, which are already being taken regularly, can be used to automatically identify movements and potential failures in earthworks.

Network Technical Head for drainage noted: Within drainage, need to understand the "whole system" – managing water all the way from where it enters the system, to the outfall. But drainage is just one part of the railway system. Working together across all assets (track, signals etc) is challenging because new solutions take time to develop and the individual assets have risks they need to manage now, so they may not be willing to wait. For example:

Near Carlisle, Northwest & Central Region: After signal equipment was flooded in 2015 (causing major delays) new signal equipment was installed on 3m stilts – however the root cause (drainage failed to prevent flooding) was not resolved, so the track may still flood.

Some teams discussed 'whole systems', in terms of looking at the whole drainage system, as opposed to just fixing the site of flooding or landslips. Others discussed whole systems in terms of multiple assets working together (typically drainage, earthworks and track). ORR expects Regions to consider both of these approaches and overlaps between all assets, not just earthworks, drainage and track, as there are often more subtle interactions with signals, OLE foundations or station enhancements.

3.2.3 Monitoring



SWM2 trial site, Wales & Western Region: 2D LIDAR technology was already being used to detect obstructions on level crossings. Network Rail used a small amount of R&D seedcorn funds to trial the use of this technology to monitor movements on earthworks slopes. The trial successfully detected movements, allowing Network Rail to intervene before a landslip.

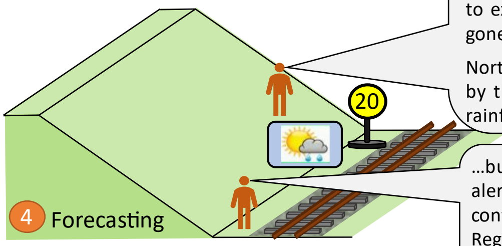
Lancs&Cumbria Maintenance Delivery Unit, Northwest & Central Region: Maintenance teams found local suppliers who could install affordable CCTV cameras at repeat flood locations in hard-to-reach cuttings. Staff can now look at these sites on their mobile phones, which is cheaper and much safer than sending staff to these locations.

Intelligent Infrastructure trial, National: Since 2018, Network Rail have been trying to develop an affordable and reliable set-up for tilt meters, which can be installed on slopes to detect movements, so that train operators can be warned to slow or stop before hitting landslips. So far the trial, covering up to 158 sites, has not found a configuration of solar panels, batteries and inverters which allow year-round operation in all conditions, with particular issues in the Northernmost sites and in deep, sheltered cuttings. While the costs are coming down, it will not be affordable to install monitoring everywhere.

Many interviewees mentioned "remote condition monitoring" and the 2D LIDAR example above could provide some indication of slope movements before an earthwork failure occurs. However, most of the monitoring discussed was actually "remote failure detection", such as tilt meters or CCTV cameras which are being used to inform engineers about landslides or flooding when they occur, without them having to be on site. Remote failure detection does not prevent failures from occurring, so ORR would expect the focus to be on the reliability of the process to send alerts to train controllers and engineers, so they can make timely and informed decisions.

We saw some examples of data sharing between assets, such as track geometry data to identify wet beds. With advances in data storage and visualisation software, we would expect to see all asset data becoming available to other assets, if needed.

3.2.4 Forecasting



Convective Alert Tool trial, Northwest & Central Region: Network Rail started working on a weather alert tool after a derailment at Watford in 2016, but this could not predict sudden 'convective' storms. Following the fatal derailment near Stonehaven in August 2020, the tool is being updated to try and predict convective storms up to 3 hours in advance and send real-time alerts to train control centres. This Region has been heavily involved in the trail, because it tends to experience more of these storms – more than 10 interviewees mentioned that these have gone from happening "once every few years" to "several times every year".

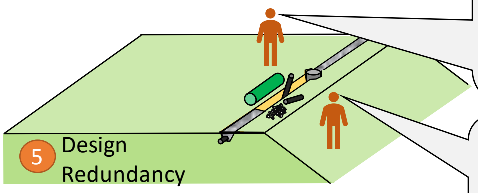
Northwest & central Region are also installing around 60 new weather stations. This was driven by the need for real-time wind speed data, which affects overhead electric lines, but adding rainfall data at each weather station had a very small additional cost.

…but, the same **Convective Alert Tool trial** has had issues with setting the right thresholds for alerts. 'Table-top studies' using data from real landslips in 2020 correctly predicted the site of convective storms which led to landslips– but they also produced so many other alerts across the Region that train controllers would not have enough resources to manage all of them; and speed restrictions in all the highlighted areas would have a major impact on Regional train performance.

As with Monitoring above, the technology for measuring the weather, analysing data and generating real-time alerts is advancing rapidly. ORR would expect the focus to be on the reliability of processes to turn alerts into decisions about speed restrictions or cancellations and, crucially, criteria for restoring normal service once it is safe to do so.

