UK ROADS LEADERSHIP GROUP

Emergency Preparedness, Response, & Recovery

3-yr Retrospective on DfT Highway Sector Learning from Extreme Weather Events review (2021): including analysis of UKRLG Hazards Survey (2024)

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"The local road network in England is essential to everyday travel and the movement of goods. Almost all journeys start and end on the local road network, which consists of 183,000 miles of road and represents 98% of the total road network."

National Audit Office (2024: p.5)

"In an advanced supply chain, the process from the production and delivery of a product to the final customer relies on an efficient and dependable logistics infrastructure. Roads are one of the most basic modes of logistics, and even during disasters caused by extreme weather events, roads must always function to maintain the logistics process at all times. Roads also play a critical role in disaster response operations, ensuring access to impacted areas for rescue workers and the delivery of emergency supplies. Roads must stay functional at all times.

Therefore, road administrators need to be prepared for these extreme disasters by providing road infrastructures resilient against new magnitudes of disasters and also by developing robust road management systems that react quickly against disasters. In other words, road maintenance, improvement, and disaster mitigation is an investment in building a resilient society in the future."

PIARC Strategic Plan 2024-2027 (PIARC, 2020: p.39)

Evidence is emerging that sub-daily rainfall intensification is related to an intensification of local flash flooding. This will have serious implications for flood risk management and requires urgent climate-change adaptation measures.

Climate Change Risk Assessment 3: Chapter 1 (Slingo, et al., 2021: p.28)

"The study indicates that, despite being the warmest and second warmest years on record, 2022 and 2023 are not necessarily extreme in the context of the UK's current climate and therefore emphasizes that observations alone do not provide the full context for year 2023. An important implication of the study is that there is the potential for a far higher UK annual average temperature, not just in the future but also in the present-day climate."

The State of the UK Climate 2023 (Kendon et al., 2024: p.76)

"Instead of considering climate change as a gradual process, or even a predictable one, we should consider it to be "hugely volatile" and appreciate that "what might seem impossible and even implausible can happen, and it can happen tomorrow".

Readiness for storms ahead? Critical national infrastructure in an age of climate change (JCNSS, 2022: p.6)

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Plate 1: The A421 Marston Moretaine interchange in Bedfordshire was inundated on 22nd September 2024 after an unnamed storm deposited “a month’s worth of rain” across the area in 48hrs. The interchange was reopened on 11th October following a pumping operation to remove 72 million litres of flood water[a].

(Image: ©Terry Harris Photography)

Cover image: A Gritting vehicle being driven past a road sign displaying a red weather warning to mark the arrival of Storm Éowyn in Scotland on Friday 24th Jan 2025.

(Image: ©Andrew Milligan (PA Images))

[a] Footnote: https://www.bbc.co.uk/news/articles/cy5y2l2wg7vo

Foreword

Foreword

I was privileged to have co-commissioned with the DfT, the Lessons from Extreme Weather Emergencies (2021). This retrospective goes further, underscoring the need to bring about change with you, the Highways Directors and Heads of Services and the services you lead.

The 2021 report provided a compelling message: '*prepare for your worst day not an average day*'. This report provides a further siren warning, to be ready for more intense and more frequent events. A legacy of underfunding has left us with older and more frail assets: our roads, drainage, and retaining walls, are now more vulnerable to the coming storms.

As Chief Officer in Calderdale I lost six bridges during Storm Eva on Boxing Day 2015. This event was binary – assets here today and gone tomorrow – lifelines lost, and communities impacted. We cannot presume that assets, upon which we depend, and for which our politicians locally and nationally allocate resource, will always be open for use.

The catastrophic collapse of, or damage to, 1,234 assets in Cumbria, (Storm Desmond 2015) was a *disaster* by any definition, and serves as the UK's current 'high watermark'. However, we must prepare for a repeat of Desmond, plus 30%.

When faced with these challenges, all 200+ Highway Authorities step up time and again: your teams, our Highway Heroes, offering ceaseless energy but with limited tools to hand. However, the backdrop is the growing risk that 'just in time' could become 'just too late'. Valencia 2024 and the Belgium / Germany Floods 2021 are harbingers of the magnitude of risk that our changing climate has delivered and will again.

We should be rightly proud of our local skills and of the national winter service standard. A cohort of dedicated and skilled decision makers focussed on the *freezing point,* underpinned by £1Bn+ of gritters, barns and salt, fuel and staff. Should that freezing-point threshold for gritters now be mirrored by equivalent activation thresholds in respect to other hazards (e.g., rainfall events of over 20mm in one hour)?

As Chair of the newly created UK Board for Adaptation, Biodiversity, and Climate (UK ABC Board), part of UKRLG, my legitimacy comes not through having lost six bridges. It is how I lead the debate to unfreeze fellow professionals through my narrative of the shock of how our Victorian road and rail assets are increasingly threatened by what I encountered.

Last year, I was privileged to host the Disaster Management Committee of the World Road Association (PIARC), and an event at Highways UK. DfT and the Devolved Administrations were present to share the insights and personal experiences of practitioners leading the sector's effort to prevent global disasters. Dr Deeming joined us, and we discussed Atmospheric rivers in Vancouver, impacts to logistics following the Baltimore Bridge Collapse, earthquakes and landslides in Japan, floods in Romania, and advances in Rapid Impact Assessment.

It is through sharing knowledge and experience that highways authorities across the country will best be able to implement the findings of this new report. This conversation must involve all authorities, not just those who have the resources to engage, or who have had the misfortune to have experienced extreme weather over the last few years. With support from

DfT, 2025 will see every authority invited to regional events to help you consider your climate risks and challenges in the context of your local geography, geology and climate.

We are a great sector, standing ready to support each other against the multiple hazards and threats to which our transport network is exposed. Practically we must use the forthcoming 2025 review of the *Code of practice for Well Managed Highway Infrastructure* as an opportunity to embed extreme weather resilience throughout the guidance. We already have specific guidance on winter service: however, we must also better define our response to broader hazards. We are an innovative and responsive sector and through learning and sharing we must better understand how to equip our highway heroes with new skills, training and capabilities to do their jobs well.

I am delighted to have already engaged with incoming Presidents of the ICE (David Porter), CIHT (Mitesh Solanki), LGTAG (Emily See) and ADEPT (Angela Jones) on this report and the actions flowing from it. It is twenty years since I joined the (then) County Surveyors' Society (now ADEPT) and these bodies, including SCOTS and CSS Wales, are vital to providing capacity and driving change.

As this report states, you must not wait for your own 'personal epiphany' of witnessing and experiencing our communities in dire need. Through this report, and forthcoming regional workshops, we can build a solid network and will make friends before we need them. This will ensure our sector's deep expertise and skill bases evolve to meet the challenges of the coming years and decades.

As Chair of the ABC Board, I will be the sector's champion to the best of my ability. Through the DfT regional workshops I want to find new voices with fresh insight. With broader and more visible leadership from others, underpinned by support from Politicians nationally and locally, we can make the required changes—identified by Deeming in this report—at pace.

John A. Lamb

Chair of UKRLG Adaptation, Biodiversity and Climate (ABC) Board

Executive Summary

1. Executive Summary

This retrospective has been commissioned by UKRLG to reflect on highway sector response to the Lessons from Extreme Weather Emergencies (2015-2020) review, which was published by DfT in November 2021.

In the period since the publication of the *Lessons* review, the UK has continued to experience significant impacts from extreme weather. In addition, in July 2021, our European neighbours in Germany and Belgium experienced catastrophic damage from a storm that resulted in over 240 fatalities and over €32Bn in damage (€2 Billion to transport infrastructure). This latter event—or rather, the risk of a similar event occurring here—set the context for retrospective examination of sector resilience and progress in adaptation.

To inform the review, an initial analysis was carried out of the UKRLG Winter 2023 / Spring 2024 *Hazards* survey. The *Hazards* survey represents a first of its kind, in that it was intended to question Local Highway Authorities' experiences with a range of hazards that are being enhanced by climate change (i.e., hazards whose effects are increasing in frequency, intensity, and/or magnitude, as a result of the warming climate).

From an adaptation perspective, the *Hazards* survey was designed to create a very basic baseline understanding of the entire national highway network's exposure to winter, flood, heat, and geo-hazard risks.

The survey found that whilst~ 25% of respondents (*n* =64) had experienced main river or coastal flooding during 2023, that figure doubled to 52% in respect to surface water flood incidents (i.e. a local authority responsibility). In terms of geo-hazards (e.g. landslides), whilst just over 23% of the national sample had experienced these, whereas for the 'Pennine 17' authorities this figure was 55%. These findings confirm that some councils are more exposed to particular types of hazard than others.

Whilst a majority reported their *proactive* management of drainage infrastructure, others were either used *reactive* or *hotspot-only* regimes. Against this only 50% of those on reactive regimes reported their ability to respond to Red, Amber, Yellow, weather warnings (65% for proactive).

Against this backdrop the review then drew the lens out to discuss three areas where sector leadership in extreme events is becoming increasingly important: managing hazards; leading during emergencies; equipping the sector leadership to manage future emergencies (SQEEP).

In respect to managing hazards, this discussion focuses on the idea that adaptation to climate risks needs to start in the obvious places (i.e., the existing hazard hotspots). It is these places, where chronic flooding already occurs and where adaptation 'quick wins' can be achieved. The case study of Worcestershire's *Network Resilience Forum* was used to illustrate how collaborative approaches can have beneficial effects in reducing risks.

From an extreme events perspective, it was also suggested that thinking should be fundamentally realigned, from focusing on the network always being open, to accepting that functionality may sometimes need to be lost, to protect homes and businesses (e.g. as roads become floodwater pathways). In this case the importance of understanding

communities' fall-back lifeline connections underpins a new understanding of what constitutes a resilient network.

In respect to leading in emergencies, the discussion focussed on DfT's role as Lead Government Department for transport emergencies, and suggested ways that this responsibility could be better delivered, in full collaboration with the sector. The importance of sensitising and preparing stakeholders for the requirements of managing *possible* catastrophic contingencies (e.g. the Germany / Belgium floods) is vital though. Recommendations here include the need to normalise contract conditions to include exigency circumstances and the critical need to develop a pan-region mutual aid system.

Underpinning the whole report is the need for more people to be trained for leading the sector into a future that will include more frequent and more intense extreme weather. Is it only by having concerted, strong, and informed leadership, to drive effective adaptation, to embrace innovation, and to strengthen resilience that the sector will be able to continue to effectively manage its responsibility to maintain the nation's 'lifeline' highway network into a turbulent future.

Introduction

2. Introduction

In November 2021 the Department for Transport (DfT) published its independent review of highway sector learning from extreme weather emergencies that had occurred between 2015 and 2020 (henceforth, the *Lessons* review)[1].

That report made 28 observations and recommendations, which identified key findings in respect to the way the sector had managed extreme weather events and other emergencies.

One of the important elements of the *Lessons* report was that instead of focussing on the sector's lone role in managing emergencies, the discussion was framed to investigate how effectively the sector was delivering Integrated Emergency Management (IEM) as a partner in an inherently multi-agency endeavour. In this review we will explore how the related concepts of *adaptation* and *resilience* can be used to inform the way highway structures and processes need to urgently evolve if we are to lessen the impacts of increasingly severe extreme weather.

From this perspective, the report focussed on Local Highway Authorities' designation as a Category 1 (Cat 1) Responder under the Civil Contingencies Act (CCA). Cat 1 responders have seven statutory *duties* in respect to anticipating, planning for, responding to and recovering from emergencies[b]. This is an important consideration, because if local highways are understood as *community lifeline*[2] infrastructure (Box 1), then the CCA duties provide a stimulus to generate new ways to think about and deliver sector resilience. A move to this way of working would be transformational for the sector.

Taking this perspective, the *Lessons* review identified a range of good and innovative practice that had allowed emergency impacted councils to effectively manage a series of extreme events and keep the network running. It also identified areas for improvement.

Accordingly, in 2024, the UK Roads Leadership Group (UKRLG) has commissioned a retrospective review of whether and how sector practice has evolved since the publication of the *Lessons* review.

This retrospective review will not revisit all the original findings. As with the Quarmby[3] and Brown[4] reviews—which created the foundations for the *Lessons* review—all 28 recommendations and observations remain valid, i.e. there remains an imperative on councils to adopt them. Rather, this review will explore how the sector's understanding of how Adaptation and the significance of resilience to extreme weather events has evolved over the intervening three years: by identifying key barriers and gateways that are preventing or encouraging the evolution of good practice.

[b] Footnote: The Act places 7 statutory duties on all Cat 1 responders: to cooperate; to share information; to assess risks in their area; to plan for emergencies; to communicate with the public; to ensure their own business continuity and, for local authorities only, to provide business continuity advice to businesses

Box 1: FEMA 'Community Lifelines' (adapted from *Lessons* review: p.12)

In July 2023, the US Federal Emergency Management Agency (FEMA) updated its guidance on the management of eight designated types of infrastructure which they defined as 'community lifelines'.

The listed infrastructures: safety and security; food, water & shelter; health and medical; water systems; energy (power & fuel); communications; hazardous materials; transportation. Each of these infrastructures, FEMA suggests, bear three key attributes [emphasis added]:

Lifelines are **the most fundamental services** in the community that, **when stabilized**, enable all other aspects of society to function.

Lifelines are the **integrated network of assets**, services, and capabilities that are used day-to-day to support the recurring needs of the community.

When disrupted, **decisive intervention** (e.g., rapid service re-establishment or employment of contingency response solutions) is required to stabilize the incident.

This framing of specific services and assets as lifelines is useful, because it underlines for those managing them the importance of adopting risk-based asset management approaches befitting this function.

Most importantly, and whilst not wishing to accept a US concept into the UK emergency management lexicon uncritically, there is an over-riding factor that makes consideration of this concept particularly relevant for this review.

Understanding and designating highways as community lifeline infrastructure bears a dual imperative: 1) highways can be considered as lifelines in their own right; 2) highways also host (e.g., aligned gas and water), carry (e.g., hazardous material in transit), or connect (e.g., facilities, buildings and assets) all the other types of infrastructure. This bestows a principal importance.

2.1 Definitions

The Intergovernmental Panel on Climate Change (IPCC) has stated that adaptation to the effects of a changing climate (including the 'locked in' effects which are now unavoidable) and the mitigation of future climate change (e.g., through decarbonisation and emissions reduction), are not mutually exclusive activities:

> *"The cumulative scientific evidence is unequivocal: Climate change is a threat to human well-being and planetary health. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all."*[5]

The Joint Committee on the National Security Strategy has also clarified this imperative in respect to the UK:

> *"The scale of the challenge facing Government, operators and regulators is clear: there is an urgent need to adapt our infrastructure to the potentially rapid effects of climate change."*[6]

In order to understand the relevance of some of the activities we are going to discuss, it is important to revisit what we mean when we talk about *adaptation* and *resilience* in the context of the more intense and more frequent extreme events that are projected to occur in a changing climate.

2.1.1 Adaptation

To align with World Road Association (PIARC) guidance, *adaptation* is defined here as the process of adjustment to actual or expected climate and its effects in order to moderate harm or take advantage of beneficial opportunities. Adaptation plays a key role in reducing exposure and vulnerability to climate change, where adaptation can be anticipatory or reactive, as well as incremental and/or transformational.[7 p.4]

2.1.2 Resilience

Whilst the resilience concept has been framed in many ways to describe different system, individual, social, and infrastructure attributes[8], for the purposes of this review we will adopt the new World Roads Association (PIARC) definition of the concept:

> *"The ability of a system, exposed to a hazardous event, a trend or a disturbance, to adapt to, transform, learn, and recover from the induced effects in a timely and efficient manner that maintains essential function, identity and structure."*[9]

In addition, as resilience can cover such a broad range of topics even within the highway sector, we shall treat this definition as describing an umbrella concept, which can be broken down into six key domains: Robustness, Reliability, Redundancy, Resourcefulness, Rapidity, and Recovery[c] (Figure 1)[10 d].

[c] Footnote: During review of the draft of this report the author was challenged that it did not include a detailed discussion of highway's role in Recovery. Recovery processes and the Recovery Coordinating Group (RCG) role were described in detail in the *Lessons* review, and it was never the intention to reproduce that discussion here. This report is focussed on understanding recovery as one of six resilience domains, all of which require planning and adaptation attention.

[d] Footnote: DfT commissioned a 20min presentation by Dr Deeming of the *Lessons* Review findings: here

Defining the concept in this way allows us to investigate the way its presence (or absence) is manifesting *systemically* (i.e., across the full spectrum of highway sector influence)

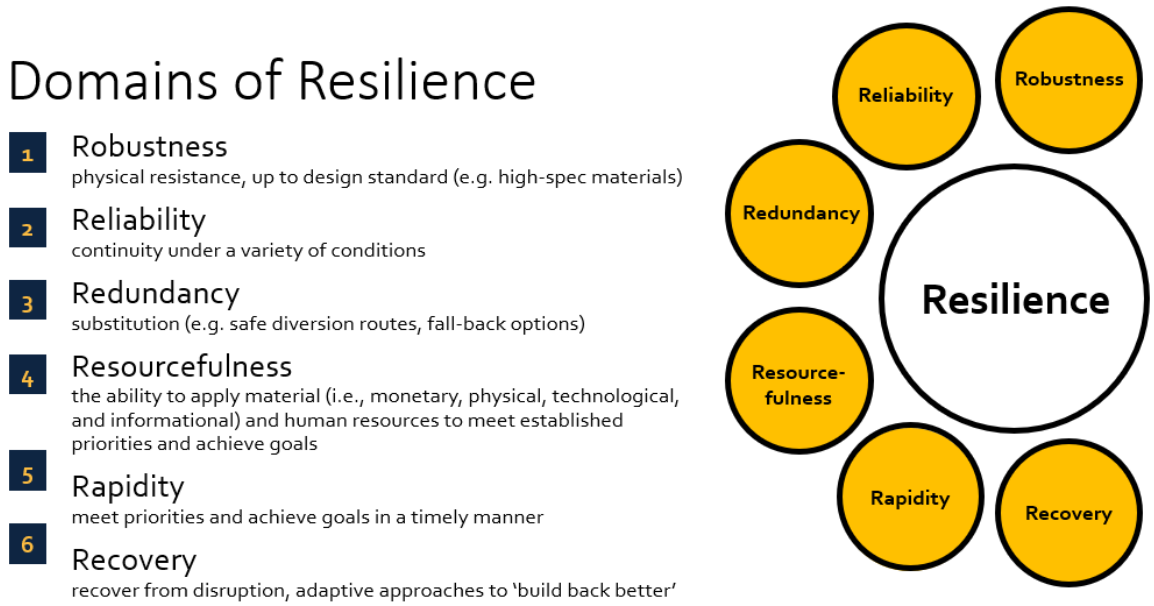


Figure 1: The six domains of Resilience (Deeming & Lamb, 2023)

2.2 Extreme weather events: update

The sector's experience of a range of extreme weather events and other emergencies informed the *Lessons* review. This included the effects of Storm Desmond in Cumbria, with its record 24^{hr} rainfall that led—in a matter of a few hours—to the damage or destruction of 1,234 highway assets across the county[e], which cost >£120m to repair. This remains the highest intensity event to have affected the UK in recent years.

However, extreme events did not stop with the publication of the *Lessons* review. In fact, in the week of its publication Storm Arwen tracked across the UK, driving winds of such intensity and unusual direction that it resulted in 8 million trees being blown over. This led to 5,000 households losing their power for <5 days—with 32% of the damage to power infrastructure caused by falling trees, which also blocked roads[11]: exacerbating access issues for power-restoration teams and isolated communities, i.e., significant *lifeline* disruption.