We are aware of previous studies by Network Rail, looking for relationships between weather (rainfall) and the sites of landslips but, to date, we have not seen any reliable predictive models coming out of this. So, ORR would expect to see some explanation of how weather forecasting is being related to the risk of landslips (or flooding, or desiccation etc) in specific geographic areas.

3.2.5 Design Redundancy

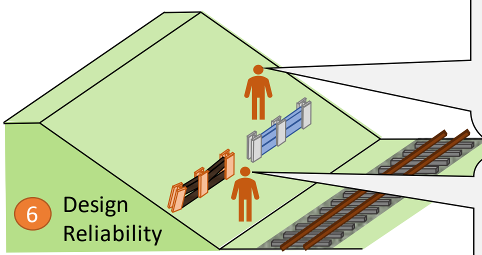


Gaerwen drainage renewal, Wales & Western Region: Standard 300mm diameter pipe was not quite large enough to manage the volume of water in a 1-in-50 year event. Rather than use a slightly larger pipe, NR installed 450mm pipe (more than double the cross-sectional area of 300mm pipe) and extra deep catch-pits. This provides a lot of spare capacity, allowing it to function in more severe weather events (e.g. 1-in-100 or 1-in-200), or if the "1-in-50" event gets worse due to climate change. The larger pipe costs roughly 50-100% more per metre, but this is just a small part of the project costs, along with labour, plant, design costs and access. In fact, overall this project cost roughly 10% less than the national average for this type of work.

Ashdon Way drainage renewal, Eastern Region: The project would like to add spare capacity, but drainage has to connect into either a highway culvert (which the Local Authority are not clearing out), or a fixed 300mm outfall into a private water company's sewer. The project's current design is proposing a short section of very large pipe (30m x 750mm diameter) just to attenuate (slow down) the volume of water in the standard design case. Because of the constraints, this project is expected to cost more than the average for this type of work.

Installing larger components (e.g. larger diameter pipes) may provide a way to increase capacity with a relatively small cost for the additional materials and slightly larger excavations. However, this needs to be considered in terms of 'whole systems' (item 2 above), as the performance of the system may be governed by bottlenecks or the 'weakest link'. Very few interviewees discussed redundancy in terms of a 'second line of defence', as opposed to 'spare capacity'. One designer from the supply chain gave an example of a drainage system which was likely to overflow where it was constrained by a narrow outfall, so the most efficient solution would be to let it overflow but control it, with a spillway and erosion protection on nearby soil slopes.

3.2.6 Design Reliability



Maintenance Off-Track manager, Eastern Region noted: Modern, plastic drainage pipes have a longer design life 'on paper' than metal pipes installed by British Rail 20+ years ago, but plastic pipes are more flexible and can form sumps; and they are easily damaged during maintenance (rodding or jetting).

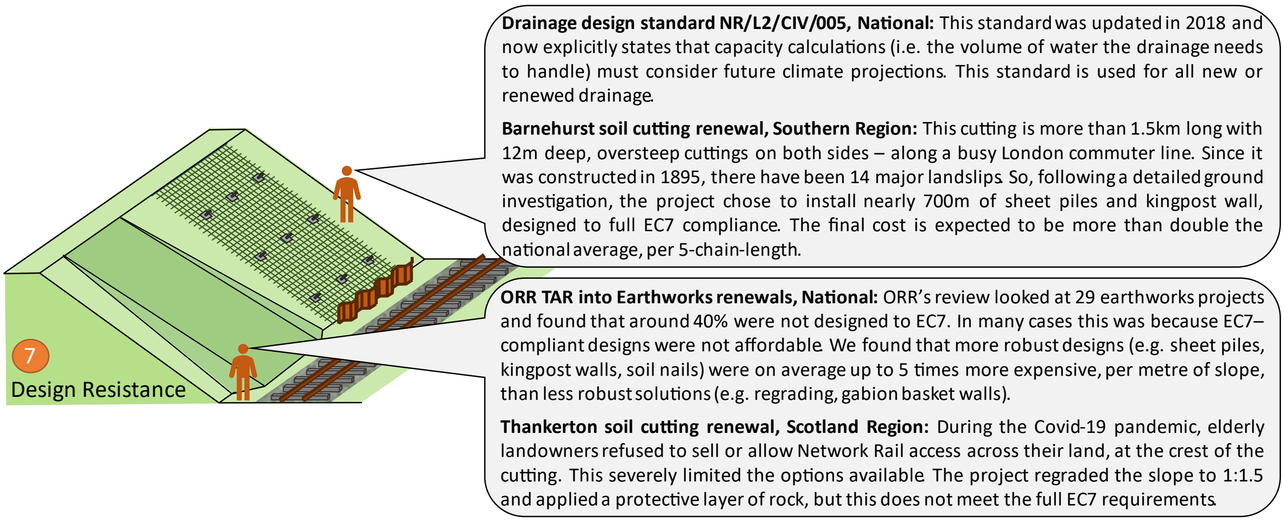
Somerton drainage renewal, Wales & Western Region: Replaced 30m lengths of standard drainage pipe in a tunnel, with 60m lengths of thick-walled, smooth-bore pipe. This is tough enough to be maintained by jetting machines from the ends, reducing the need for staff working in the tunnel.

Design consultant, Eastern Region noted: Network Rail's standard details specified 'galvanised' piles – zinc coated to protect against corrosion and increase design life. But, driving these piles through certain materials (e.g. gravel) can damage the galvanised coating, so designers have to assume piles are not galvanised, and design the piles slightly larger to allow for corrosion. So, specifying better, more expensive materials (galvanised piles) did not help.

The Cabinet Office define reliability as "the capability of Infrastructure to maintain operations under a range of conditions… e.g. to operate in extremes of heat and cold" and it should also consider the ability to continue functioning after many years of operation and maintenance. Engineering components used in earthworks and drainage are exposed to surface and ground water (which can often be corrosive), the build-up of leaves, silt and debris, seasonal ground movements (swelling in wetter months, shrinking in drier months), growing tree roots and burrowing animals. But in many cases the most damaging conditions they face are during installation (e.g. driving piles through hard, uneven materials) or during maintenance (e.g. rodding or high-pressure jetting of drainage pipes).

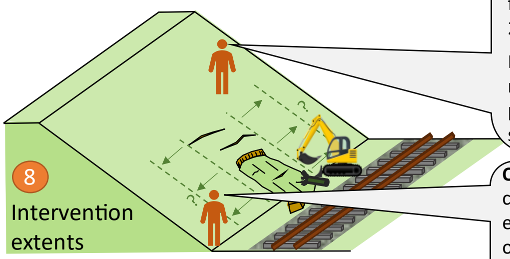
Examples from our interviews highlighted that simply buying more expensive components with longer theoretical design lives, was less effective at improving reliability than designing with consideration for how components will be installed, maintained and renewed; followed up with effective inspection and maintenance.

3.2.7 Design Resistance



The forces, groundwater levels and surface water volumes which assets are designed to withstand is driven by Network Rail's choice of design standards. So, if Network Rail's Regions want assets to function under more extreme weather conditions, they have two choices: (1) change their own design standards (as drainage did in 2018, to consider future climate projections); (2) or change their policies, to instruct asset managers and delivery teams to design to more demanding standards. Following standards which explicitly require consideration of future climate projections is a key mechanism to build long-term resilience into the asset portfolio. The choice of design standard has a significant impact on cost, so ORR expect that this trade-off between cost and the 'quality' of interventions is an area which we will need to discuss in detail as part of CP7 planning.

3.2.8 Intervention extents



Whitmore landslip, Northwest & Central Region, in June 2020: A landslip occurred at this site in 2010. Because of underfunding at the time, the project team only renewed the section which had failed, using a rock blanket. This did not treat the root cause of the failure, which was poor drainage. In June 2020 another landslip occurred adjacent to the 2010 failure and appears to have the same root cause (poor drainage).

Now, the Regional team have a policy of assessing and renewing the surrounding slope, rather than just fixing the failure. This costs more in the short term, but it is more efficient per metre to do a larger renewal while the contractor is already on site – and it is significantly cheaper than doing emergency works to repair a landslip.

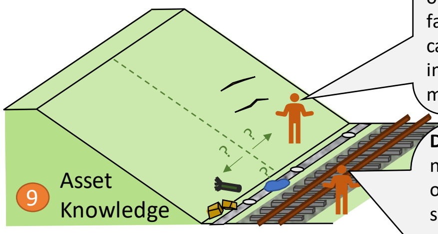
ORR TAR into Earthworks renewals, National: Network Rail's earthworks are split into "5-chain" (100m) lengths for risk scoring and planning purposes. ORR's review looked at 29 earthworks renewal projects and found that 20% of the 5-chain-lengths were only renewed over part of their length, often on sites with difficult ground conditions, where renewing the full length was not affordable. For reactive projects (fixing the site of a landslip), 45% did not cover the full 5-chain-length, often renewing only 20-40m.

ORR acknowledges that Network Rail has to work within an agreed budget, to manage risk across a portfolio of assets. There may be cases where the best way to make the whole Region more weather resilient is to renew short sections, at the highest risk locations, at a large number of sites across the Region. However, many interviewees, including RAMs, delivery project managers, maintenance crews and the supply chain, stated that one of their biggest efficiencies was when they were able to work on longer sites – as this avoided the need to mobilise and de-mobilise repeatedly, setting up access roads and site compounds each time; and they could make use of larger, faster plant for installation and handling materials. As with item 7 above, ORR expects this Regional policies around this to be a key area of discussion for CP7.