In 2022, the UK experienced the transit of three named storms within a week for the first time. Storms Dudley, Eunice, and Franklin compounded the effects of Storm Arwen and added flooding and further transport disruption.

Fast forward, to the unprecedented heatwave of 2022, where wildfires drew greatest attention but whose raw temperature effects resulted in melting roads, buckling barriers, overheated roadside electronics and a heat stressed workforce. October 2023, then brought

[e] Footnote: This is in addition to over 5,300 properties and 1,000 businesses flooded

Storm Babet which delivered exceptional rainfall to parts of eastern Scotland, with 150 to 200mm falling in the wettest areas and the Met Office issuing two red warnings for rain. The severe damage to the 240-year-old Bridge of Dun in Angus was just one of the indicators of the storm's severity[f]. Interestingly, Storm Babet followed directly behind an unnamed storm, which had also tracked across Scotland, causing a landslide that had dumped an estimated 15,000 tonnes of debris across the A816 near Ardfern, Argyle & Bute[g]. This slip blocked the sole practical access route to local communities who had to resort to sending their children to school via an impromptu ferry service[h]: more lifeline disruption.

As well as weather events, there have also been examples of other types of emergency that have directly tested local highway authorities' resilience and interoperability with partner agencies. For example, the discovery of an unexploded WWII bomb in Keyham, Plymouth in February 2024 set in motion a massive evacuation and security operation[12] which placed highways teams at the leading edge of the successful multi-agency incident management process[i].

Internationally too, extreme events have provided a lens through which to reflect on UK highway resilience. The collapse of the Francis Scott Key Bridge in Baltimore, US, in March 2024—following a strike by the container ship the MV Dali—provided an illustration of how vulnerable critical, and iconic, highway infrastructure can be to relentlessly evolving, but quantifiable, risks[13].

Also, occurring outside the *Lessons* review's time window, the European floods of July 2021 should act as the new benchmark for an event that would test our society to the full. Whilst the storm that traversed London on July 12th, 2021, caused significant damage to homes, businesses, and transport infrastructure, resulted in the Mayor of London commissioning the *London Climate Resilience Review*[14] and acted as a catalyst to accelerate the development of the *London Surface Water Strategy*[15], it was what the storm did next that bears greater consideration.

Over the course of the next three days, the low-pressure system moved east, accumulated moisture and energy from air flowing off the Baltic Sea, stalled over Germany and Belgium, and proceeded to drop record rainfall amounts. This resulted in the death of over 240 people and between €32 and €46 Billion in damage in Germany alone (€2 Billion of which was damage to transportation infrastructure[16]). It is worth acknowledging, that the epicentre for this destruction lay approximately 325 miles from London, roughly the same distance as from the Capital to Edinburgh.

Moving beyond the memory of Storm Desmond. What the European floods of 2021 provide us, is a valuable precedent against which we need to start planning our sector's worst-case contingencies. In Germany, reviews of their resilience, response, and adaptation processes have identified key areas where risks could be mitigated[17]. The UK sector needs to learn these lessons and, mindful that such a catastrophe could occur here, should start to actively play its role in preparing.

However, it should not be forgotten that for councils, extreme events will play out against a backdrop of chronic climate risk exposure. This means that as well as developing contingencies for disaster, the sector will also be increasingly needing to identify, prioritise,

[f] Footnote: https://www.thecourier.co.uk/fp/news/angus-mearns/4790268/storm-babet-bridge-of-dun-hole/
[g] Footnote: Personal communication – Jim Smith (13/11/2024)
[h] Footnote: https://www.bbc.co.uk/news/uk-scotland-67438057
[i] Footnote: In December 2024 the Lord Mayor of Plymouth awarded a certificate of recognition to South West Highways (the council's term maintenance contractor), for their team's "admirable contribution" to the safe resolution of the incident.

and manage lesser risks on a day-to-day basis. There is no better illustration of this challenge than the Environment Agency's publication of its second National Flood Risk Assessment (NaFRA)[18].

Using its updated methodology, the Environment Agency has identified that...

> *"... 113,900 kilometres out of 302,100 kilometres of roads in England are in areas at risk of flooding. This is around a third (38 %) of all roads in areas at risk from one or more sources of flooding. Of that, about 18 % of roads are in areas at high or medium risk of flooding. If we apply the climate change projections the road network at risk rises to 137,700 kilometres or 46 % at risk by mid-century, an increase of 21 %".*

Simply put, these figures suggest that we will not be able to make our whole network completely robust to flooding, we will need new approaches.

Having now framed this review's objective and set the scene, with a targeted selection of the extreme events that have impacted us since the *Lessons* review's publication, we will now start to explore how sector resilience and resilience thinking have evolved in the last three years.

We will start this discussion by examining whether resilience and adaptation are being given sufficient weight against the drive to deliver NetZero.

2.3 Resilience and adaptation vs. NetZero

The transportation sector is the largest emitting sector of greenhouse gas in the UK[j]. Accordingly, substantive efforts are needed to decarbonise the transport system if the risks of further climate change are to be reduced. However, if we are to accept that adaptation and mitigation represent essentially parallel objectives, when it comes to understanding efforts by the UK highway sector to *adapt* to versus its efforts to *mitigate* climate change, an inequality exists.

Funding opportunities for research and innovation projects, such as both LiveLabs 1 and 2, have focussed on funding NetZero/decarbonisation, with any adaptation objectives needing to fit tightly within that overall framing. Whilst DfT has recently funded £10m to the Newcastle University based DARe Hub, to research "*decarbonised, adaptable, climate resilient transport for a sustainable future*" [e.g.,k], this represents the exception of recent years, rather than the rule of research funding.

The smaller Transport Research Innovation Grants (TRIG) programme in 2021 and 2022 did include bidding lanes for "*Covid 19 Recovery and Resilient Transport Systems*" and "*Transport Resilience to Severe Weather & Flooding*" respectively. However, these represented a fraction of the projects, compared to those focussed on decarbonisation and other objectives. Only 2 of the 50 projects funded in the 2021 round and 5 of the 68 in the 2022[l] round could be described as focused on an element of adaptation / resilience to extreme weather.

To make sense of this, it may be useful to look at evidence from spending. For example, the National Audit Office (NAO) discusses DfT's "*Wet weather funding/flood resilience*"

[j] Footnote: https://www.gov.uk/government/statistics/transport-and-environment-statistics-2023/transport-and-environment-statistics-2023
[k] Footnote: https://dare.ac.uk/news/hackathon-1-towards-resilient-urban-transport-systems/
[l] Footnote: https://cp.catapult.org.uk/transport-research-and-innovation-grants/

contingency, which was used to direct a total of £314 million to specific English local authorities to repair exceptional storm damage in four of the years from 2015 and 2020 (Appendix 1). This funding effectively constituted a set of emergency grants where, due to the lack of alternate options, it became necessary for DfT to act as the impacted authorities' 'insurer of last resort'. It could be argued that this was something that had not been fully anticipated during DfT's 2014 consultation, when the sector chose not to top-slice some funding from the highway maintenance block for an emergencies contingency fund, choosing instead that all funds would be distributed to cover proactive maintenance and intervention[m].

Although the funding agreement between Government and local authorities in Wales is different from in England (as it also is in Scotland and Northern Ireland), the Welsh Government has reported spending £8,775,000 directly on schemes "*to address disruptions caused on the highway network by severe weather*" during FY2023-24[n].

So, notwithstanding the significant £314m total paid by DfT for emergency repairs in England, given how many severe to extreme weather events have occurred since the last emergency grant was paid in FY 2019/20, does this suggest that there is no longer a problem? Local Authorities have obviously been soaking up the costs of weather-related impacts on their networks from other budgets (e.g., their Highways Maintenance Block, or Potholes grants).

Through this lens, adaptation remains an issue for the future, not so much for now.

However, if you try to explore the data on extreme weather impacts on the local highway network, both the NAO and the Climate Change Committee (CCC) have discovered that such data does not exist in any nationally consistent format.

Without this data, how can we understand the level of weather-hazard related expenditure the nation's highway authorities are currently dealing with, or what the opportunity costs of that expenditure are, i.e., relative to other things those authorities *could* be spending that money on?

> *"Government does not know how much is being spent on managing extreme weather risks. Without this information it is difficult to conclude on whether its current approach represents value for money."*[19]

and

> *"On roads, problems are more likely to occur on local roads and smaller schemes and indeed, there is an underlying need to assess the impact of single points of failure more broadly (e.g. bridges), earthworks and subsidence. Often a paucity of data is restricting progress in these areas. [...] It is not clear from the available evidence whether there has been a systematic evaluation of climate change risks to either the local road network or to local highway bridges. Better indicators are needed to assess progress in managing the impact of climate risks on local roads."*[20]

Through this lens, we realise that without such data we cannot know—on a national scale—how many extreme-weather related impacts we are already suffering, or how many of them

[m] Footnote: i.e., contrary to the impression given in the NAO report, there has not been a discrete Wet Weather funding/Flood Resilience *budget* since 2014.
[n] Footnote: https://www.gov.wales/resilient-roads-fund-schemes-funded-2023-2024-html

could be avoided through the implementation of targeted proactive adaptation and resilience building.

This all feels somewhat ironic given that by October 2024, 328 Councils had declared a Climate Emergency[o], suggesting they understand and accept their need to act on the causes and impacts of climate change. Yet the narrative of even this declaration is weighted toward communicating climate change as primarily a decarbonisation issue[p]. Accordingly, there is little information available to tell us anything about how many, if any, councils have integrated highway resilience into their climate plans, even on the basis of a climate emergency declaration.

2.3.1 Local Highway Resilience and Inventory Survey

To date the principal means through which DfT has gathered data on hazards, has been the *Winter Survey,* which was circulated most recently as the *Local Highway Resilience and Inventory Survey* in November 2023. In recent years this survey has evolved from its original purpose, to collect data on councils' winter service arrangements, e.g., salt stocks, contact details, and base asset inventory (e.g., the number of streetlight columns), to a survey that also asks questions about preparedness for other types of hazards: principally flooding.

Unfortunately, in its 2023 format this survey was incapable of informing our understanding of the distribution of hazard impacts across the sector. This is because nobody was asked questions about *impacts* on their networks, they were asked unchallenging questions requiring Yes/No answers about *measures* in place.

For example, in respect to flood resilience, respondents are asked:

> "Which of the following flood prevention measures do you have in place?
>
> - *Measures to reduce landslips*
> - *Use of pumping machines*
> - *Use of gully sucking lorries*
> - *Use of sandbags (or equivalent) to keep floodwater off roads*
> - *Additional gully and drain inspections*"

Yes/No answers to this question tell us nothing about a council's experience of hazard impacts or the scale of those impacts. At best it could be seen as a prompt to get respondents to think about their depot equipment inventory from an *all-hazards* rather than just a *winter service* perspective. However, it provides no useful information to inform adaptation decisions.

This appears to be a fundamental challenge. If hazards are viewed from a winter-service perspective, there is a risk that all hazards are regarded as bearing only manageable, temporary, effects. This is a completely inappropriate framing.

Winter hazards (snow and ice) come and go. They cause disruption and risk to life if inadequately managed, but they do not so readily cause damage in the same way as other hazards (e.g., flood and mass movement/landslide). Once the snow and ice have melted away (more often these days, in hours or days at most), the network returns to business-as-usual[q]. Whereas the asset damage that other hazards can cause endures, eating into

[o] Footnote: https://cape.mysociety.org/councils/
[p] Footnote: https://www.local.gov.uk/delivering-local-net-zero
[q] Footnote: notwithstanding that intense rain-on-snow events can induce rapid thaw and runoff that amplify flood effects: with the most consequential event of this type being the March 1947 floods

business-as-usual resources and budgets[r] or, in dire cases requiring emergency funds to be negotiated either as Bellwin claims[s] or as "one-off, exceptional funding" (as was required for bridge repairs at Codgen Beck and Grinton, North Yorkshire in 2019)[t].

Currently, DfT allocates almost all capital funding to local highway authorities based on road length and the number of bridges and lighting columns in each local authority area. This is a funding system based on the principle of *equality* (i.e., funding is distributed equally, dependent on those three variables). The approach was agreed between DfT and the sector in 2014. This formula does not take traffic volume, road condition, or other factors that affect deterioration into account[19].

However, as the climate changes and if the current projections for increases in the intensity / frequency of extreme-weather related hazards materialise, then this formula may become increasingly *inequitable*[u]. It is possible that some authorities will be faced with managing intensifying hazards and their impacts, whilst others will not. This would manifest as opportunity costs to the communities served by the affected authorities, who instead of investing their share of funding in a range of network improvements—delivering a range of community benefits—they would be tied to spending a greater percentage of their funds on hazard mitigation and repair. This could include, for example, more hilly communities requiring the continuous (i.e., section by section) reinforcement to retaining walls and measures to reduce run off, or significant carriageway repairs by communities served by roads built on clay that is vulnerable to shrinkage during drought, and heave during sustained wet conditions.

From this perspective, it can be seen that knowing a council has a gully-sucking capability, or not, provides no insight whatsoever into that council's vulnerability to extreme-weather related hazards or how that level of vulnerability is changing. For that we need hazard and impact data.

Recommendation 1: Sector professional bodies and DfT should review whether a substantive budget and funding framework should be created for adaptation to, reduction of, and recovery from, chronic and acute extreme-weather risks.

[r] Footnote: whilst accepting freeze-thaw cycles are a fundamental mechanism driving chronic damage to road surfaces and structures over time.
[s] Footnote: https://www.gov.uk/government/publications/bellwin-scheme-guidance-notes-for-claims/bellwin-scheme-of-emergency-financial-assistance-to-local-authorities-guidance-notes-for-claims
[t] Footnote: https://www.bbc.co.uk/news/uk-england-derbyshire-49299106
[u] Footnote: In his landmark review of health inequalities Lord Marmot defined inequity *as "referring to those inequalities that are judged to be avoidable by reasonable means and are not avoided."*

The UKRLG Hazards Survey

3. The UKRLG Hazards Survey

From a non-existing baseline, DfT's principal objective, outlined in its submission to the third National Adaptation Programme (NAP3)[21] provides an opportunity to remedy this lack of knowledge in respect to councils' all-hazards resilience. Regarding local-roads resilience, DfT promised to work with UKRLG to "*devise a framework for local authorities to implement the extreme weather recommendations from recent incident reports by the end of 2024*" Ibid., p.38.

Realising the basis for developing an effective implementation framework is the need for data, in November 2023 UKRLG commissioned a preliminary *Hazards Survey*.

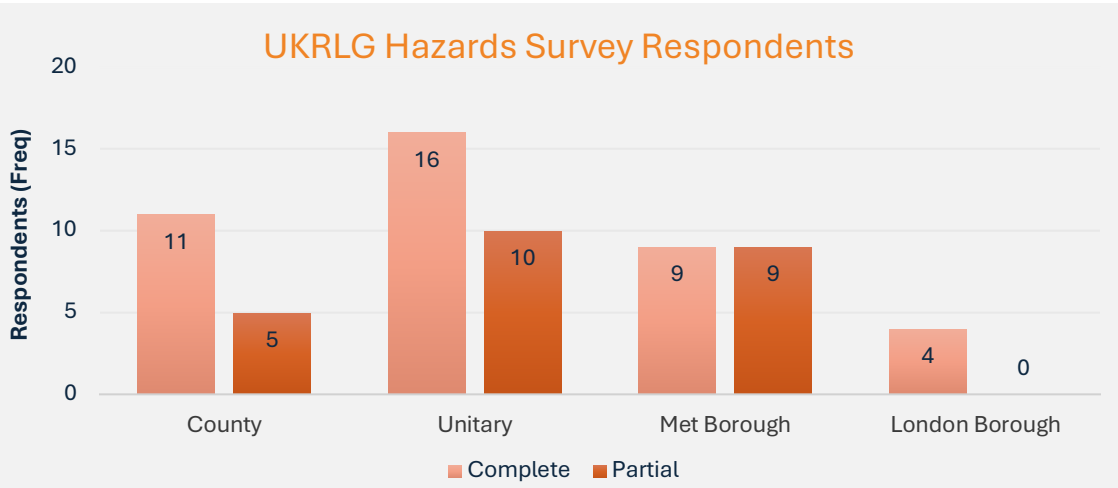
The survey comprised 85 questions split over five sections:

- Key Contacts
- DfT Guidance and Best Practice
- Flooding, Landslide, Heave
- Deployment of Technology
- Salt, Grit and Liquids

The survey was initially sent out to all English authorities via a link from the DfT Local Highway Resilience survey email. Subsequently, the survey was also circulated to Scottish authorities following a presentation by the UKRLG Adaptation, Biodiversity and Climate (ABC) Board Chair John Lamb at the SCOTS conference[v]. Wales was not initially canvassed, and Northern Ireland did not participate.

Engagement with the DfT *Winter Survey* is an expectation, which means response rates are always >90%. However, the *Hazards Survey* was optional. Thus, it was always anticipated that response rates would be lower.

Ultimately, the survey received 64 (complete or partial) responses from across England and Scotland: a representative ~34% response rate across a range of authority types (Figure 2).



[v] Footnote: https://www.scotsnet.org.uk/__data/assets/pdf_file/0021/48621/SCOTS-2024-Conference-Agenda.pdf

Figure 2: Local Authority respondents by type

As a first ever survey of its kind it is to be applauded. It is also noteable that DfT Director and Chair of the ABC Board both showed strong leadership in seeking to drive up returns. However, three years since the publication of the *Lessons* review it could be seen as illustrative of a sector really struggling to frame and prioritise its own resilience and adaptation dilemmas, that so many councils did not automatically see the survey as a basis upon which their voice, challenges, and needs could be showcased.

The following section presents discussion and analysis of some of the key survey results[w].

3.1 Hazard Survey: findings:

3.1.1 Lessons Learned

Initially, respondents were asked a question in respect to the status of the *Lessons* review in their council, and what they had done over the period since its publication in November 2021 to institutionalise the learning opportunities it described.

Figure 3 indicates that of the sample, 16% of respondents reported having fully integrated the review's lessons into practice, with others having reviewed with their portfolio holder or having passed it directly to officers for an "operational response".

However, what should be of most concern was that for 39% of councils, the report was still 'under review'.

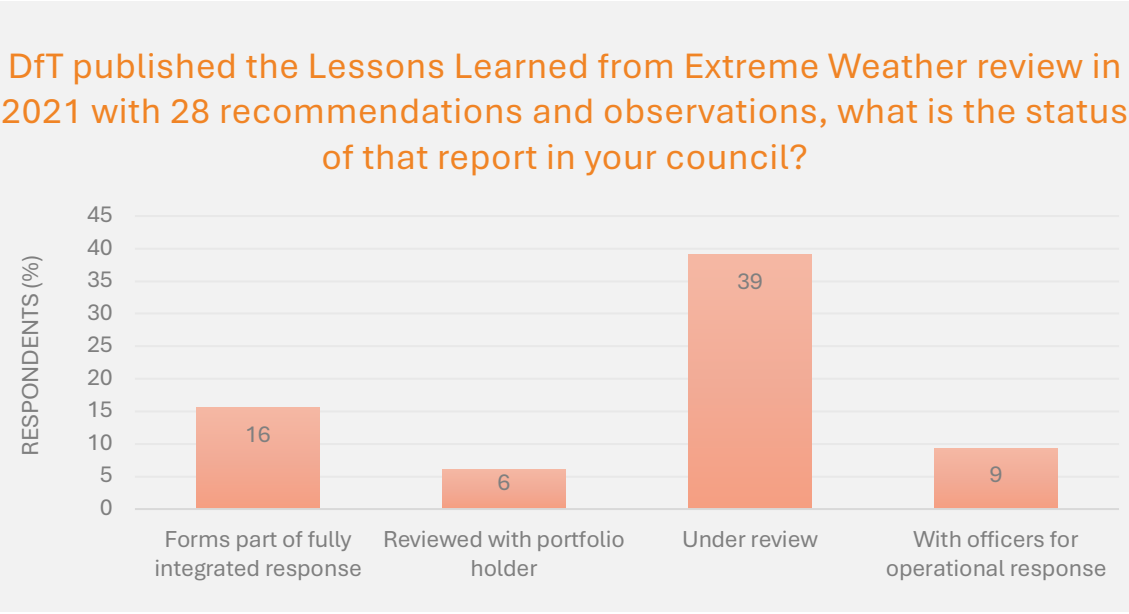


Figure 3

In effect, this response indicates that most councils—who were engaged enough to complete the survey—are still reviewing whether lessons learned by peers (who had directly

[w] Footnote: Key elements of the survey methodology are described in Appendix 2

experienced extreme weather events between four and nine years ago), are relevant to them and worthy of adopting into practice.

It is possible that these councils have nothing to learn, because they already have systems in place that align with the lessons. However, it is also possible that with the pressures presented by delivering Business as Usual, councils are simply struggling to grasp opportunities for implementing beneficial change.

From this second perspective it is useful to look at the responses to two later questions in the survey, relating to the respondents' adoption of lessons from two LiveLabs 1 projects that bore relevance to sector resilience to extreme weather: the use of smart gully sensors and efficiencies in winter service (Figure 4).

Looking at these responses we see that 47% and 52% of respondents respectively stated they had not yet reviewed their service against these projects or had no intention of doing so (with 6% planning to look at the winter service innovation this year).

Individual examples of notable practice in winter service and drainage were provided. For example, two councils described how temperature sensors attached to their Internet-of-Things (IoT) networks were being used to inform gritting decisions, and thirteen respondents reported their councils' use of gully sensors (with two saying sensor tests had not shown sufficient benefit to justify adoption). Many of these uses of technology, however, appeared to be largely locally bespoke and internally driven, rather than resulting from a nationally consistent improvement programme.

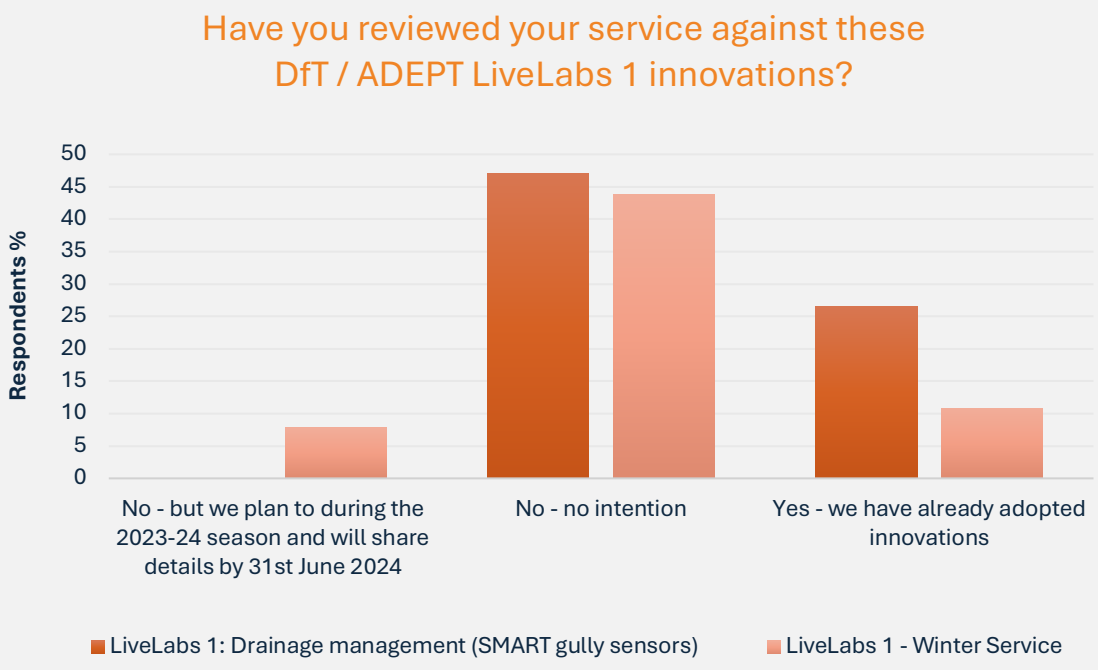


Figure 4

In asking about the respondents' engagement with three specific pieces of learning (i.e., the *Lessons review* and the two LiveLab 1 projects), which are all relevant to extreme weather resilience, and finding only moderate levels of engagement at best, are we simply identifying a degree of overwhelm, or organisational inertia, where embedded culture dictates that something created 10- 20 years ago is something that cannot (easily) be changed?

Looking around the sector, a huge amount of innovation is occurring. Simply walk around one of the big sector conferences, visit a Transport Technology Forum event, or read any of the trade journals, and you are exposed to any number of businesses or organisations plying for your interest and/or trade. There will be efficiency innovations, decarbonisation innovations, asset management innovations etc., etc., etc. Each of these has to be mentally weighed, both to ascertain if it would provide a benefit, and whether that benefit would be sufficient to justify both the financial investment and the *work* required to implement any changes (e.g., staff training). Without direction or consensus, how these options are assessed for value may come down to nothing more than a practitioner's subjective gut feel.

In addition to this, as already discussed, whilst there have been increasing levels of funding and innovation to support a reorientation of practice in respect to pursuing the NetZero goal, there is less consensus in respect to the objectives of adaptation. Accordingly, it is clear that adaptation has not yet gained sufficient traction at the levels of basic understanding, action, or programmes of work, to initiate and empower widespread cultural change.

There is clearly an opportunity here for the sector's professional institutions to play a part in defining what evolving good adaptation practice needs to look like. Here, case studies of good practice would include the London Surface Water Strategic Group's on-going work to deliver a *London Surface Water Strategy*. Significantly, the formation of this collaboration followed directly from surface water flooding being upgraded to one of the highest risks on the London Risk Register after the July 2021 flood[15]. In effect, an extreme weather event acted as the necessary stimulus required for stakeholders to overcome the culture of fragmented responsibilities, which had previously defined the City's surface water infrastructure.

But the imperative of climate change is such that we can't wait for everyone to experience a personal epiphany through the direct experience of hazards: we need to learn collectively.

The challenge from this perspective is that membership of sector bodies tends to be voluntary and relies on a quite modest cohort of engaged people. For example, although the National Winter Service Research Group (NWSRG) has spent years defining a comprehensive code of practice in respect to Winter Service delivery, actual membership of NWSRG is still relatively low (Figure 5) and its code of practice has still not been universally adopted[x].

[x] Footnote: The author has been at several 'Winter Service' conferences where the delegation has been asked directly "*How many of you use the NWSRG Code of Practice?*", with surprisingly few hands ever raised.

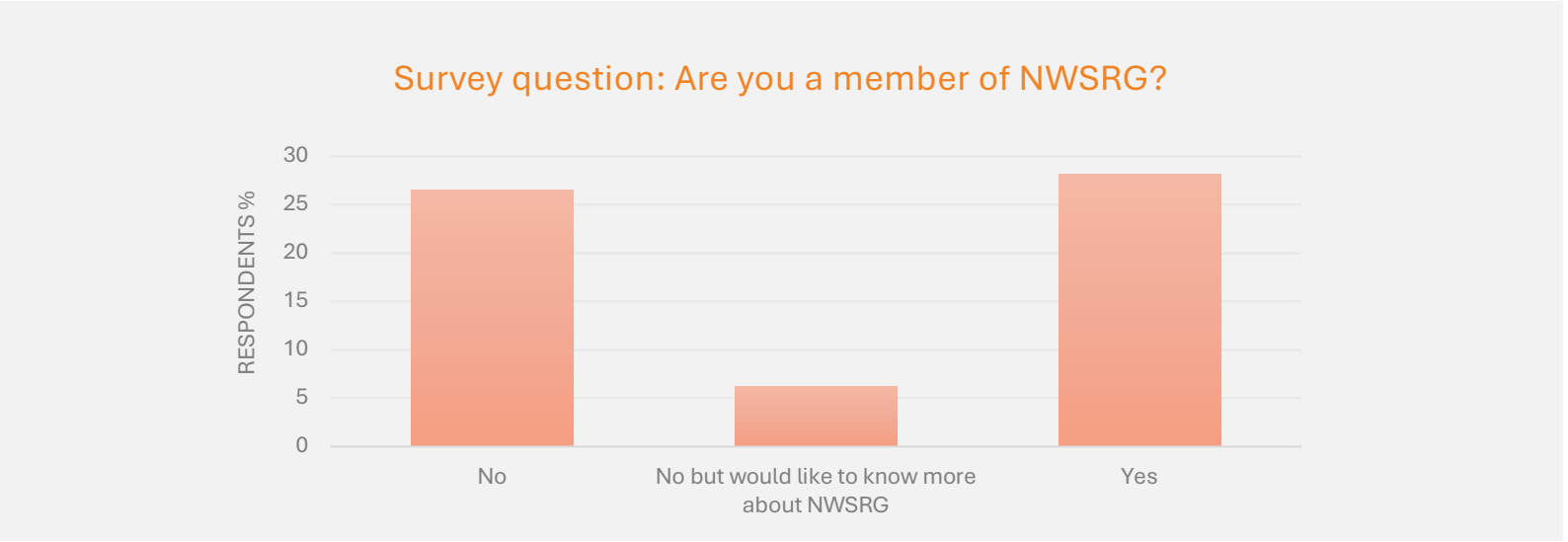


Figure 5

That the adoption of these evidence-based approaches has neither gained the traction, nor raised the bar of expectation sufficiently to deliver the research's proven benefits more widely should provide impetus to understand, why?

To shift forward from the status quo, requires the exploration of whether that state results from a lack of awareness (i.e., a communication issue), apathy, lack of resources, lack of consequences for spurning opportunities to change, a combination, or something else. It also requires a willingness and strategy to break through those barriers.

As with the two Live Lab 1 projects, this type of research supports incremental, if not revolutionary, change. For example, deploying smart gully sensors for the year-round monitoring of flood risk, or winter service that integrates data, insight, and AI to deliver more effective deployment of drivers, gritters and salt, i.e., the *targeting of interventions where and when needed,* involve adapting practice: but they are also cost effective and increase resilience.

Therefore, whether it is driven internally by practitioners, by Government, or by aligning to international best practice, the sector needs to grasp and drive change.

In this context, a key concern in respect to the sector's understanding of extreme-weather resilience, is the response to the survey question about contingencies for 'Storm Desmond + 30%' (Figure 6).

Following the severe storms of winter 2015/16, the Government commissioned a national review of flood resilience, to be led by the then MP, Oliver Letwin.

Part of this review involved the Met Office developing plausible 'uplifts' to describe the risk of future storm events, by accounting for climate change. Even though Storm Desmond resulted in new national 24^{hr} (341.4mm) and 48^{hr} (405mm) records for total rainfall in the mountainous terrain of Cumbria, the Met Office concluded "*that winter monthly rainfall totals could plausibly be 20% higher than recent past extremes in some parts of the country and up to 30% higher than recent past extremes in other parts.*"[22 p.7]

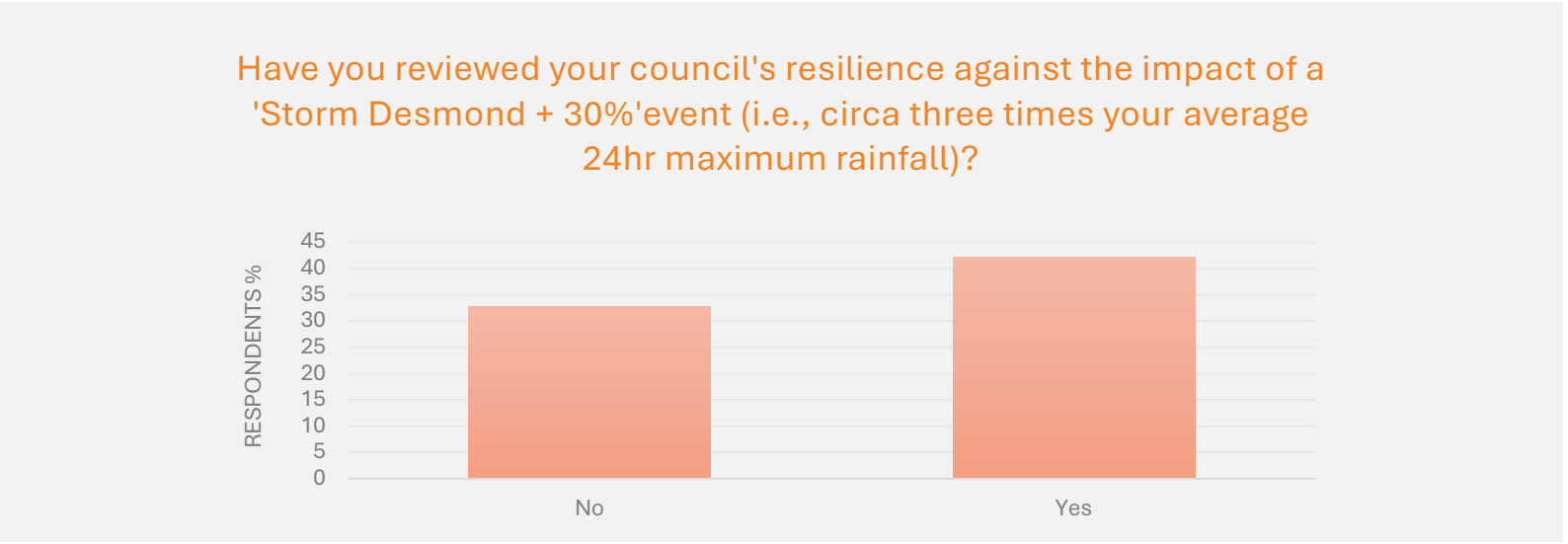


Figure 6

Whilst the actual amounts reflected in these percentage uplifts will differ by region (dependent on, for example, topographic factors), 2020 brought an indication of the kind of extreme rainfall event that can affect non-mountainous terrain. On the 16th of August 2020 a rain gauge in Norfolk recorded 239.9mm of rain in 24 hours. This value set a new UK August record. In July 2021 an even more intense event deposited 181.3mm of rain at Brettenham, Suffolk, in less than 2 (two) hours[23].

This prompted the Met Office to explain, that *"while daily totals of over 200mm are exceptional for the UK, there has been a marked recent increase in the number of such observations, with 200 mm recorded in 2008, 2009, 2012, 2015 (two dates), 2017 and 2020 (two dates)"*[24]. As projected by the National Flood Resilience Review, the risk of increasingly extreme rainfall events occurring at any location across the UK is, itself, increasing.

Furthermore, as an evolution of the National Flood Resilience Review methodology, the Met Office modelling undertaken for the 3rd Climate Change Risk Assessment (CCRA3) found "*that daily rainfall intensity is projected to increase by as much as 25% relative to coarser models, particularly in the south-east*."[25] The increasing risks presented by 25-30% 'Letwin' uplifts in extreme rainfall totals that this finding has reinforces, must be understood as a concern for everyone, not just for those living in mountainous areas.

In addition to concerns about extreme 24hr rainfall totals, there are growing concerns about intense 1hr rainfall events. At the UK's first Adaptation, Resilience & Response conference (*Learning lessons from extreme events in preparation for future challenges*) in November 2023, Dr Will Lang of the Met Office described observations of an increasing trend in events delivering 20mm to 30mm of rainfall in an hour.

An increase in all these types of events should be troubling for the sector, because they cross thresholds in respect to the damage and disruption they can cause. As well as increasing aquaplaning risk and reducing visibility on our high-speed networks, intense rainfall rapidly overwhelms drainage infrastructure and if sustained causes damage through inundation and erosion, with roads acting as pathways, able to discharge water—potentially at high velocity—into built-up areas, homes, and businesses.

The fact that only 42% of respondents had consciously reviewed their inventories, processes, and procedures against the National Flood Resilience Review's plausible worst case rainfall scenarios does appear to be a matter for sector reflection.

Whilst not detailed in the *Hazards* survey, there are some key metrics that are becoming increasingly useful for understanding risk thresholds in respect to highway infrastructure:

- **2.5mm** *depth* over >10m carriageway length – threshold for surface water to induce aquaplaning at road speeds in excess of 70 – 80 km/h [26]
- **20-30mm** rainfall in 60 mins – emerging threshold for drains and gullies exceeding capacity[y]

Aside from the imperative to look at Letwin figures (for simplicity 'Desmond plus 30%') such operationalised thresholds could be seen as a way of starting to guide professionals around preset choices in service delivery and in understanding consequences (i.e., akin to freezing point).

Recommendation 2: DfT and Highway Authorities should jointly agree the frameworks necessary for councils to conduct Climate Change Risk Assessments that are not wholly future looking but encompass the full range of contemporary risks for which greater resilience is needed *now*. This would be best led through a well-resourced ABC Board and through linking with the international expertise of PIARC

3.1.2 Flooding

Respondents were asked if they had experienced one or more of a range of flood hazard types during the year. Figure 7 provides the figures for main river, coastal, and surface water flooding. It can be seen that, within the sample, serious surface water flooding has been experienced by twice as many respondents as main river and/or coastal flooding.

[y] Footnote: https://www.metoffice.gov.uk/about-us/news-and-media/media-centre/weather-and-climate-news/2023/new-research-shows-increasing-frequency-of-extreme-rainfall-events

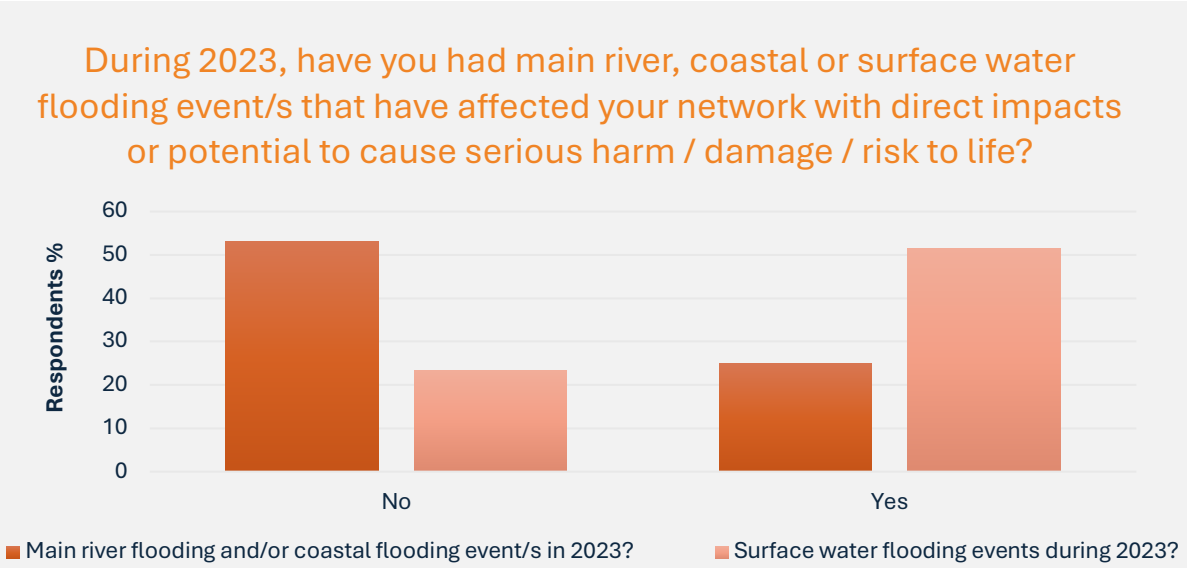


Figure 7

Respondents were also asked how many incidents they had to deal with. Here individuals' interpretation of the question led to some interesting results, which should inform future hazard surveys.