More details on the decision making process behind items 7 and 8 can be found in a separate ORR TAR, looking at cost and volume transparency for earthworks renewals[5].

[5] Earthworks Cost and Volume Transparency TAR: https://www.orr.gov.uk/media/22458

3.2.9 Asset Knowledge



RAMs, Northwest & Central Region, noted: Roughly 75% of all their earthworks failures are caused by a failure to manage surface or groundwater. Some of this is due to extreme weather events or issues on neighbouring land. But the best lever within the Region's control, to bring down the number of failures, is to get a better understanding of their drainage assets – to understand where there are capacity issues or regular blockages. Over the last few years, drainage information had been improving, which was bringing down the number of failures. But now this is being cancelled out by more 3rd party issues and a clear increase in the number of convective storms over the last 5-6 years.

Drainage asset surveys, all Regions: At the start of CP6 (2019), all regions acknowledged that they did not know the condition of all their drainage assets - and that there were many more drainage assets on the rail network which were not recorded in databases or maps. In 2019, all Regions committed to surveying their entire network and ensuring the location and condition scores for all drainage assets are entered into a database. However, in March 2021 this has still not been completed. Northwest & Central Region are attempting to complete this by March 2022, but all other Regions are aiming for March 2024.

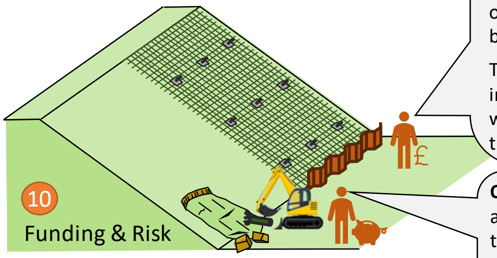
Maintenance Off-Track manager, Eastern Region noted: they have just started receiving lists of drainage assets, highlighting those with the worst condition scores (indicating drainage is partially or completely blocked). But, the maintenance teams have not been given any instruction on what to do with this new asset knowledge, or any extra resources to do more maintenance work.

RAMs in three out of the five Regions identified better knowledge of their drainage assets as their number one priority for improving weather resilience – and the other two Regions mentioned it as a key lever. This has been high on ORR's list of concerns since CP5 and progress is being reviewed regularly through our business-as-usual engagement with Network Rail. All Regions are transitioning from 'defect inspections' (walkover surveys, which only report blocked drainage) to 'condition inspections' (where every asset is inspected and given condition scores). However, maintenance teams in two Regions said they are doing condition surveys themselves, but are not yet using the data to prioritise work; while a third Region said the condition surveys are being done by Works Delivery and the maintenance teams are not familiar with it.

In all regions, they were more concerned about sites where flooding has major performance impacts, rather than the worst condition scores. We expect asset information to be used in decision making, rather than simply repeating plans from previous years, or only intervening after an asset fails. We expect this information to be used intelligently, for example drainage condition scores on the same asset over several years would give an indication of how quickly the asset is degrading, what weather events trigger blockages, or how condition correlates with train performance – as opposed to simply doing maintenance and renewals to make the condition scores lower.

Given that all Regions are placing so much emphasis on drainage asset information, ORR will expect to see clear policies and guidance on how this information will be used to prioritise work – and how this will improve weather resilience.

3.2.10 Funding & Risk



RAMs, Southern Region, noted: The wet winter in 2013/24 caused a large number of landslips and many of the projects planned for CP5 had to be cancelled to fund all the repairs. To prevent this happening again in CP6, Southern secured 40% more funding than in CP5 and they also secured access to a significant risk fund. This made the CP6 plans much more resilient to extreme weather events. Southern earthworks and drainage also have a strategy of 'overplanning' – preparing to deliver additional projects, in case any additional funds become available, if other assets do not spend their whole budget.

This was tested by a wet winter in 2019/20 followed by 3 named storms arriving back-to-back in Spring 2020. Southern were able to fund the repair works without cancelling planned works. But, only 2 years into CP6, they have already doubled their expected spend for CP6 and there may be insufficient risk funding left to cover another wet winter in CP6.

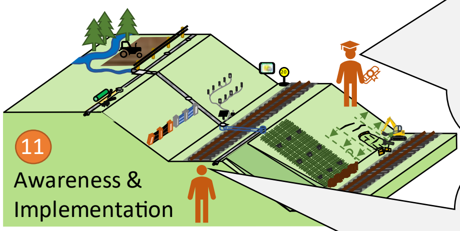
ORR TAR into Earthworks renewals, National: ORR's review looked at 29 earthworks renewals and found that a reactive project to repair one asset after a landslip was, on average, more than twice as expensive as a planned project, to proactively renew an asset before it failed. Taking into account the fact that reactive projects tend to repair only a short length within the asset (just fixing the part which failed), reactive works were nearly 4 times as expensive as proactive works. This shows how inefficient it can be to carry out a lot of reactive works.