When asked to state the number of flood incidents experienced (i.e., river/coastal or surface water), responses mostly ranged between 1-10, but then leapt up to 205 for one, then to the highest reported figure of 11,196 for another. Double checking these inconsistencies revealed that the lower scores related to the number of storm events which had led to flooding, with potentially the occurrence of flooding at multiple locations at the same time aggregated into a single event (e.g., response "*Storm Babet affected the whole of* [the county] *culminating in a major incident being declared*"). Whereas the very precise very high figures were found to relate to the number of public reports of surface flooding recorded in the councils' asset management system (i.e., each single storm leading to multiple public reports).

This is an interesting finding, because it indicates the importance of clarifying exactly the metric being examined. It is understood that some of the work groups, formed from councils who have adopted the NHT Performance Management Framework (PMF)[z], have also identified this issue and worked collaboratively to develop consistent metrics across a range of variables (e.g., "*% of flooding incidents that result in road closure*"). This has included the quantification of public satisfaction with the council's management of flooding of roads and pavements[aa]. NHT benchmarking also allows similar councils to compare their performance directly against peers. This approach appears useful in informing future methods to monitor adaptation and resilience.

Whilst NHT offers one approach to understanding risk (i.e. public satisfaction / reputation), the importance of developing consistent data and data collection techniques in respect to

[z] Footnote: https://nhtnetwork.org/

[aa] Footnote: NB. it should be noted that the NHT is a *general* survey and does not explore public satisfaction with the way *specific* flood incidents are managed

flooding has also been identified as a broader objective of the *London Surface Water Strategy* (LSWS):

> *"...stakeholders have disparate data sets and action plans to tackle surface water flood risk in London. Fragmented data can limit understanding and also the efficiencies that can be delivered through integrated knowledge and working"*[15, p.9]

Looking at London as a microcosm of the UK. The London Surface Water Strategy's defines 13 surface water catchment areas, whose hydrologically and geo-physically (e.g. geology) defined boundaries cross but differ significantly from the political boundaries of the City's 32 boroughs. In effect, it has been realised that if surface water flood risk is to be managed effectively, then boroughs—particularly those exposed to similar catchment processes—are going to need to collaborate, and to do this effectively there is a need for consistent flood data. As this aspiration works for London, so too should it be applied to the UK more broadly.

It will only be possible to effectively explore the cost-benefit opportunities of highway adaptation, if we have a baseline understanding of what extreme weather is currently costing us to prepare for, respond to, and recover from. Accordingly, the sector needs to follow the London Surface Water Strategy's example and develop and adopt consistent methodologies for collecting flood data, including the identification of flood hotspots, both nationally (e.g., as an indicator of disproportionately hazard exposed councils) and locally (e.g., to map street level hazards in order to inform solution planning). We shall return to this point in the section summary.

3.1.3 Flood hazards, vulnerable features, and hotspots

Flood water on highways carries risk for users, including risk to life. Without increasingly active management and/or adaptation any rise in frequency of intense precipitation events will make the flooding of roads more likely, thus increasing these risks.

To gain a snapshot of potential types of risk related to highway users entering 'dangerous' water (i.e., in terms of its depth and/or its velocity), the *Hazards* survey asked whether the respondents managed any river fords and/or underpasses subject to inundation (Figure 8).

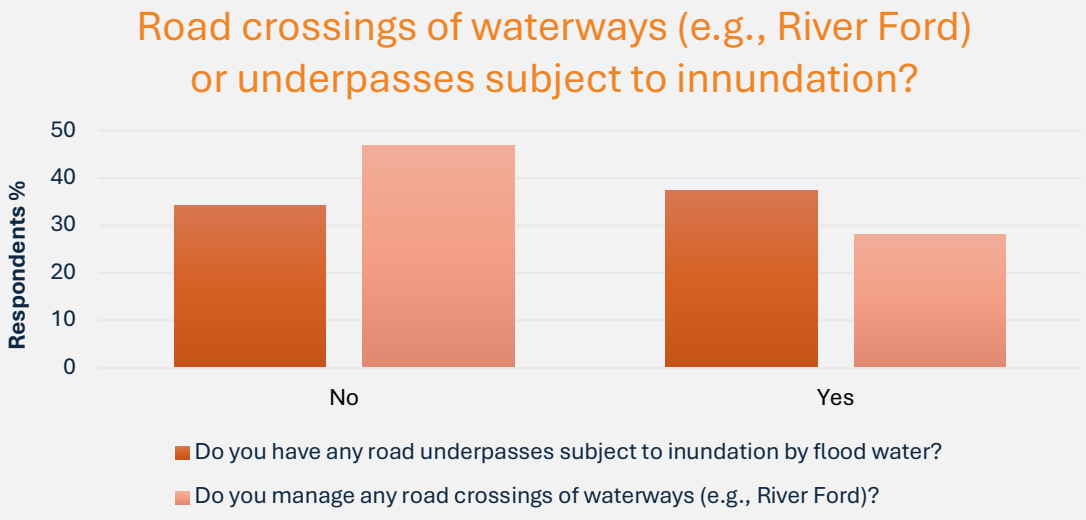


Figure 8

In respect to the numbers of river fords managed, replies ranged from 0 to 151 (the larger number including minor cattle crossings). For underpasses, the figures ranged from 0 to 10.

In respect to fords particularly, this once again suggests an imbalance in respect to the respondents' risk profiles, where nearly 50% of responding authorities have no fords but others manage a significant inventory.

The *societal* risk of death presented by river fords and flooded underpasses is very low (i.e., it happens very rarely, representing a fraction of a percent of road deaths). This is because there are a broad range of factors that influence people's entry into flooded fords or underpasses (e.g., visual cues; warnings; drowning prevention initiatives; spontaneous bystander rescue). However, it does occur, and analysis has indicated that up to 38% of flood fatalities can be attributed to vehicles entering water[27].

When this happens the *reputational* and *litigation* risks to the authorities responsible for managing those road features increases, particularly if evidence is found that the risk was known but was not adequately mitigated (NB. with what constitutes 'adequate' usually decided by the coroner or court). If a coroner has a concern that circumstances around a death create a risk that other deaths will occur, and in their opinion, actions should be taken to reduce or eliminate that risk they can issue a *Prevention of future deaths* report to the person they believe may have power to take such action.

In recent years notable *Prevention of future deaths* reports have been submitted in respect to deaths that occurred in river fords due to signage issues[bb] and communication issues between responding agencies[cc]. In his ruling on the death of Heike Mojay-Sinclare in 2018, the coroner expressed concern over the lack of mandatory regulations in respect to the risk management and maintenance of *permanent* signage (i.e. gauge boards) at fords.

> *"The inquest heard that river fords and depth gauges do not currently lie within mandatory highways inspection requirements and therefore there is no guarantee of their maintenance and review, and therefore no guarantee that they continue to provide on-going usability and safety"bb*

Following the death of Russell William Sherwood, the coroner found deficiencies in inter-agency communication in respect to *emergency* signage:

> *"The evidence revealed that having rescued a motorist from flooding, at a time when the flooding continued to pose a risk to life, the Fire Service Unit departed the scene before the Highways authority arrived and without closing the road or leaving any warning signs."*[ccdd]

Whilst these are only two incidents[ee] that have occurred against a background ten-year average of ~1,600 deaths per year being recorded on UK roads (Appendix 3)[ff], the projections

[bb] Footnote: https://www.judiciary.uk/wp-content/uploads/2021/09/Heike-Mojay-Sinclare-Prevention-of-future-deaths-report-2021-0313_Published.pdf
[cc] Footnote: https://www.judiciary.uk/wp-content/uploads/2017/08/Russell-Sherwood-2017-0192.pdf
[dd] Footnote: it has been pointed out to the author that in Scotland it is currently only the Police who hold the legal power to close roads.
[ee] A desk analysis of news articles related to deaths at river ford crossings suggests that seven incidents involving nine deaths have occurred between 2012 and 2024, including one fatality that occurred during Storm Bert (23/11/2024) and one during Storm Darragh (09/12/24), which were reported as this report was undergoing peer-review.
[ff] Footnote: https://www.gov.uk/government/collections/road-accidents-and-safety-statistics

for increased river flows resulting from high intensity rainfall could be said to indicate a need to increase the safety of crossings or at least to review the legislation and regulations.

It is inappropriate to comment on the ongoing coroner's inquest relating to the two deaths in the Liverpool underpass. However, it is clear that the combined bridge/underpass asset constituted a complex structure, where the split of drainage responsibilities will likely be found to be equally complex (i.e., Network Rail Bridge, local roads passing beneath, and a series of assets owned and operated by the local water company). Accordingly, this should highlight the fundamental importance of multi-stakeholder communication in respect to these types of structure, to ensure that shared understandings of risk and risk management responsibilities are agreed and do not slip through a gap. We shall return to the issue of flooded underpasses in Section 4.2.

River fords and underpasses are not, however, the only highway features that may present increasing risk to life in the future if not sufficiently managed. In April 2018 Jordan Pry died after losing control of his vehicle on the M25. In his *Prevention of Future Deaths* report for this incident the coroner identified "*a long and significant history of aquaplaning incidents at the location, including a previous similar fatality*"[gg].

The coroner found that despite some changes made to drainage at the location, a contributory 'flat spot' in the carriageway remained. He also found that the development of a comprehensive risk management plan for the location was dependent on a decision being made by the operator. This decision was still awaited at the time of the inquest, nearly five years after the original incident.

Following the death of Ryan Taylor on the A390 in Cornwall in March 2019, the Prevention of Future Deaths Report identified that surface water flows converging and running over the road had directly contributed to Ryan's death. As with the Pry case too, this hazard had been reported to the authority previously. Following this fatality, drainage works, costing £370,000, were undertaken to negate the risk.

Similar findings have been made in respect to at least three other deaths linked to aquaplaning on surface water in separate incidents around England[hh]

Tragedies have occurred in other ways too. The deaths of Peter Harnwell in May 2018, Annie Hall in November 2019 and Peter Pelling in October 2023 all occurred as a result of their vehicles being driven, not through fords, but simply along roads submerged under deep and/or fast flowing flood water. Whilst no prevention of future deaths recommendations were issued in these cases, the tragedies do remind us of the potential risk to life presented by any stretch of road that is known to flood.

Finally, in respect to emerging extreme flood risks, we need to talk about coastal flooding. Whilst climate change is generally associated with changing coastal flood risk in respect to relative sea-level rise—which is occurring at an accelerating rate—the principal danger from coastal flooding during extreme events comes from the power of wave action, particularly during storm surge events[28].

In relation to cost, the most recent extreme coastal flooding event affecting large parts of the UK coastline occurred in 2013, when the best estimate for the recovery funding directed

[gg] Footnote: https://www.judiciary.uk/prevention-of-future-death-reports/jordan-pry-prevention-of-future-deaths-report/
[hh] Footnote: These were the deaths of: Josie Archer-Smith, 22yrs (Oct, 2020); Harvey Blount, 18yrs (March, 2021); Natalie Doherty, 33yrs (Nov, 2021)

toward the remediation of damage and disruption caused to the road network by coastal flood effects was £70m[29].

In respect to risk-to-life, the power of waves and the dangers they represent for users of the local road network has been graphically demonstrated on numerous occasions. This includes the tragic deaths of five people on South Uist, after two cars were washed off a single-track road into the sea during a storm in 2005[ii]. More recently, there was also the 'near-miss', at Newgale, Pembrokeshire, when ten people required rescue from a bus after it was struck by a large wave and incapacitated in February 2014[jj]. As sea levels continue to rise and coastal storms become more intense, we are going to need to better understand and adapt against these flood hazards too.

The Climate Change Risk Assessment (CCRA3) has identified that the length of *major* roads (i.e., A class and motorway) located in areas exposed to flooding more frequently than 1:75 years (on average) increases in the 2080s by between 41% and 120% from the current baseline of 2,400km, under the 2˚C and 4˚C emissions scenarios respectively. However, CCRA3 gives no assessment of either the current or projected levels of exposure of *local* roads to climate risks[30]. This potentially creates a moral hazard, where knowledge in respect to the condition and resilience of *major* roads is mistaken for knowledge in respect to *all* roads: thus, the increasing need to ensure the resilience of local roads is more easily overlooked.

With the publication of its latest NaFRA review[18], the Environment Agency has reduced this moral hazard somewhat—in respect to England—by including analysis of the flood exposure of local roads. The figures are sobering. The analysis found that "*around a third (38 %) of all roads are in areas at risk from one or more sources of flooding*"[p.5]. However, with climate change projections the road network in areas at risk rises to 46 % by mid-century, representing an increase of 21 % above current exposure (Table 1).

In summary, if the prevalence of extreme weather events is to increase, then it is becoming clear that the sector should commence a parallel quantification and adaptation process to recognise, risk assess, and manage known flood hotspots (i.e., fords, underpasses, low spots: all sites exposed to surface water, river, and coastal flooding), primarily to reduce risk to life, but also to avoid reputational harm by preparing for potentially increased levels of litigation.

Recommendation 3: DfT and the professional bodies should commission a review, led by UKRLG, on whether the legislation and regulations in respect to flood water management and safe use of highways in flood conditions (e.g., warning signage) are fit for purpose.

[ii] Footnote: https://www.theguardian.com/lifeandstyle/2015/oct/10/south-uist-storm-tragedy-10-years-on-peter-ross
[jj] Footnote: https://www.bbc.co.uk/news/uk-wales-26005597

A.	Present day (km)	Present day % of total	With climate change (between 2040 and 2060)	With climate change (between 2040 and 2060) % of total at risk	% change with climate change (between 2040 and 2060)
Roads	113,900	37.7 %	137,700	45.6 %	20.9 %

B.	High risk (%)	Medium risk (%)	Low risk (%)	Very low risk (%)	Total risk (%)
Roads	12.3 %	5.9 %	15.9 %	3.6 %	37.7 %

Table 1: A.) Road infrastructure in areas of flood risk from rivers, sea and surface water – present day and with climate change, and B.) present day as percentage, by level of risk (Source: Environment Agency, 2024: p.31)

Two measures that bear direct scrutiny in respect to councils' ability to manage hotspot flood issues are their proactive drainage inspection regime and their reactive ability to respond to warnings of imminent weather events.

The *Hazards* survey asked a question about each of these measures.

3.1.4 Inspection regimes

Respondents were asked to describe their current drainage inspection regime (Figure 9).

Overall, 19% of respondents stated that they operate a purely reactive regime. This suggests that, in these authority areas, drainage issues will be dealt with as they are reported (i.e., as they become a problem for the public), rather than through proactive management. The risk with this approach is that drainage assets will likely become less effective through lack of maintenance, thus requiring higher (more costly) levels of intervention when they do become an issue.

The Code of Practice recommends: "*Drainage assets should be maintained in good working order to reduce the threat and scale of flooding. Particular attention should be paid to locations known to be prone to problems, so that drainage systems operate close to their designed efficiency*"[31, p.55]

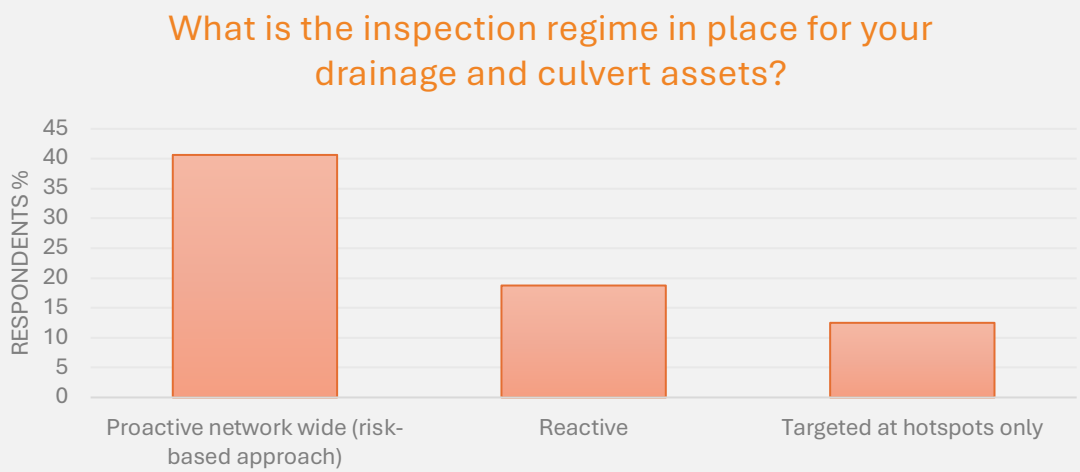


Figure 9

This recommendation appears to inform the 13% of respondents who have adopted a 'hotspots only' targeting regime. These authorities have apparently developed a process for identifying where the chronic flood hotspots are on their network and are focusing on managing those only. This suggests that maintenance of other drainage assets may be left until issues start to occur when, it is assumed, they too would be subject to an appropriate proactive cleanse or added to the hotspot inventory.

The final 41% of respondents indicated that they adopt a risk-based approach to drainage management. This mirrors the Code of Practice which recommends that a risk-based approach should be adopted "*for all aspects of highway infrastructure maintenance, including setting levels of service, inspections, responses, resilience, priorities and programmes*"[31 p.55].

The Code also says that a "*risk-based approach to highway maintenance needs to be founded on information that is sufficiently robust to enable decisions on levels of service to be taken and reviewed over time*" [p.12].

Following the Code, authorities that have adopted a risk-based approach to their inspection regime should have considered risks in respect to network safety, serviceability and sustainability and should have the basic condition data required to inform maintenance programmes. If applied correctly a risk-based approach will identify deficiencies which, if untreated, are likely to adversely affect long term performance, serviceability, and safety on the network. In effect a risk-based approach should identify hazard hotspots very effectively, making their reporting very straightforward. Yet, of all the survey respondents only two provided information that suggested they had a precise (easily interrogated) dataset of individual flood incidents on their networks, which went beyond a cursory "*Storm Babet affected the whole [County] culminating in a major incident being declared*."

3.1.5 Dynamic flood response

Respondents were asked whether they had processes in place to respond reactively to Red, Amber, and Yellow, weather warnings (Figure 10). In effect, this question was asking if the respondents had a process in place to receive and react to the Flood Guidance Statements (FGS) which are issued by the Met Office *Flood Forecasting Centre*[kk] in Exeter[ll].