A key challenge in weather resilience for earthworks and drainage is the uncertainty about which sites will experience severe enough weather to cause failures. It is not realistic to expect zero failures, so securing enough risk funding to recover from failures is a crucial part of managing a resilient railway. It is also important that this funding can be released and delivery teams mobilised quickly, to prevent further failures and resume train services safely.

From other TARs[6] we found clear evidence that, for a given asset, reactive works are significantly less efficient than renewing the asset proactively, before it fails. However, in order to realise more of this efficiency, Regions would need to improve their asset knowledge and processes for predicting which sites are most likely to fail. Given the likely funding challenges for CP7, ORR would expect a clear discussion on the balance of funds between proactive work (with more uncertainty about targeting the right sites) and risk funding for reactive work (which is less efficient).

[6] Earthworks Cost and Volume Transparency TAR: https://www.orr.gov.uk/media/22458

3.2.11 Awareness and Implementation



RAMs, Eastern Region, noted: Looking to increase the size of their teams, for both earthworks and drainage. If they were given more funding today to improve resilience, they would not have enough competent people or spare capacity to manage the additional work.
RAMs, Northwest & Central Region, noted: After the current re-organisation, want a dedicated environmental team within the Region – looking at climate change, decarbonisation and biodiversity. Also noted that their current contractors are fully occupied, so any additional resilience work would require additional framework contractors.
RAMs, Scotland Region, noted: After the current re-organisation programme, aiming to have at least 1 new role dedicated to weather resilience, covering all asset types for Scotland.
RAMs, Southern Region, noted: Looking to assign a Regional lead for weather resilience (TBC what the title will be, after the current re-organisation programme)
RAMs, Wales & Western Region, noted: They have a dedicated environmental liaison officer, who works for both Network Rail and the Environment Agency and has greatly improved collaboration.

Maintenance delivery staff, all Regions: Where we asked maintenance delivery teams about their involvement in weather resilience and climate change conversations, they all consistently noted that they they had not been involved in the conversations, but they would like to be more involved. Many noted that they are the first to see weather resilience issues on the ground, such as flood sites which have never flooded before, and that they try to escalate these up to the asset management team.

Capital Delivery and Works Delivery staff, all Regions: Where we asked project managers about their involvement in weather resilience and climate change conversations, only around 40% said that this was something they discussed regularly on projects – and all of these were in the context of drainage capacity, where the Network Rail standard tells them to consider climate change. None mentioned any feedback to Regional teams about what they were seeing on the ground.

The final lever we identified was the level of awareness of weather resilience within different teams – and how this translates into decisions on the ground. As shown in the examples above, RAM teams in every Region aim to have dedicated, competent staff with a focus on weather resilience, before they begin planning for CP7. Network Rail's central WRACCA team state that they provide a centre of excellence for weather resilience and climate change and they noted that, rather than creating a separate set of documents covering weather resilience, they are aiming to work with the Technical Authority to build weather resilience into the existing policies and standards they use on a daily basis.

While this is all positive, the majority of delivery staff we interviewed (Maintenance Delivery Units, Works Delivery, Capital Delivery) indicated they had not been involved in these Regional or national conversations around weather resilience. Unless weather resilience was specifically included in remits from the RAM teams, then budgets and volumes were often the factors driving their decision making, not weather resilience. It is worth noting that Regional and delivery teams seemed better aligned in Wales & Western and there were far more examples of delivery projects considering weather resilience in this Region.

There were some good examples of delivery teams reporting first-hand evidence of weather resilience issues up to the RAM teams (in particular the regular 'Star Chamber' meetings in Northwest & Central, to discuss flooding sites), but ORR would expect to see a clearer line-of-sight of weather resilience strategies between Regional teams and delivery teams – with feedback going in both directions.

4. Conclusion and Recommendations

4.1 Conclusion

The evidence we collected in this TAR has provided ORR with assurance that Network Rail's Regions and central teams are all taking measures to improve their weather resilience. However, this is still a work in progress and there are significant opportunities for improvement, by sharing best practice and lessons learned between the Regions. There are also opportunities to benefit from better communication of weather resilience strategies to Network Rail's delivery teams (Maintenance Delivery, Works Delivery and Capital Delivery) and for these teams to give more feedback on issues or changes they are seeing on the ground.

The key themes which require sharing between Regions and with delivery teams are:

(1) **Systems**: Collaborations with 3rd party neighbours provided significant technical and social benefits – and often had much better cost:benefit ratios than solving the problem within the railway boundary. The most valuable information to share between projects would be: who initiated these schemes; how the project team interacted with 3rd parties (especially EA, SEPA and NRW); and how the project secured the use of Network Rail funding for this. In this report, we gave examples of collaborative projects in Eastern and Northwest & Central. This concept also extends to collaboration between different assets within Network Rail.

(2) **Operations**: Monitoring high-risk sites and forecasting during severe weather can provide cost effective ways to improve resilience, by mitigating the risk to railway users if assets do fail. However, monitoring all assets is not currently cost effective and triggering weather alerts under less severe weather would impact on train performance and resourcing for Network Rail staff. Key information to share between Regions are details of different hardware and software solutions being used and lessons learned about where and when to implement these. We gave an example of CCTV cameras for access-constrained drainage in Northwest & Central.

(3) **Design:** There is a lack of transparency regarding the solutions individual projects are designing to maximise weather resilience, while dealing with specific site conditions and constrained funding. This is described in more detail in a separate TAR[7]. The most valuable information to share between Regions and projects would be any innovations developed by the project team or offered by the supply chain; as well as 'all-in' costs and any issues from installing larger, or higher-specification components. We gave an example from a drainage renewal project in Wales & Western.

(4) **People and decisions**: At the core of improving weather resilience and being able to adapt to climate change is an improvement in how well Network Rail understands its assets – by increasing the quality and quantity of data, but also by ensuring Network Rail teams have competent people, with sufficient time to look at this data, analyse it and use it to improve decision making. All Regions are taking a different approach to this and all are currently going through changes to their teams, so it is important that the Regions share examples of what is working well and any unforeseen issues as they arise. We gave several examples which highlighted a good understanding of drainage in Wales & Western, where they are more advanced in their use of drainage condition data to steer decision making, than other Regions.

It is important to understand the balance of proactive and risk funding in managing a resilient portfolio and it would be useful to share approaches to this and lessons learned between the Regions. We gave an example from Southern, who have seen the largest use of risk funding for earthworks so far in CP6.

As well as providing practical examples, this report has proposed a framework (the eleven levers in Figure 3) for how Network Rail, ORR and other stakeholders can discuss any changes from CP6 to CP7 (and beyond) and the implications those changes will have in terms of funding and other regulated outputs (safety, performance, sustainability, efficiency). Below we have given recommendations on specific actions to help us achieve this clearer discussion around CP7 planning.

[7] Earthworks Cost and Volume Transparency TAR: https://www.orr.gov.uk/media/22458

4.2 Recommendations

(a) Green recommendations – We recommend Network Rail implements a process to formally share identified examples of good practice internally.

REC G1 Network Rail central teams to facilitate sharing of best practice and lessons learned between Regions, on current levers for improving weather resilience. This should cover all of the ‘levers’ detailed in this report and could either follow the framework set out here (Figure 3) or an equivalent developed by Network Rail.

Action on WRACCA team to identify examples of best practice; and action on Network Technical Heads for earthworks and drainage to provide evidence to ORR of knowledge sharing between Regions.

(b) Amber recommendations – The need for early engagement ahead of Network Rail issuing Strategic Business Plans for CP7.

We are aware that Network Rail will be developing Regional WRACCA plans, which will form part of their submission to ORR for PR23. It may be possible to address some of the following recommendations through this mechanism.

REC A1 Network Rail Regions should provide written clarifications to ORR, explaining their plans to improve weather resilience in CP7. This can either be based on the framework set out in this report (Figure 3) or an equivalent developed by Network Rail, but it must be able to describe the following for each of the eleven ‘levers’:

- The current position and actions currently underway in CP6;
- What the Region proposes to change in CP7 specifically to improve weather resilience – along with benefits and consequences; and
- Any changes the Region may be forced to make in CP7 due to funding challenges – along with any consequences.

Action on DEAMs in each Region to provide written clarification to ORR.

REC A2 Network Rail Regionally (or agreed nationally) should develop a plan and guidance on how a clear line-of-sight can be established between Regional weather resilience strategies and delivery teams (including both capital project teams and maintenance delivery units), including mechanisms for feedback from all delivery teams and the supply chain.

Action on DEAMs in each Region to provide plan and guidance to ORR.

5. Appendix A – Phase 1 summary (issued to Network Rail, 19th June 2020)

Summary of NR's responses (Phase 1, Apr-Jun 2020)

In April 2020 ORR sent a questionnaire to STE and to all earthworks and drainage RAMs, to understand better how the subject of "weather resilience" is defined, measured and acted upon, across NR.

We have now received all the responses. The details given in the responses were extremely useful and they will form the basis of more detailed face-to-face discussions later in 2020 (Phase 2), depending on Covid19 restrictions.

However, we felt it would also be useful to share a high level summary of all the responses now, to encourage discussions between the different NR teams.

The responses to all 10 questions are summarised graphically on the following pages. We are not suggesting that there were any "better" or "worse" responses, we are simply highlighting the spectrum of different answers to the same questions. We will share the full responses, as a separate attachment.