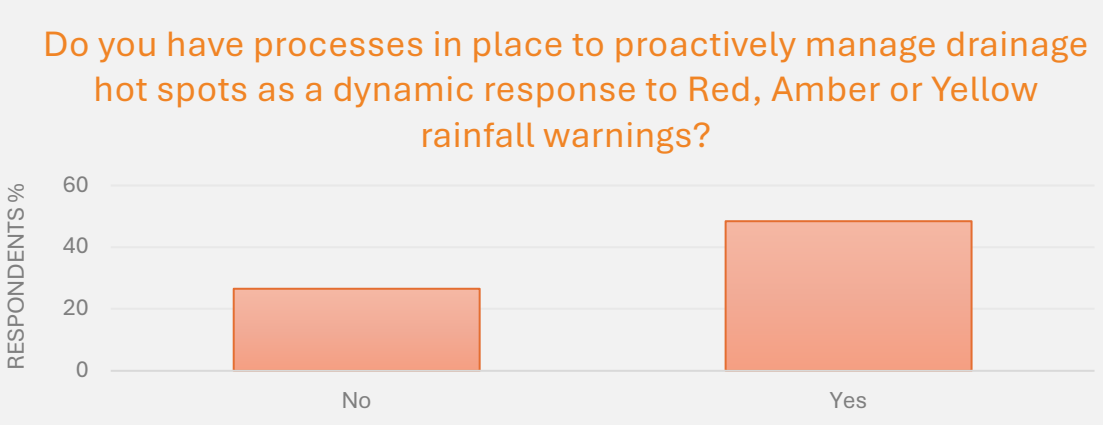


Figure 10

The daily FGS shows the forecast level of flood risk for the coming 5 days for surface water, river, groundwater, and coastal flooding. It uses a detailed risk matrix approach based on a combination of likelihoods and impacts and provides these forecasts at a local authority scale.

As Category 1 responders, Local Highway Authorities are entitled to receive the daily FGS, which provides the FCC's reasonable worst-case scenario, which indicates...

- the forecaster's assessment of the upper range of rainfall, river or groundwater levels or coastal conditions and impacts that may occur
- situations that could cause flooding, threaten communities and pose a risk to lives and livelihoods

If there is sufficient risk of potential impacts, the FGS will provide Red, Amber, or Yellow, warnings dependent on the predicted risk (risk = likelihood x impact).

The FGS has become a fundamental part of Local Resilience Forum (LRF) partnerships' ability to create shared situational awareness in respect to imminent extreme weather affecting their areas. The FGS, complemented with additional analysis and input from their local Met Office Civil Contingencies Advisor[mm] will provide the LRFs with the intelligence and the basis needed to identify whether multi-agency Tactical and Strategic Coordinating groups should be set up to manage an event. If Highway Authorities are not structured to act proactively on FGS weather warnings (e.g., tasking gully suckers to clear hotspots), there is a

[kk] Footnote: https://www.gov.uk/government/organisations/flood-forecasting-centre
[ll] Footnote: It is acknowledged that the Environment Agency (England), NRW (Wales), Northern Ireland (DfI), and SEPA (Scotland), provide flood warnings to their LRF and Strategic Coordinating Group (Scotland) partners. However, the focus of this section is on weather-forecast monitoring, interpretation, and decision-making within local highway authorities, so this analysis centres on the role of the Met Office.
[mm] Footnote: https://www.metoffice.gov.uk/services/government/environmental-hazard-resilience/civil-contingencies-advisors

risk that their operations will be completely reactive. In effect, highway issues during incidents will likely be dealt with as they are reported, rather than in a risk-based manner.

Figure 7 indicates that whilst 48% of respondents had processes in place for responding proactively to Flood Guidance Statement warnings (Box 2), 27% did not.

Box 2: Examples of respondents' dynamic strategies for Red, Amber or Yellow rainfall warnings

"Critical asset cleaning regime in place; clearance of trash grills and high priority gullies when severe weather events are forecast. Severe weather plan to activate reactive plan, this can include sending personnel (spotters) to report back from known flooding hotspots."

"In receipt of adverse weather reports, including Red, Amber or Yellow rainfall warnings additional staff are placed on standby, vehicles and plant availability secured in advance, all trash screens to watercourses placed on routine cleanse throughout period. Known hot spots for potential surface water flooding placed on routine scout for any required action. Depending on severity and warning type, local suppliers of additional plant/pumps contacted in advance for any call off requirements. Internal protocol in place to alert EMRT if required, in collaboration with the E/A and FIDO and local Housing Authority"

We deploy "Strategic Flood Alliance Drainage Rangers"

Revisiting the 19% of respondents who indicated they operated a *reactive* inspection regime, it could be expected that these authorities, particularly, would seek to have access to and to use FGS information. However, cross referencing the responses to these two questions (i.e., regime and warnings) reveals that only 50% of the respondents using the reactive approach also had processes in place to proactively react to Red, Amber and Yellow warnings (Table 2).

The fundamental point here is, that where authorities are not using the FGS to inform their incident preparedness, what are they using? Do they actually have a preparedness strategy, are they purely reactive, in effect, completely dependent on customer calls or on decisions made by LRF partners or their LRF partnership?

Regime	Receives FGS	%	Freq
Reactive	Yes	50	6/12
Risk-based	Yes	65	17/26
Hotspots only	Yes	75	6/8

Table 2: Respondents' drainage regime against Proactive measures in place to manage drainage hotspots during Red, Amber, Yellow warnings

This concern is informed by direct conversations with several suppliers of bespoke weather services (e.g., MetDesk, MeteoGroup). In which the general opinion was expressed that highway authorities only really used these commercial weather forecast services to inform their winter service arrangements and decision making (i.e., "Is it going to freeze tonight?").

However, even if authorities' are using alternative weather forecasts for their flood information, their partner agencies will be using the FGS to inform their own decision making, so the use of alternatives still risks a lack of coordination, which could introduce confusion into multi-agency decision making (e.g., "*Our forecast says* [...], *but the FGS says* [...], *what should we do?*").

Aside from flooding, the commercial weather forecasting products do work extremely well for snow and ice forecasting and have been integrated into several suppliers' climate-zone and route-based forecasting products (Figure 11).

These products can provide clients with much higher resolution intelligence than is available from the Met Office[nn], but as Figure 11 illustrates, only 33% of respondents reported investing in either Route-based or Climate-zoned weather products (whilst a single authority uses both).

Yet even with this relatively low take up, according to the suppliers, these services are generally only used over the six months of autumn/winter and are then switched off. This 'saves' councils some money. However, by focusing solely on snow and ice and winter-forecast interpretation skill sets, there appears to be a lack of appreciation that as all types of weather hazard are predictable to an extent, and they can impact on highways at any time of year (e.g., albeit heatwaves do not occur in winter, nor snow storms in summer), these services could be redesigned such that they could be used to support highway team decision making and *shared* situational awareness against a range of extreme weather hazards.

[nn] Footnote: NB. These products tend to reanalyse Met Office data and enhance it using data derived from locally situated sensors

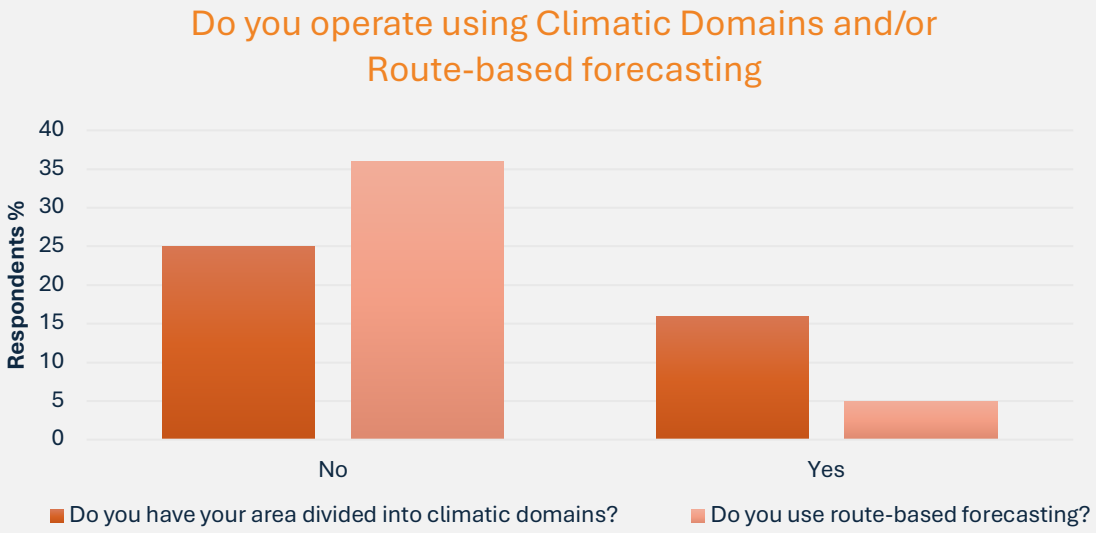


Figure 11

Used this way, it can be seen that the combination of appropriately trained highway managers', able to interpret high-resolution weather forecasting, and their levels of *transferable* local knowledge in respect to 'lifeline' vulnerability and criticality, access issues, and cascade risks, *if recognised* and *empowered* could transform the way that both highway authorities and their LRF partnerships respond to all types of extreme weather events.

In respect to heatwaves, such expertise would also inform the importance of all-year contingencies. For example, whilst DLOs with fleet to hand are likely to be able to deploy gritters to spread sand on heatwave affected asphalt at short notice, term contractors may not have been encouraged, or contractually expected, to develop these contingencies (i.e., gritters may be parked up for the summer period). Having a cohort of all-weather hazard trained decision makers, who appreciate the increasingly 24/7/365 nature of their role, should translate directly into better contractual arrangements and emergency contingencies (because these people will be thinking about, talking about, and planning more openly for the various risks).

Returning to flood forecasting, following the circulation of the *Hazards* survey the Flood Forecasting Centre commenced a trial to test its ability to provide weather warnings with 0 to 6-hrs notice of impact (i.e. rather than 1 to 5 days). *Rapid Flood Guidance*[oo] (RFG) statements were issued between 14th May and 30th September 2024, where Met Office forecasters suspected that flooding would:

- ...start within 6 hours of rain
- ...cause water to get trapped in urban low spots, overflow drains, and/or flow from small streams and rivers

This RFG pilot was undoubtedly a significant evolution from the type of dynamic forecasting and warning products that were available during the devastating Boscastle floods of twenty years ago[pp]. That flood was exactly the type of short notice event that the RFG has been

[oo] Footnote: https://www.gov.uk/guidance/rapid-flood-guidance-service-trial-user-guide
[pp] Footnote: https://www.bbc.co.uk/sounds/play/p0jjp4kb

designed for: to extend the critical lead time needed for responders to activate plans, warnings, and contingencies. The RFG programme, if adopted, could genuinely save lives and significantly reduce harm.

However, in order achieve the potential of *Rapid Flood Guidance* messaging, Cat 1 responders need to have processes in place to allow them to respond to the messaging, fast. Sadly, given that around 50% of respondents report not having procedures in place to convert a 1-to-5-day *Flood Guidance Statements* into proactive action, it appears that very few would currently be able to respond effectively to a 6-hour notice *Rapid Flood Guidance* notification. Here again, framing highways as lifelines elevates the importance of highway authorities stepping fully into their Cat 1 responder role, creating an imperative to develop these critical response processes and procedures.

So, to summarise this topic, the surest way to build the sector's status as an engaged partner in multi-agency integrated emergency management is for highway authorities to *adapt* their institutions away from the currently widespread reactive (catching up) approaches to extreme-weather emergency management, to fostering an intelligence-informed proactive (getting ahead) approach to hazards and hazard hotspot management.

Understanding the power of the nationally recognised *Flood Guidance Statement* and more recently trialled *Rapid Flood Guidance* weather warnings and developing training and exercising procedures to embed them directly into each authority's operational decision-making processes should be regarded as representing a critically important quick-win climate adaptation and resilience initiative.

Recommendation 4: UKRLG to lead sector bodies in a collaboration with the Met Office to develop principles and techniques for consistent and more location specific geographic domain and weather hazard forecasting for application in extreme weather planning and response

3.1.6 Landslides and other Mass Movement

Reports of landslides, debris flows and rockfalls have been associated with extreme rainfall events[qq]. Water loading of slopes can result in slope failure in engineered embankments or natural slopes. The Climate Change Committee has suggested that there "*are implications here for the more rural areas of the UK where there is inherently less resilience in transport systems due to less dense infrastructure (i.e. single train lines). This is especially relevant where linear transport infrastructure frequently follows natural features such as steep sided river valleys prone to landslide risk*"[41 p.75].

Recent examples of significant landslides affecting roads include the collapse of a hillslope above the A816 at Ardfern in Argyll and Bute, which deposited ~15,000 tonnes of debris along a 200m stretch of road. What is interesting about this event, is that whilst the comprehensive Scottish Road Network Landslide Survey (SRNLS)[32] provided a good overview of debris flow hazard for Scotland's Trunk Road network, the exact location of this event on the local network had not been previously identified as having a significant hazard potential. Whilst the same methodology *could* be used to assess local network vulnerability it relies on national scale data and not detailed surveys specifically being carried out at a site. To

[qq] Footnote: https://www.bgs.ac.uk/geology-projects/landslides/landslides-and-rainfall/

illustrate this point using Ardfern, desk-based analysis indicates an average 'B' susceptibility[rr] rating is presented for this slope, with small (50m grid cells) pockets of higher potential in the area.

This example alone provides a clear illustration of the importance of understanding that relatively coarse resolution analyses of this type can *guide* our understanding of geological hazards but can also *hide* information in respect to elevated risk at specific locations. The point to take from Ardfern, is that there are many other locations along our network where generalised mapping of landslide susceptibility may be masking a very real potential of a significant landslide occurring in the 'right' (e.g., climate-change enhanced) conditions. Accordingly, there is always a need to develop contingencies for such an event, rather than become complacent that only those areas with known and fully surveyed susceptibilities represent an area's entire high-risk portfolio.

The Welsh Government has commissioned a landslide project to ascertain whether live rainfall data, combined with near-future rainfall forecasting, can be used to alert regional safety patrols of an elevated risk of slope failures within/adjacent to a broad range of infrastructure assets[33]. Phase 2 of the project analysed landslides reported on the strategic and local road network between Sept 2022 and March 2024[34].

The project identified a total of 26 events during the period, with an average of two to three significant events occurring through the autumn/winter periods: a frequency that indicated a general trend of increased landsliding being related to higher levels of seasonal precipitation. However, these events were not being identified as a problem because Local Authorities were tending to simply deal with events as they occurred. Accordingly, to both increase our understanding of the cumulative effect of landslide impacts and our ability to study them, the project recommended the creation of a substantive national landslide inventory and data collection methodology[ss].

Further landslide incidents of note include:

- the £3.5 million damage on the B6343 in Northumberland,
- the *circa* £8m total cost of repairing the A40 Brecon and A40 Sennybridge,
- the on-going repair of the B5605 at Ruabon, Wrexham County, and
- the chronic landslide hazards being managed along the A83 Rest and be Thankful in Argyll, and A57 Snake Pass in Derbyshire.

Other causes of ground instability are also affected by extreme weather conditions. Transitions from drought to wet affecting the clays and 'mudrocks' of predominantly south-east Britain cause the swelling and shrinking of expansive soils that are regarded "*as the most damaging geohazard in Britain today*" [tt].

In respect to shrink–swell soil hazards, collaborative research by Lincolnshire County Council and the British Geological Survey (BGS) has found that the shallow foundations of the county's rural evolved roads increase their vulnerability to movement, with a direct relationship between road condition and geohazard susceptibility being demonstrated. The

[rr] British Geological Survey (BGS) landslide susceptibility analysis uses A (low) to E (high) categories, where a high susceptibility score of D or E indicates that the ground conditions imply a significant potential for future instability via down slope movement of material.
[ss] Footnote: the Motts project collated landslide information from a range of sources, including: BGS; Traffic Wales; reports to Motts by Transport for Wales and Local Authorities; media and social media reports.
[tt] https://www.bgs.ac.uk/geology-projects/shallow-geohazards/clay-shrink-swell/

research found that compressible ground has a greater correlation with road damage than originally considered.[35]

In light of these examples, the applied research, and the correlation between extreme weather and these geological hazards, respondents were asked if they had experienced mass movement effects on their networks during 2023 (Figure 12). Of the whole sample only 23% answered that they had. However, when a sub-sample of respondents who could loosely be defined as belonging to the 'Pennine 17' authorities was analysed the positive response rate went up to 55%[uu].

As with flooding, is it possible that the unequal distribution of these hazards across the nation is creating inequitable opportunity costs for those authorities needing to manage them?

This question can only really be answered through applied research, so it has been good to see that the BGS is keen and willing to work with the sector. For example, by making hazard mapping products available (e.g., GeoSure[vv] for ground movement and GeoClimate[ww] for the projection of potential geohazard change under climate scenarios).

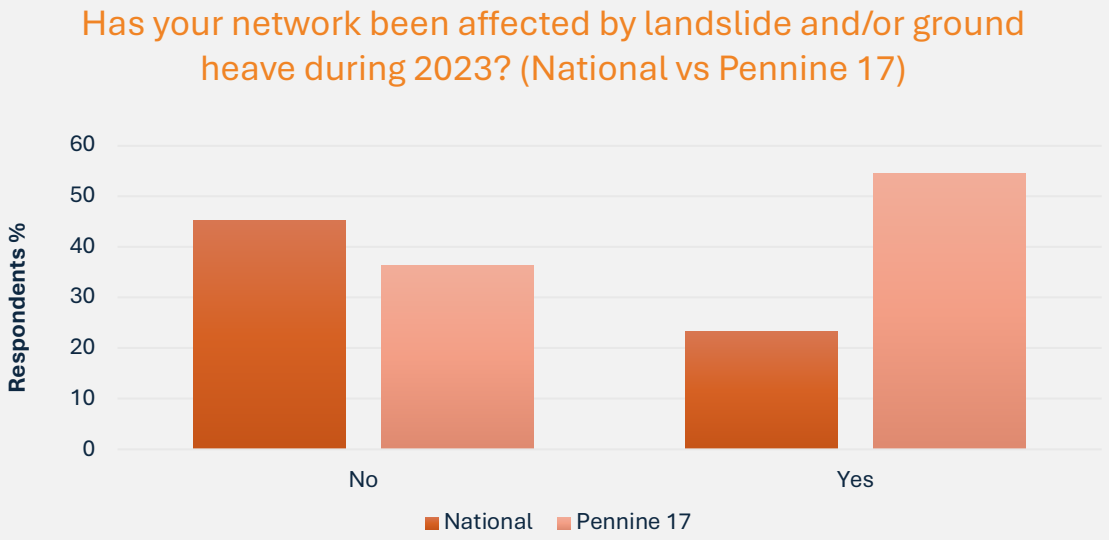


Figure 12

However, due to the current BGS commercial funding model within DSIT, the open versions of these datasets are of relatively coarse resolution. Councils are required to pay for the higher resolution versions. These are more precise, but large numbers of map tiles are required to facilitate analyses to be useful in describing linear network vulnerabilities: this drives up cost.

[uu] Sub-sample comprised a total 10 responses out of the 17 Pennine Authorities
[vv] https://www.bgs.ac.uk/datasets/geosure/
[ww] https://www.bgs.ac.uk/datasets/geoclimateukcp18-open/

So, with this model, appropriate budgets or research funding streams need to be made available so councils can access the best BGS data and expertise. Yet some smaller councils with significant hazard exposure, may struggle to justify this type of expenditure. If so, their ability to understand vulnerability to geohazards will be reduced.

Does the sector accept that many authorities are likely facing an increasing vulnerability to geohazards? If so, are the lead bodies prepared to request that DfT and DSIT consider creating more funding opportunities through which to actively explore these projections or, given the lifeline importance of the highway network, that they consider making more of these products available as open data?[xx]

Reassuringly, from this perspective, BGS has awarded a grant to support the *National Infrastructure Vulnerability Assessment for future Risks* (NIVAR) project[yyzz]. This project will shift BGS traditional modelling of risk related to building and structures to create a methodology for analysing the geohazard vulnerability of linear infrastructure[aaa].

Recommendation 5: As part of an update of the *Well-Managed Highways* code of practice, UKRLG should work with the British Geological Survey (BGS) and relevant Local Highway Authorities to assess and define the data and insight on highway network geohazards that should be consistently collected and shared by Local Highway Authorities as a matter of course.

[xx] As part of this sector review, the author attended a one-day event at the BGS in Nottingham with the Chair of the UK ABC Board. The day was focussed on better understanding the key areas of risk and current learning as well as sector gaps in understanding or application of knowledge. Thanks are expressed to Katy Freeborough and her BGS colleagues in providing context, insight and possible future opportunities for sector collaboration.
[yy] Footnote: this is the same team that is working on developing *Route Specific Earthworks Resilience Plans* for the SRN.
[zz] NIVAR is supported by East Riding, Lincolnshire councils.
[aaa] Footnote: it may also be interesting to consider the work currently being conducted by AtkinsRéalis and the South Wales Trunk Road Agent (SWTRA), to translate the use of Atkins' *Washout Vulnerability Tool* from its original rail focused development to the strategic road network.

3.1.7 Innovations

NUAR / CReDo as resilience enablers

One of the main survey questions in respect to resilience innovation related to respondent's take up of the National Underground Asset Register (NUAR)[bbb], which is currently being rolled out as an operational tool across England, Northern Ireland, and Wales[ccc] (Figure 13).

Although the NUAR (and Scotland's more established VAULT) digital maps of underground pipes and cables were initially designed around a 'safe dig' use case (i.e., to reduce accidents during excavations), their value in providing a means to understand interdependency risks has recently increased following responses to a consultation exploring additional use cases for the system.

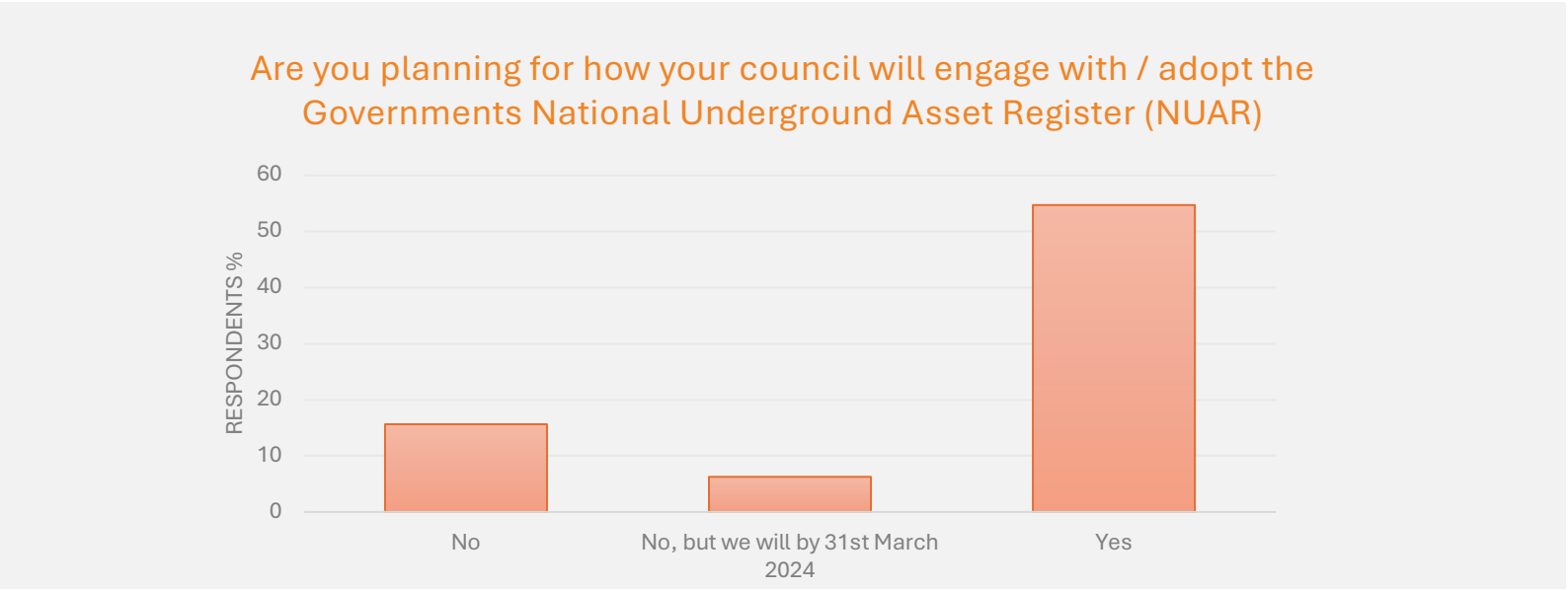


Figure 13

Both the 2014 *Transport Sector Resilience*[4] and *Lessons* reviews identified the issues in respect to bridges and other highway structures acting as key lifeline 'bottlenecks' (Plate 2), where multiple services are hosted within potentially vulnerable structures (e.g., the collapse of Tadcaster Bridge during Storm Eva disrupted gas, electricity, water as well as the fibre supporting of the emergency services' Airwave communications network).

The *Transport Sector Resilience* review specifically recommended that consideration should be given to identifying 'single points of failure' on the strategic networks which if broken could "*leave parts of the country at risk*". What the experience of extreme events since 2014 has certainly shown us, however, is that the interdependency risks associated with the failure of 'bottleneck' assets on the highway are not situated solely along on our strategic networks. Local road structures are carrying increasingly important infrastructure. Neither are national risks the only metric that should be considered: significant impacts can be experienced very locally when lifeline assets fail.

[bbb] Footnote: https://www.gov.uk/guidance/national-underground-asset-register-nuar
[ccc] Footnote: Scotland operates the separate VAULT system

In effect, 'lifeline bottlenecks' have been identified as carrying increasing levels interdependency risk[ddd]. Yet, these risks are not being sufficiently quantified[36].

Plate 2: Elland Bridge Calderdale during its reconstruction following Storm Eva. Note the multiple aligned service conduits being built into the 'bottleneck' structure. (Image courtesy John Lamb, 2017)

In its review of *Progress on adapting to climate change*[37] the Climate Change Committee recognised that even within organisations tasked to report under the Climate Change Act *Adaptation Reporting Power* (i.e. National Highways and TfL in respect to highway infrastructure), the understanding of interdependency risk was too low.

> *"While almost all reporting organisations commented on their sources of interdependency risk, detailed mapping of specific interdependencies and incorporation into climate risk assessments and adaptation plans is a critical gap. [...] The scope needs to be broadened, including* ***local roads*** *and key supply chain organisations."*[p.183]

Accordingly, whilst resilience and interdependency risks are not yet a substantive NUAR (VAULT) use case, the fact that 61% of respondents are already engaged with the project suggests there is already a foundation from which to encourage the sector to start to work with a broad range of service owners and operators to develop these much-needed methods

[ddd] Footnote: Interdependency risks are defined by the CCC as: *risks that arise from an organisation's reliance on another organisation or sector*. Whilst highways may not always be dependent on the services buried beneath their surface (notwithstanding cabling to power streetlights, etc.), the pipes and cables that carry those services are dependent on the highway retaining its structural integrity during extreme weather events.

for mapping, risk assessing, monitoring, and managing these assets from an integrated 'lifelines' perspective.

The methodologies underpinning the development of these registers has been encouragingly collaborative and genuinely groundbreaking. As a result, they allow consistent information about underground assets' location, type, and ownership to be shared with partners more efficiently than ever. As well as use in planning, if used to their full potential, these registers could provide detailed intelligence to support post-incident highway Rapid Impact Assessment processes and procedures (Appendix 4). This would undoubtedly enhance the *Situational Awareness* of highway managers during major incidents and allow them to feed substantive insights on lifeline-affecting risks directly to the decision makers in the multi-agency information cells and incident coordinating groups.

Whilst this alone would be transformational, in respect to the aspects of preparedness and risk prevention these registers have not been designed to support the type of pre-event criticality analysis that should underpin the prioritisation of which structures should be the most resilient to hazard effects (i.e., the registers will identify and provide the contact details for owners for all affected assets but further steps are required to quantify the wider potential consequences of those assets' disruption).

Here a separate project may be offering insight into the considerable added value that might be achieved by combining digital twinning with the underground registers. Although in early stage, the UKRI-funded Climate Resilience Demonstrator (CReDo) describes itself as *"a pioneering climate change adaptation digital twin project that provides a practical example of how connected data can improve climate adaptation and resilience across a system of systems."*[eee]

Thus far, the CReDo team has focused on mapping water, energy and telecoms infrastructure interdependencies, to showcase the advantages of combining data and insights across sectoral and organisational boundaries. If the CReDo approach were to be supported in respect to developing a collaborative and secure process to identify and assess the criticality of 'bottleneck' highway structures, this would go a long way toward moving the sector from its traditional focus on the single dimension of road surface condition, to raising its profile as a key partner in understanding the three-dimensional space where the co-development of effective impact prevention, response, and recovery procedures are essential in ensuring the resilience of the nation's 'lifeline' infrastructure.

Recommendation 6: DfT should work with MHCLG / UKRI to extend the remit of the CReDo project and apply it to local highway sector. Defining the scope / nature and brief would be a logical first step to understand and describe the logic and locus of highway asset criticality assessment, and with it provide a compelling case to fill what is clearly a sector void in understanding and application.

[eee] Footnote: https://digitaltwinhub.co.uk/climate-resilience-demonstrator-credo/

Returning to the level of disruption caused by mass movement events—as opposed to the transient effects of winter snow and ice hazards—two further factors need to be considered from the perspective of the resilience domain.

The impact of extreme weather can be described by the equation:

$$\text{Impact} = (\textit{damage} \times \textit{consequences}) \times \textit{duration}^{\text{of effect on user communities}}$$

For mass-movement related impacts to highway structures (e.g., slope failure, bridge scour), reducing the duration of effect becomes the greatest challenge, i.e., a collapsed road takes more planning, technical capability and resources to stabilise and repair than gritting or ploughing ice and snow. This means that affected communities will be experiencing the impact of the originating event for a longer duration.

Taking a resilience perspective, in order to reduce the time needed to *Recover* lifeline roads affected by a range of hazards more *Rapidly*, there is a need for two types of *Resourcefulness*. Councils and operators need to be able to:

1) ...prioritise and deploy suitable capabilities (e.g. technical geophysics and engineering expertise; debris removal) efficiently. NB. This requires consistent and effective Highway Rapid Impact Assessment.
2) ...access, operate on, and engineer (if required) the land adjacent to the damaged asset

Highway Rapid Impact Assessment (RIA) can be defined as assessments undertaken within the first 8 to 48hours of an emergency. Its purpose is to obtain a quick, broad, and consistent picture of the extent of the impact on the highway network's *lifeline* functionality.

This is done to:

- Create Shared Situational Awareness and Common Operating Picture
- Determine *defensible* initial response and stabilisation activities
- Prioritise and direct the initial distribution of resources and capabilities
- Serve as a precursor or first step to more technical investigations, e.g., detailed structural assessments

Highway Rapid Impact Assessment (RIA) provides the evidence incident managers require to make *defensible* decisions in respect to which damaged assets need to be prioritised over others for the deployment of the finite available capabilities and resources needed to carry out stabilisation and repair works.

If it is being conducted consistently across the country, RIA creates the crucial levels of Shared Situational Awareness (SSA)—from local coordinating groups up to the Lead Government Department—which are required for effective decision making and for the active coordination of assistance needed to deliver the stabilisation and repair activity: including the negotiation of mutual aid support. Consistent RIA also offers a concrete basis upon which decisions in respect to the emergency grants (e.g.) from a re-formalised *Wet weather funding/flood resilience* and/or *Bellwin Scheme* budget could be equitably distributed.

When framed as a potential institutional adaptation, the combination of risk-based asset management—informed by state-of-the-art warnings and a consistent Rapid Impact Assessment method/system—offers the type of quick win that could elevate the sector to a position of leadership as the principal lifeline infrastructure manager during emergencies[36].

Once work is prioritised, the ability to draw and deploy sufficient capabilities effectively is greatly increased if council and operators' contracts with the suppliers of these capabilities contain pre-emptive 'call off' clauses. Such clauses need to acknowledge the urgency of recovery operations, accept the fact that recovery operations will carry a price premium (e.g., capabilities drawn from distance will inevitably cost more than business-as-usual), and have the flexibility to accommodate these factors in advance.

Beneficially, the *process* of negotiating these clauses—in 'peacetime'—raises the potential for their operational use in the respective parties' minds and encourages them to think *in advance* about how these things will work if/when required. In addition to the need to repair highway assets, the provision of site clearance capabilities will also likely fall to highway authorities[38]. Lessons from storms, particularly Desmond and Eva, also illustrates the need for substantive contingencies to be developed in respect to significant bridge losses. Box 3 discusses the DfT / Highways England *Temporary Bridges* Portal initiative, whose development reached a key testing stage but then appears to have stagnated.

In respect to land access, recent examples demonstrate that the restoration of community lifeline connections can be delayed by third parties contesting access to the site. This occurred at Tadcaster Bridge following Storm Eva. It has also been a defining factor in the ongoing negotiations around the repair of the partial collapse of the A226 at Swanscombe[fff], which whilst not extreme event related *per se*, clearly demonstrates the challenge.

Given the significant lifeline nature of many hazard-vulnerable road links and key assets, is it time for DfT to consider sponsoring a change in law which gives highway owners and operators greater 'step-in' access powers?

[fff] Footnote: https://www.kentonline.co.uk/dartford/news/at-long-last-full-investigation-to-finally-start-on-collaps-306788/

Box 3: The DfT / Highways England *Temporary Bridges* Portal

Following the loss of significant bridge structures during extreme weather events (e.g., Workington, Tadcaster, Pooley Bridge, Elland), DfT and the then Highways England, started to develop a web-based portal to support bridge owners looking for urgent bridging solutions. This work was conducted under the mission statement:

> *"To better serve the public by reducing the time it takes to procure temporary bridge solutions in case of extreme weather conditions as well as to encourage innovation from temporary bridges suppliers by creating a centralized marketplace for bridge owners to find fit-for-purpose approved solutions and connect them with approved suppliers"*

However, although the portal got to beta-testing stage in 2020, it has yet to go live. It has been suggested this was because either DfT was unable to secure a platform to host and manage the information or was unable to reach agreement with temporary bridging companies as to how they would keep their data and stock up to date.

Whatever the reason for this initiative's stagnation, if we apply a lifeline perspective, we need to acknowledge the critical importance of some bridges to the communities they serve (i.e., their primary lifeline role in providing connectivity for work, school, shops, etc.). Combining this with the length of time it can take to bring a collapsed bridge back into service—when compared to other assets—we can see the stagnation of the *Temporary Bridges portal* initiative as a failure of a potentially useful opportunity to build resourceful resilience against a future where more bridges are likely to be lost to intense extreme weather.

It should not be forgotten, that a key lesson that can be taken from the way bridge failures were dealt with in Cumbria following the 2009 and 2015 flood events is that the generally held assumption that military options will always offer a fall-back for lack of pre-planning, is inappropriate, and worse, may be creating a false sense of security that is preventing operators developing their own emergency contingencies for bridge loss.

In Cumbria, the Army did provide the temporary 'Barker Crossing' pedestrian bridge in Workington following the 2009 flood, in *effect* providing the community with a most basic and urgently needed *lifeline* connection. Accordingly, the perceived efficiency of that work meant that when Pooley Bridge was lost during Storm Desmond, some in the community expected that the Army would step in again and provide a solution there.

However, the deliberations in the Recovery Coordinating Group between the Army, Cumbria County Council and contractors rapidly led to the decision that the civilian option was by far the most appropriate in the circumstances. The Army quite simply did not have the most appropriate bridging options available to deliver the type of structure required, e.g., purely military bridge options are not deemed safe for public use without on-going military support (as had been provided in Workington). Also, in most cases the military use the same civilian suppliers to support their bridging capabilities anyway.

Accordingly, there remains a genuine need to understand levels of civilian temporary bridging capability and capacity and to use this information in the development of emergency contingencies for bridge loss between suppliers and the highway sector's bridging experts. This should include planning for how the sector would prioritise and respond—in the sense of a national capability—in support of several *lifeline* bridge owners exposed to multiple, simultaneous, and significant bridge losses across a wide area.

From this perspective re-activating the *Temporary Bridges Portal* appears to be an important technical element required to support this level of national approach. However, the portal should be seen as supporting not replacing the associated requirement for focussed and on-going communication and coordination around this subject by DfT, the UK Bridges Board, and the key private sector suppliers and experts in the field.

Recommendation 7: DfT should collaborate with DSIT in the development and operationalisation of a resilience use-case for the National Underground Asset Register (NUAR), which includes the development of a methodology through which NUAR can inform multi-agency situational awareness and decision making in respect to the integrated management of emergency risks (e.g. potential impacts on 'lifeline-bottleneck' assets).

Recommendation 8: DfT should define the essential criteria for the broad sector adoption of consistent Rapid Impact Assessment (RIA) as part of all Local Highway Authorities' emergency planning contingencies

Recommendation 9: DfT should act to improve Local Highway Authority 'Step-in' access in respect to property adjoining highway assets, to allow the stabilisation and restoration of lifeline function to critical assets following damage resulting from extreme weather events. This should include exploring the feasibility of changing the law to allow this.

Recommendation 10: Led by UKRLG, the sector should define template contract clauses, whose function is to allow term contractors to carry out work under emergency conditions or as an exigency for their clients following extreme events, without compulsory recourse to a competitive process.

Recommendation 11: Led by the UK Bridges Board and supported by DfT, the aims and objectives of the original *Temporary Bridges Portal* initiative should be reassessed. New focus should be placed on outlining, developing, and delivering a portal that is able to support expert-agreed contingencies and a national (Mutual Aid) response capability for lifeline bridge loss.

3.1.8 Asset management systems

Respondents were asked which commercial asset management system (AMS) they used (Figure 14), with the market leader within the sample being *Confirm*™.[ggg]

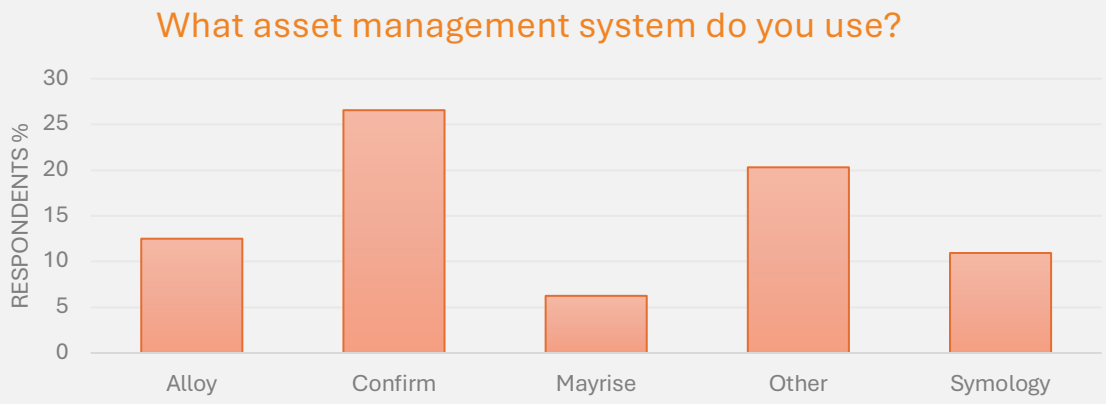


Figure 14

[ggg] Footnote: Other systems listed were: Gaist *AssetStream*; WDM; *BridgeStation*; Pontis; XAIS *XA*; *InfoAsset*; *KaarbonTech*

This question was asked because if consistent hazards data is to be collected and collated, then to reduce bureaucratic burden, we need systems that can be trained to generate this data.