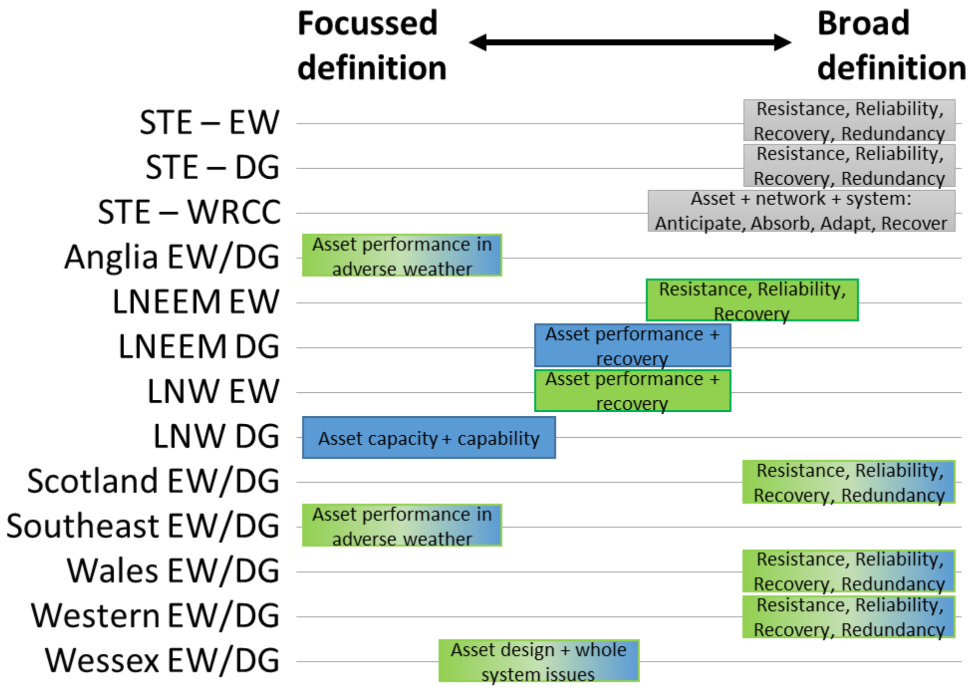
The key trends which we want to follow up in Phase 2 are:

- There is not a consistent definition of "weather resilience" across NR. STE provided formal, holistic definitions, but these differed between the professional heads and the WRCC programme. Many of the RAMs are using a more "problem-centric" definition, focussed on reducing the number of asset failures. [Q1]
- Almost all groups measure their resilience with lagging indicators (asset failures and delay minutes), with only a minority mentioning leading indicators (asset condition, number of assets with out-of-date designs etc). [Q2]
- Drainage-only RAMs and the drainage professional head all indicated that weather resilience is a distinct activity, over and above their business-as-usual plans. Conversely, earthworks all indicated that weather resilience is built into their BAU. It is interesting to note that, despite saying it was built into BAU, the majority of earthworks RAMs gave examples of additional works, improvements within their teams or projects which they were developing in CP6, specifically relating to weather resilience. [Q3, Q6, Q7, Q9, Q10]
- Insufficient funding was the most commonly cited constraint to weather resilience. However, the vast majority of RAMs described other sources of funding which they were accessing (or hoping to access), to improve their weather resilience beyond the CP6 base plans. Several groups indicated that, even if additional funding was made available, NR and the supply chain might not have the resources, access or asset knowledge to deliver as much increased resilience as they would like to. [Q4, Q8]
- The majority of groups noted that they are increasing their weather resilience because the standards require consideration of climate change (this was already in EC7 and has been added to NR drainage, environmental, track and vegetation standards). There were only limited suggestions of innovation to designs or construction techniques through R&D or in-route initiatives. [Q5]

Next steps

We will contact each of you later in the year (approx. Sep 2020) to arrange face-to-face discussions.

Q1: How do you define ‘increased weather resilience’?



Q2: What measures do you use to determine your weather resilience?

	LEADING		LAGGING			
Response mentioned…	Asset condition	Design/ risk reviews	Delay mins	No. of Failures	Relate to adv/extr weather events	TSRs
STE – EW	X	X				
STE – DG			X	X		
STE – WRCC						
Anglia EW/DG			X	X	X	
LNEEM EW			X	X		X
LNEEM DG			X	X		
LNW EW			X	X		
LNW DG		X	X	X	X	
Scotland EW/DG	X			X	climate change KPIs	
Southeast EW/DG			X			
Wales EW/DG	X	X	X	X	X	
Western EW/DG	X	X	X	X	X	
Wessex EW/DG		X		X		

Q3: Is 'weather resilience' a specific item on your current lists of priorities, risks, targets etc?