In effect, an important factor to consider in respect to the variety of systems available, is that although all systems will be able to create reports in respect to workflows (e.g., number of streetlights damaged), the fact that each system will likely be customised to the individual client authority's specifications, means that outputs may not be comparable, even between users of the same system.

The range of different systems in operation, appears to further elevate the importance of the key sector groups agreeing a set of precise operational metrics for measuring extreme weather impacts and the remediation costs in a consistent way, rather than a way that favours the respective system provider's own commercials.

Recommendation 12: Led by the UKRLG ABC Board, the Asset Management Group and other boards should develop consistent metrics and technical methodologies for recording the impacts and remediation costs of extreme weather hazards in accordance with asset information management principles

3.1.9 Winter Service

Whilst winter service is covered in some detail by the annual DfT *Winter Survey*. The *Hazards Survey* also asked a series of questions in respect to salt stocks and winter decision-making.

Whilst the *Winter* Survey asks solely about salt stocks, and whether the council complies with the Quarmby 12-day reserve, the *Hazards* Survey explored whether knowledge of an authority's use of salt is sufficient to understand its winter service capability. From this perspective, Figure 15 illustrates how the sector is evolving from focus on covered or uncovered salt piles to a situation where a number of innovative alternatives are being experimented with: 41% of respondents stated they were also using other types of de-icer and liquid products.

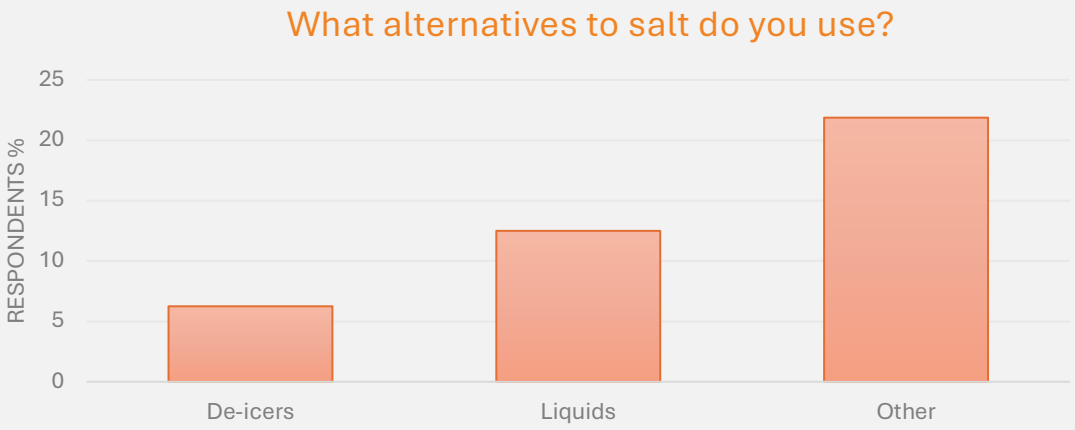


Figure 15

So, whilst there appears to be a general reticence against both adopting LiveLabs 1 Winter Service innovations (Figure 4), and engaging with the NWSRG (Figure 5), Figure 15 does appear to illustrate that councils are increasingly open to experimenting with new winter technologies.

A further Winter related survey question asked respondents the temperature at which they deployed precautionary salt (Figure 16). The NWSRG guidance on spread rates for precautionary salt[39] provides comprehensive temperature/salt (g/m^2) treatment matrices. However, the decision regarding at which temperature to spread precautionary salt is left to the guidance user.

The different temperatures at which respondents generally send out their teams (Figure 16), therefore, could be showing that:

- Winter teams have developed a mature and very localised understanding of the way their network responds to falling temperature (e.g., "*I know that at 1.0°C most of our vulnerable links will get hazardous with any temp variability*".
- Winter teams have developed a level of risk tolerance in respect to certain temperature profiles

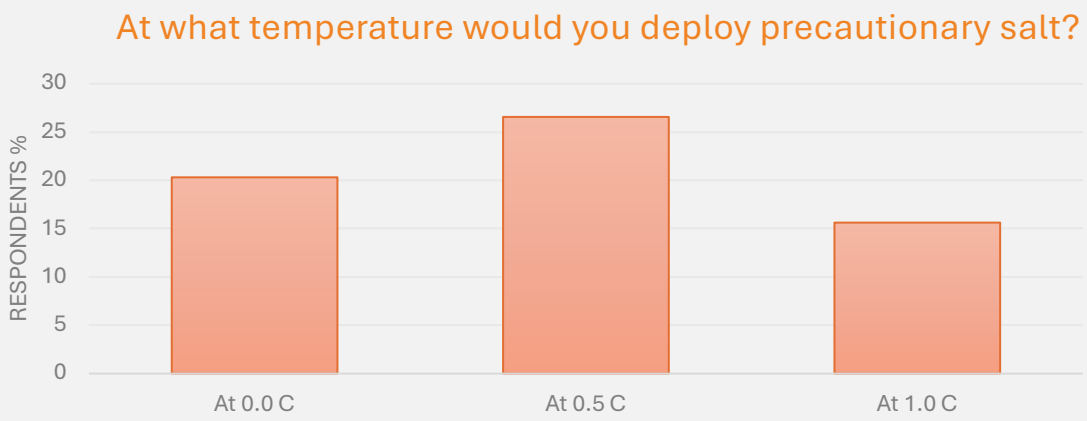


Figure 16

To understand some of the issues faced by a sector that has institutionalised its approach to *winter service* into a well rehearsed, trained and largely well resourced (compared to other types of hazard management) Business-as-Usual delivery for the six months of autumn/winter, it may be useful to consider a particular climate change uncertainty.

In 2001 the Intergovernmental Panel on Climate Change (IPCC) developed a schematic to explain the respective impacts of changes in temperature distribution and variablility (Figure 17). The schematic illustrates how a changing climate may affect weather distribution (i.e., a monotonic shift toward more heat events and fewer cold events), or variance (i.e., a shift toward more extreme hot and cold events), or both distribution and variance (i.e., much more extreme hot events and less change in cold weather).

Thinking about this, we know the science confirms that our climate is warming (distribution shift). However, in respect to winter weather, CCRA3 projections suggest that *"All parts of the UK will continue to experience a steady reduction in frost days as global warming increases, although some years will still see similar numbers of frost days and cold-related impacts as in recent years."*[25], which suggests more of a shift in variance.

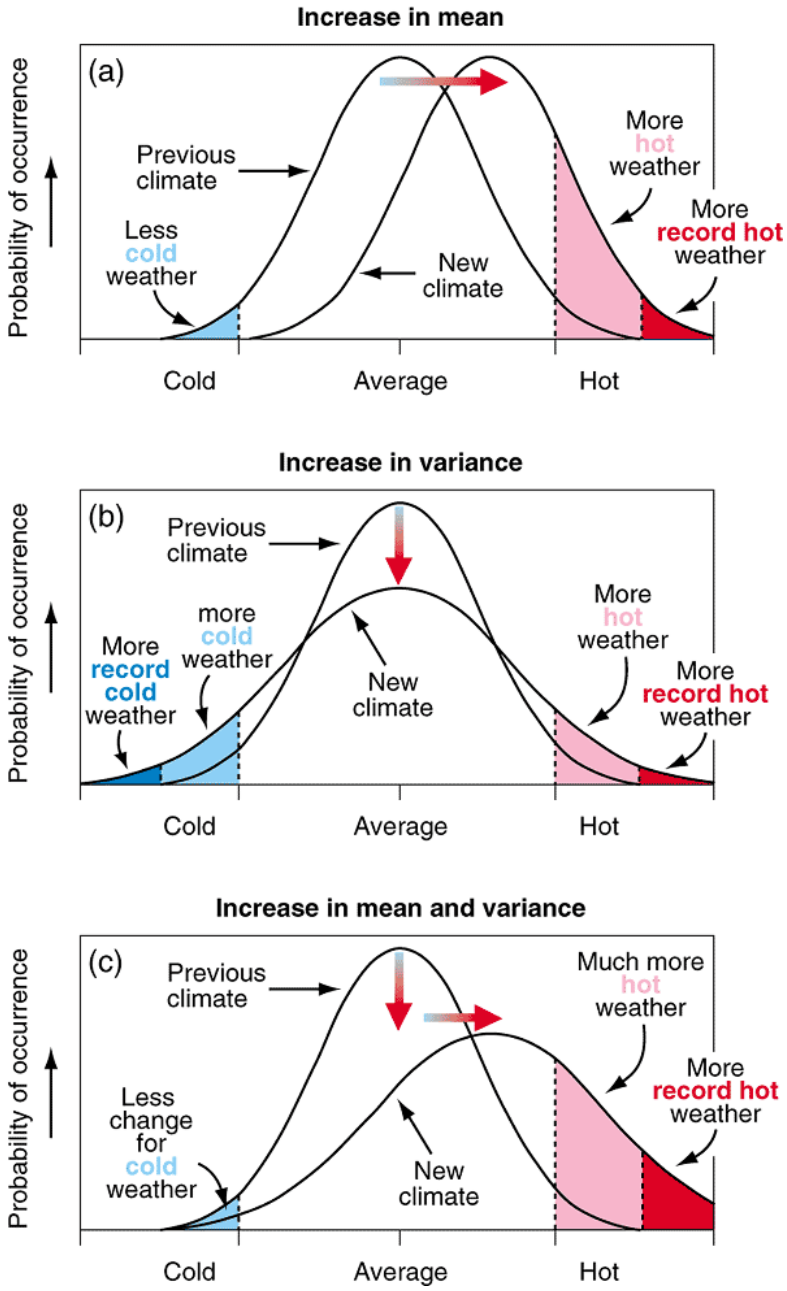


Figure 17: Schematic showing the effect on extreme temperatures when (a) the mean temperature increases, (b) the variance increases, and (c) when both the mean and variance increase for a normal distribution of temperature (Source: IPCC, 2001)

This steady reduction in ground frost days has been quantified (Figure 18)[40]. So, the sector is witnessing a general decline in the need for winter service. This has likely been experienced as an increasing challenge in respect to 'marginal nights', when winter decision makers need to make decisions to salt or not to salt based on ambiguous forecasts with the temperature hovering around freezing point.

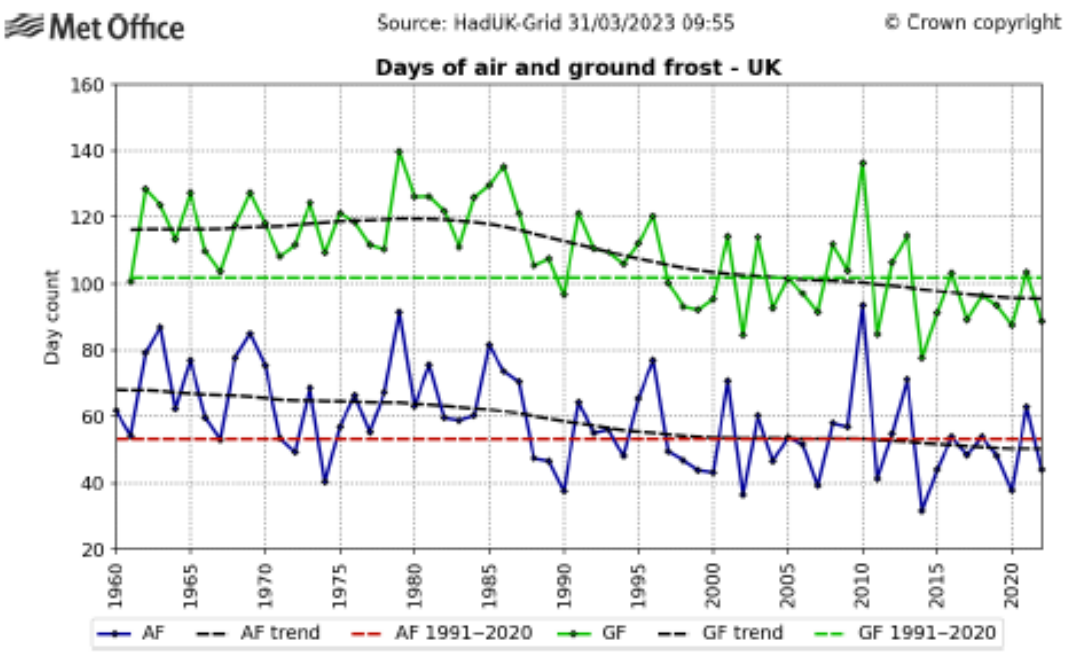


Figure 18: trends in Air and Ground frost days. Note steady reduction in average Ground frost days (Green) through and beyond 2010, the date of publication of the Quarmby review (Source: Kendon et al., 2023: p.19)

Taking this into account, the interesting date on the X axis in Figure 18 is 2010, which is when DfT commissioned David Quarmby to conduct his *Winter Resilience Review* following the two *relatively* cold winters of of 2009 and 2010.

Amongst its recommendations the Winter Resilience Review set the ground for significant improvements in the resourcing of winter service across the sector and the the formation of the National Winter Service Research Group (NWSRG), which has gone on the create the code of practice discussed above.

Against this background, the responses to the *Hazards* survey in respect to winter service were unclear. Whilst some respondents completed questions in respect to salt stocks, many did not. As a result of this it was impossible to draw conclusions about salt usage. Confounding factors here included the low response rate, but also the diverse nature of the respondent councils' geographies (e.g., area, topography). However 42 respondents did provide figures for their 'salt resilience' stocks.

This question was included because of Quarmby's recommendation 25:

> *"A new resilience benchmark of 12 days/48 runs should be adopted for pre-season stockholding for English local highway authorities; they should then review their history of usage and mutual aid or other arrangements to consider:*
>
> *a) whether there is a case for increasing capacity towards 48 runs if it is currently less than this, in addition to filling the capacity they have; or*
>
> *b) at what level to stock – at or above the 48 runs level – where the capacity exists to do so."*

The responses to the *Hazards Survey* question ranged from councils holding 3 to 138 days reserve (Figure 19).

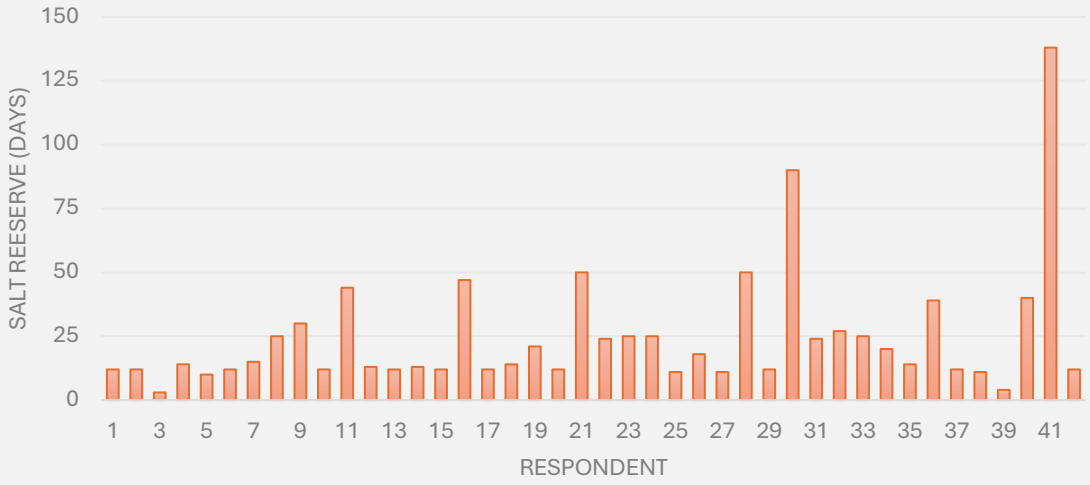


Figure 19

At first glance, Figure 19 appears to show clear inconsistencies in respect to the councils' interpretation of best practice (i.e. 12-days reserve). However, what the survey was unable to identify was *why* some councils kept objectively huge salt stocks compared to others. These stocks are expensive to buy and to store if the salt is to be kept in good condition. So why the discrepency?

- Has the knowledge and/or experience of intense snow and ice events, such as the '*Beast from the East*' (26th Feb – 8th Mar, 2018), *Storm Darcy* (7-13th Feb, 2021) and *Storm Gerritt* (26-28th Dec, 2023: Scotland) reduced these councils' risk appetite such that they are only prepared to resource for worst-case scenarios?
- Are these truly risk informed decisions based on knowledge of the *variability* of local conditions, which mean that considerably more than two weeks salt resilience is still an essential insurance policy to deflect the potential for reputational impacts if a prolonged event does occur?
- Are these councils reading the science on low probability / high consequence risks, such as the collapse of the Atlantic Meridonal Overturning Circulation (AMOC)[25 p.78] and deciding that there is a need to have additional resilience in place, just in case?
- Are these councils so pessimistic of the ability of their supply chains and sector mutual aid to replenish stocks during an long-duration cold event, that they are simply not prepared to consider these as contingencies?

This analysis cannot answer these questions, but given the inconsistencies in stocking levels the survey has exposed, these are genuine questions that the sector needs to be following up.

The main reason being, is that as the survey has quantified for the first time in this way, highway authorities are genuinely struggling to manage a range of hazards whose effects are damaging highway infrastructure and impacting user communities throughout the year, not just in winter.

It is incontestible that snow and ice present safety risks including risk to life. People die on icy roads and vulnerable communities can be isolated by significant snow falls. However, managing these risks has a cost and if money is focussed on 'gold plating' the resourcing of six months of a winter service delivery each year, without exploring alternatives (such as developing safe systems approaches[hhh], which acknowledge the risk but actively share the responsibility for managing it amongst stakeholders), that money spent on salt cannot be spent on managing other hazards: it is a zero sum.

Winters are getting warmer, but whilst climate variability means the risk of extreme snow and ice events remains, the disruptive effects of other weather and geo- hazards are increasing.

Whilst the Quarmby review introduced a period of genuine improvement and consolidation in terms of winter service delivery, those recommendations were made nearly fifteen years ago. The *Hazards* survey has provided evidence to suggest the sector still needs to accept Quarmby, but given the changing climate, there is also a need to develop a substantive, iterative, review process to ensure those recommendations are still appropriate.

Recommendation 13: Led by the UKRLG ABC Board, NWSRG should work with the Met Office to develop an iterative 5-yr review process to ensure winter service delivery is fit for purpose in the context of climate change risks. Considering the sector's increasing need to understand extreme-weather risk management this process should drive an all-hazards resilience approach, rather than solely snow-and-ice focus

[hhh] Footnote: https://www.pacts.org.uk/safe-system/

3.2 Summary of *Hazards Survey* findings and next steps

An initial analysis of the UKRLG *Hazards Survey* 2023 has revealed several key insights. These include the fact that as no sector survey has ever really explored local highway authorities' experience of extreme weather hazards, there has been a level of uncertainty, and possibly reticence, involved in responding to this one. People didn't necessarily see the benefit to them.

However, as this analysis is clearly showing those who did complete the survey have provided invaluable evidence to support a review of sector assumptions about what constitutes extreme weather risk. It is only by exposing the challenges being faced in respect to weather hazards other than snow and ice, that the sector will be able to identify, evidence, and prioritise their adaptation activities and resilience capabilities.

The fact that the questions asked required answers from across a range of council departments (e.g., winter service, climate change, Lead Local Flood Authority), undoubtedly reduced respondents' ability to provide comprehensive answers.

This is at least a partial explanation as to why the Climate Change Committee and National Infrastructure Committee have failed to find the data needed for them to understand and describe the status of the local highway sector resilience and adaptation: the data does not exist in a consistent, accessible, format.