Response mentioned…	It's built into BAU	Small number of distinct items	It has separate line items / initiatives
STE – EW	X		
STE – DG			X
STE – WRCC			X
Anglia EW/DG	X	Part of proj devel.	
LNEEM EW	X		
LNEEM DG			X
LNW EW	X	£1.9m in Yrs 3-5	
LNW DG			X
Scotland EW/DG	X		X
Southeast EW/DG	X	Various forums	
Wales EW/DG	X		
Western EW/DG	X		
Wessex EW/DG	X		

Q4: Which constraints are most effecting your current weather resilience?

Response mentioned…	Funding / priorities	NR resources	Supply chain + Access	Asset knowledge / condition	Backlog from CP5	3rd Parties
STE – EW	X					
STE – DG		X	X			
STE – WRCC						
Anglia EW/DG					X	
LNEEM EW		X		X		
LNEEM DG						X
LNW EW	X	X	X			
LNW DG	X	X	X	X		
Scotland EW/DG	X	X	X			
Southeast EW/DG	X					
Wales EW/DG	X					
Western EW/DG	X					
Wessex EW/DG	X					

Q5: What changes are you making to designs or construction techniques?

Response mentioned…	Standards	R&D	Route guidance/ implementation	Supply chain products/approach	3rd Party risk
STE – EW					
STE – DG	DG				
STE – WRCC	Enviro	X			
Anglia EW/DG		X	X		
LNEEM EW			X		
LNEEM DG					X
LNW EW	EC7		X	X	
LNW DG	DG + Veg				
Scotland EW/DG	DG				
Southeast EW/DG	DG + TRK			X	
Wales EW/DG	EC7				
Western EW/DG	EC7				
Wessex EW/DG	EC7				

Q6: What changes are you making to how you prioritise interventions?

Response mentioned…	Use existing tools, reacting to adverse weather events	Develop new decision tools / risk models	R&D	New processes	Focus on repeat failure sites
STE – EW					
STE – DG		X			
STE – WRCC		X	X		
Anglia EW/DG	X				
LNEEM EW		X			X
LNEEM DG				3rd Parties	X
LNW EW	X				
LNW DG					Asset knowledge
Scotland EW/DG	…no changes..				
Southeast EW/DG	X				
Wales EW/DG		X			Asset knowledge
Western EW/DG		X			
Wessex EW/DG	X				

Q7: What interventions are you adding (or removing…) in your work bank, specifically related to weather resilience?

Response mentioned…	BAU reprioritisation	Extending scope of reactive works	Working with 3rd parties	Adding monitoring	Specific resilience works
STE – EW					
STE – DG					
STE – WRCC					
Anglia EW/DG	x				
LNEEM EW		x			
LNEEM DG			x	x	
LNW EW	x				
LNW DG	x				
Scotland EW/DG					x
Southeast EW/DG	x				
Wales EW/DG				x	x
Western EW/DG				x	x
Wessex EW/DG	x			x	

Q8: How are you sourcing additional funding for increased resilience?

Response mentioned…	From CP6 base funding	CP6 included 'resilience' cost line	Include in CP7 planning	Apply for other route fund pots
STE – EW				
STE – DG	x			
STE – WRCC		x	x	
Anglia EW/DG				Performance fund
LNEEM EW	x			
LNEEM DG				x
LNW EW				Proj. Alpha
LNW DG				Proj. Alpha + Risk
Scotland EW/DG	x			
Southeast EW/DG	x			Risk/insurance
Wales EW/DG		x		Risk + DRAM/DEAM
Western EW/DG	x			DRAM/DEAM
Wessex EW/DG				Risk

Q9: Are you making any other changes, to increase weather resilience?

Response mentioned…	EWAT/Ops processes	Additional monitoring	Competence framework	Asset knowledge	Other
STE – EW					
STE – DG	x		x		
STE – WRCC	x				
Anglia EW/DG		x			
LNEEM EW	x			x	
LNEEM DG	x	x			
LNW EW		x			Stockpiles, line-of-route
LNW DG					Unfunded schemes
Scotland EW/DG	x	x			
Southeast EW/DG					Lessons learned
Wales EW/DG					3rd party works
Western EW/DG					3rd party works
Wessex EW/DG		x			

Q10: To what extent was Q5-Q9 already included in your CP6 plans – and how much is 'additional' following completion of WRACCAs or any other "weather resilience" initiatives?

Response mentioned…	Included in CP6 plans	Include in CP7 plans	Other origin
STE – EW			
STE – DG			
STE – WRCC	x	x	
Anglia EW/DG	x		
LNEEM EW	x		Reaction to storm events
LNEEM DG	x		
LNW EW	x		Project Alpha
LNW DG	x		Project Alpha + "weather-proof" aspiration
Scotland EW/DG	x		
Southeast EW/DG	x		Reaction to storm events
Wales EW/DG	x		Reaction to storm events
Western EW/DG			
Wessex EW/DG	x		New risk registers in WRCCA plan