In many respects, the metrics needed to underpin even a provisional baseline of understanding are straightforward. For example, the Climate Change Committee has proposed that in order to better understand the reliability of local roads "*additional indicators are needed, to better monitor progress against this outcome, including:*

- *Local roads at risk of flooding*
- *Embankment and bridge condition*
- *Weather-related delays and incidents*
- *Freight tonnage delayed or disrupted by weather incidents*"[37 p.175]

In light of this analysis, we can add in the need to also identify metrics for the duration of traffic disruption and other community impacts (e.g. lifeline effects; community isolation).

However, to provide such data requires a series of steps. The relevant metrics need to be negotiated and agreed by the sector's professional bodies and experts, processes need to be put in place to collect those data in a consistent way, and it needs to be straightforward to output those data a nationally comparable reporting format.

What this survey has shown, is that there is good practice and plenty of data out there, but the data are fragmented, inconsistent and not able to support the sharing of insight across council boundaries, or even illustrate the nature of change occurring within a council from one year to the next.

However, what the survey has also revealed is that there are a range of 'quick wins' available, which if more widely adopted, could transform not only the highway sector's resilience, but also that of the range of other lifeline services whose assets' own resilience is highly dependent on the integrity of the highway's three-dimensional structure and its effective management.

These findings could not be timelier. With the approaching publication of both the Transportation Adaptation Strategy and Climate Change Risk Assessment Guidance, the results of this initial *Hazards Survey* must be used to inform and empower the sector to think differently about its resilience and how it demonstrates it.

3.2.1 The Adaptation Reporting Power model for data collection

Part 4, Section 62, of the Climate Change Act covers 'impact of and adaption to climate change'. This allows the Secretary of State to direct reporting bodies to:

- prepare reports setting out the risks presented by a changing climate
- proposals and policies to deal with climate risk, and
- to set out progress made

For the highway sector, this *Adaptation Reporting Power* (ARP) has so far only applied to National Highways (NH) and Transport for London (TfL), who have each submitted three ARP reports[iii], most recently in 2022. Accordingly, adaptation reporting is currently required for just over 2% of the national road network in England.

The Climate Change Committee has, however, recommended that Defra extend the scope of the next round of the Adaptation Reporting Power (ARP4) to cover local authority functions related to road infrastructure, ports, airports, and key supply chain organisations[37]. In response to this, DfT has intimated that a number of local highway authorities will participate in the fourth round of ARP as part of a local authority pilot[42].

ARP participants state the current common approach to reporting that has been developed and agreed between key organisations in the surface transport sector and Defra offers improved consistency, transparency, and ease of understanding of the sector's interdependency risks. However, despite the obvious interdependencies and shared risks managed along the nation's highway network, local roads are only explicitly referenced *once* in National Highways 3rd ARP[63 p.81].

This is a concern, because the *Lessons Review* had already identified interoperability challenges and clear evidence of breakdowns in communication and in the understanding of interdependencies between NH and local authorities during extreme weather events. To this we can now add the learning from this analysis of the *Hazards Survey,* which has found that local authorities have clearly differing abilities and capabilities to report hazard and adaptation related information consistently. The question must be asked, therefore, as to whether the currently agreed common approach to ARP reporting is robust enough to work effectively for not just the two strategic network operators, but for 154 highway authorities in England (plus Wales, Scotland and Northern Ireland), should ARP be extended across the sector (i.e., national and local roads)?

This analysis of the *Hazards survey* has revealed three things about the sector's current resilience and adaptation survey tools:

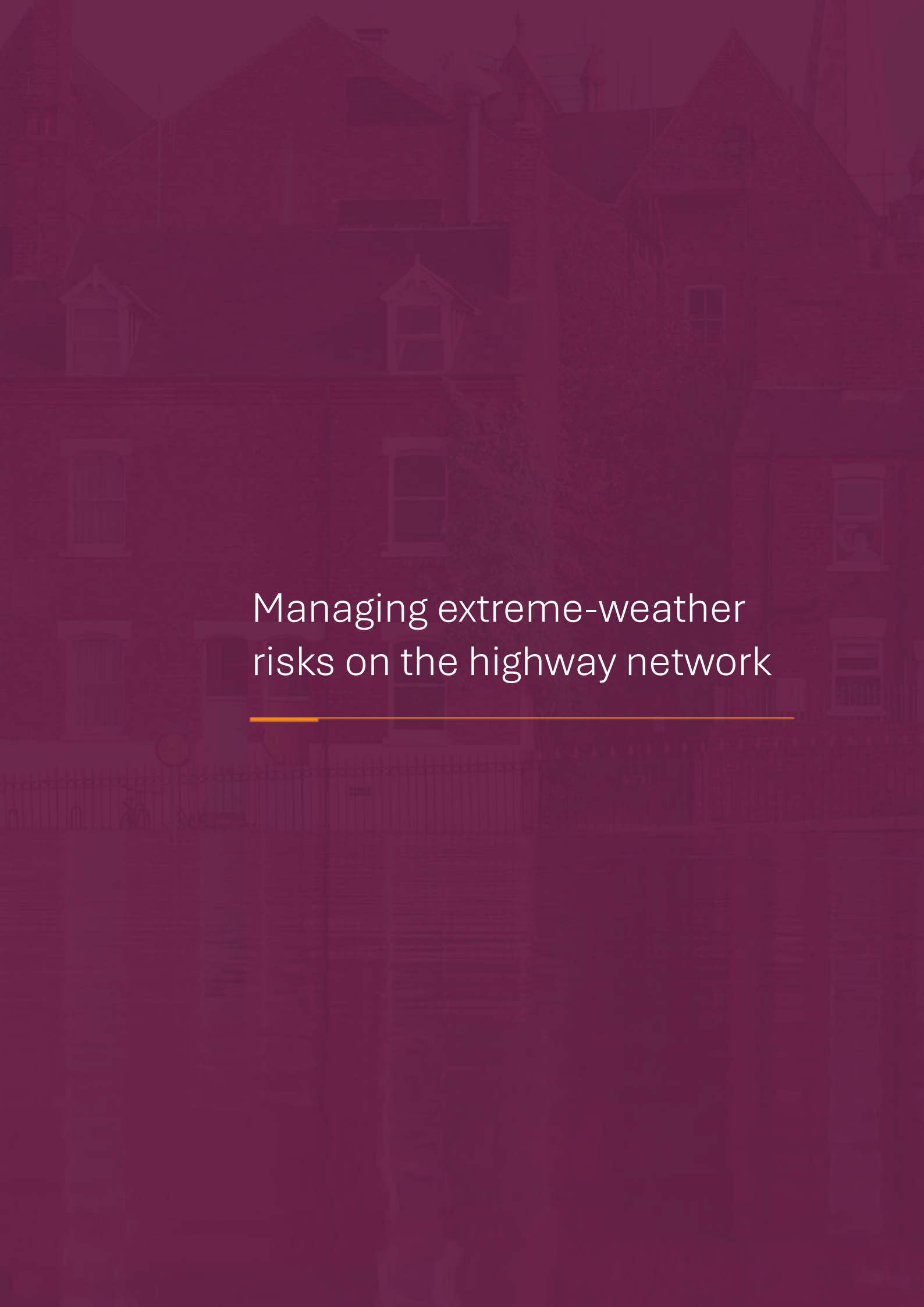
1) ...it is essential that DfT's largely winter-service focussed *Resilience* survey is adapted as soon as possible to include multi-hazard and adaptation related content.
2) ...ARP represents a useful model for creating consistent understanding of climate risks and adaptation actions and opportunities
3) in order to create a national picture of the climate resilience of our highway network, it will be essential that DfT and Defra work with the sector through UKRLG, to develop

[iii] Footnote: https://www.gov.uk/government/collections/climate-change-adaptation-reporting-third-round-reports

a common template for any future ARP reporting by the highway sector. This must provide consistent understandings of hazards, risks, adaptations, and opportunities, and requires the collaborative reporting of interdependency risks

Given these points, until such time that ARP is rolled out across the sector, the annual DfT resilience survey offers a mechanism through which to start to build and maintain a comprehensive ARP-consistent baseline understanding of the whole sector's extreme weather risks and adaptation activities and opportunities

Recommendation 14: Led by UKRLG, sector national groups should collaborate to agree key variables (i.e., questions) and mechanisms (e.g., surveys) for the collection and consistent quantification of highways specific extreme weather / impact data. These should be developed in collaboration with Defra to ensure that the data collected are consistent with and usefully inform any future sector Adaptation Reporting Power (ARP) requirements.



Managing extreme-weather risks on the highway network

4. Managing extreme-weather risks on the highway network

> *"It is important to note that transport networks (especially roads) are critical during emergency management and recovery, allowing accessibility to hospitals and to sites for repairs and replacements"*[41 p.65]

The increasing risks presented by extreme weather are in many respects larger than can be adapted to and managed in their entirety by individual local highway authorities acting alone. Accordingly, it is becoming increasingly evident that the sector needs to actively collaborate to drive improvements in adaptation and resilience

4.1 DfT as resilience facilitator

Whilst the *Hazards Survey* was in circulation, DfT opened a consultation on its draft *Transport Adaptation Strategy*[42], with a parallel consultation on draft guidance for *Climate Change Risk Assessment* (CCRA) for the transport sector following soon after.

Importantly, the draft Adaptation Strategy recognised the vital importance of data in guiding effective adaptation and resilience initiatives. It sets a goal of 2027 to "*collate the data that transport stakeholders capture on weather and climate related disruption and costs, to support them to enhance their data sets and better understand the impacts of climate change on their business.*"[p.46] By 2028 it commits to have developed indicators in partnership with the sector to measure adaptation outcomes "*with a view to having more effective metrics for local roads*".

As the discussion in relation to the *Hazards Survey* has shown, these cross-sector goals are fundamentally important. However, given the increasing levels of extreme weather driven risk faced by the sector, their delivery is also becoming urgent. DfT must recognise that the tendency to frame climate adaptation and resilience as pertaining to preparedness for *average* temperatures in 2050 and 2080, whilst vital if our highway infrastructure is going to remain fit for its lifeline purpose in coming decades, also misses a key point.

Our *current* climate is *already* weighted toward delivering extreme weather events that are unprecedented in our experience, and the probability of their occurrence in any one year is rapidly increasing[43]. Accordingly, rather that submitting to navel gazing about possible futures, DfT and UKRLG need to be actively driving sector adaptation across the spectrum of resilience domains (Figure 1).

Leadership from DfT in this is going to be important in several ways, so it is useful to discuss three areas where this leadership can manifest: managing hazards; leading during emergencies; equipping the sector leadership to manage future emergencies (SQEEP)

4.2 Managing hazards: adaptation as resilience

The publication of the *UK Government Resilience Framework* (UKGRF)[44] highlights the importance of Lead Government Departments (LGD) stepping into the resilience leadership role. In effect, UKGRF implicitly reaffirms the status of DfT as LGD for transportation risks[52jjj].

[jjj] Footnote: The LGD guidance was reissued on the same day as the publication of the UK Govt Resilience Framework

Accordingly, it has been encouraging to have been given sight of on-going work by the Department to define a set of *Hazard Profiles* to more clearly define the nature of the hazards whose effects the sector needs to be managing (i.e., beyond snow and ice). Such work is increasingly important, as it normalises the idea that the acute and chronic risks presented by extreme weather and climate effects need to be understood, accepted for what they are, adapted to and managed, proactively rather than reactively.

It is also important that in the hazard profiles work, the DfT team is consciously moving the risk conversation away from one purely based around the emergency-planning specialists' '*reasonable worst-case scenario*' approach, which is required by the statutory Civil Contingencies Act defined process that guides Local Resilience Forum members' emergency planning activities[45].

Instead, they are thinking more broadly about encouraging and empowering councils to understand hazards in ways that inform and empower their ability to make defensible decisions in respect to planning the adaptations and resourcing the capabilities and capacities needed to manage the spectrum of possible hazard intensities. For example, understanding minor, yet chronic, surface water flood hazards as representing risk—rather than simply subjectively defined 'nuisance'—to your community, can inform defensible decisions to increase investment in preventing or minimising that risk (e.g., enhanced drain monitoring, maintenance, and increasingly, SUDS). As many of these hazards are only likely to increase in intensity and frequency as our climate changes, strategies based on more actively managing chronic issues or 'hotspots' *now*, need be understood as representing 'quick win' adaptations, which can be usefully achieved, quantified and reported on.

In support of this, the anticipation, assessment, and management of flood hazards using the 'solutions hierarchy' is recommended by the National Infrastructure Commission[46]. The 3-step solutions hierarchy (Box 4) suggests optimising existing drainage infrastructure—through targeted maintenance and the effective cleaning of assets, including sewers and gullies (i.e., not just clearing gully pots)—and/or technological optimisation, that includes real time control of rainwater in the drainage system during a storm. This approach, the NIC contends, encourages the use of the lowest cost interventions. It also minimises the risks related to at least some of the lesser intensity flooding events. In effect, using the solutions hierarchy to manage chronic hazards more effectively appears to offer some of these quick wins, which are currently being missed and/or misunderstood by some councils.

If communicated effectively, the DfT work to increase councils' understanding of a range of hazards aligning along a spectrum of risks from chronic (e.g., flood hotspots) to acute (e.g., high velocity floodwater crossing carriageways), which affect the highway network's operation could underpin new collaborative approaches by councils wishing to implement no- or low-regrets climate adaptations. In effect, rather than seeing adaptation as simply too big and expensive to conceive—hence the key committees finding that adaptation is progressing too slowly—this approach empowers councils to understand, prioritise, *and record,* their management of hazards in ways that will likely have demonstrable, and popular effects in reducing impacts on all user communities (e.g., fewer instances of surface water flooding).

Box 4: The National Infrastructure Commission 'Solutions hierarchy'[46]

"The 'solutions hierarchy' sets out the order in which drainage interventions should be considered to maximise the range of benefits and reduce costs. It prioritises:

- **maintenance** and **optimisation**,
- followed by **above ground interventions**,
- with **below ground interventions** (pipes and sewers) considered last.

The first option should be optimising existing drainage infrastructure, through targeted maintenance and cleaning of existing assets including sewers and gullies, or technological optimisation, including real time control of rainwater in the drainage system during a storm. Starting with optimising existing assets ensures consideration of the lowest cost interventions and can address network blockages that can cause sewer flooding even in relatively low intensity rainfall events.

If existing drainage is not sufficient, above ground interventions, such as rain gardens, ponds and kerbs should be considered next, to manage flows of rainwater, and reduce the volumes of water entering below ground drainage. This will reduce the risk of pipes and sewers flooding and potentially reduce the cost of wastewater treatment. Considering above ground measures before underground pipes and storage also maximises the opportunity to deliver wider benefits, such as improving biodiversity, as well as tending to be cheaper. Below ground interventions – additional pipes and sewers – should be the final option considered."

From this perspective, the *Climate Resilient Streets* conference in November 2023 provided an impressive showcase that demonstrated a catalogue of adaptation schemes designed to reduce flood and heatwave risks whilst simultaneously improving local environments. The schemes discussed included elements of *source control* (e.g., rainwater capture), *site control* (e.g., rainwater storage and slow release) and *regional control* (e.g., downstream measures to control gathered run-off from large areas). These schemes illustrated the highly technical, but also impressively inclusive work to reduce chronic flood issues across London and beyond (e.g., the Natural Flood Management scheme on the River Frome). Many schemes had obviously attracted considerable support from the communities in which they were placed, which is important given that many of the designs clearly lend themselves to community-delivered maintenance (e.g. vegetation control; irrigation during extended periods of high temperature/drought).

Such schemes are becoming an increasingly important and largely popular—although sometimes contested—solution to adapting our cities and wider environment to the changing climate. These Blue-Green Infrastructure are also good to look at, they can provide both flood reduction and environmental cooling functions and, put simply, they make urban spaces more pleasant places in which to live.

However, even the teams presenting these schemes appreciated their limitations in respect to managing extreme hazards, with some schemes justified and designed against the industry standard 5% Annual Exceedance Probability (AEP) events[47], which should ensure "flooding does not occur on any part of the site for a 1 in 30-year rainfall event" [48]. According to Defra non-statutory guidance, however, schemes "*must"* also ensure 'exceptional' 1:100 (1% AEP) events do not result in flooded buildings (including basements) or utility plant (e.g., pumping stations), with any exceedance measures for events in excess of 1% AEP managed "*where reasonably practicable*" so as to minimise the risks to people and property. Given the additional 'place' benefits of SuDS, over and above flood risk management, these are rigorous expectations.

Yet, research by Sayers *et al.*, for the Climate Change Committee, has revealed that due to the 'effectiveness limit' of source-led approaches (i.e., solutions that manage surface water at site), there is an inherent need for supplementary pathway-led (e.g., piped, or channel) portfolios to deliver high standards of protection. This, they say, "*reflects inherent limitations on the performance of SuDS*[kkk] *but also constraints of space limiting the implementation of SuDS in some urban locations"*[49]. So, whilst there is huge potential for Blue Green Infrastructure to reduce higher probability risks and improve living spaces (making the value of their broad implementation self-evident), the importance of understanding that source, site, and regional-scale schemes all require designed exceedance measures, for extreme event management is still vital (e.g., modifying surface flows, which can involve using roads as pathways).

A vivid illustration of how flood management approaches may evolve in the future occurred on Monday 23rd Sept 2024, when record rainfall fell in the south of England. During this event, which delivered 100mm of rain to parts of Oxford in 24 hours (the highest in in the city's 197-year record[lll]), the 14-yr old Marston Moretaine Interchange on the A421 in Bedfordshire was inundated (Plate 1). Whilst this pushed traffic from the SRN onto diversions (including local authority networks) for several days, in effect, the intersection became a regional-scale SuDs.

Whilst potentially controversial now, thinking about similar highway assets' capacity to act as temporary floodwater stores and/or as drainage pathways may increasingly need to inform extreme-flood management thinking in the future. It is becoming increasingly clear that many assets' design capacities are not simply being exceeded by extreme events but *overwhelmed*[mmm]. Accordingly, in the future it will be the way that these foreseeable residual risk effects are managed that will best illustrate the asset owner's understanding—or lack of understanding—and engagement with all-domain resilience thinking (i.e., how quickly affected critical assets are triaged, stabilised, restored to service, and then adapted to prevent reoccurrence). As community lifeline operators, the highway sector needs to be fully and openly engaged with this thinking.

What the A421 example demonstrates is that even relatively new, *designed,* parts of the SRN are already at risk of disruption from extreme weather events.

So, given the nations' strategic road operators' clear imperative to keep the SRN—the backbone of UK logistics—open, it is important to understand the A421 and other recent

[kkk] Footnote: Sustainable Urban Drainage System (SuDS)

[lll] Footnote: https://www.geog.ox.ac.uk/research/climate/rms/oxford-climate.html

[mmm] Footnote: National Highways 2020 guidance on Design of highway structures for hydraulic action (CD356) proposes a 0.5% (1:200) *design event* and a 0.1% (1:1,000) *check event* be used to inform the design process of assets on the strategic network. However, it is not unreasonable to suggest that the robustness of a significant proportion of our legacy stock of (e.g.) stone masonry arch bridges on the local network would be tested to destruction by events of much lesser magnitude.

incidents where the SRN has been closed due to flooding[nnn] as providing an inflection point in thinking for the *whole* highway sector.

At this point it is important to note the stated aim of National Highways[ooo] is to ensure that by 2050 the SRN in England *"is resilient to climate change and incidents, such as flooding, poor weather conditions* [and] *blockages on connecting transport networks"*[63] and that this will be achieved by focussing "*on reducing flooding on our roads and minimising risks for local communities* [and], ***retrofitting our assets*** *to meet new environmental and drainage standards"* [my emphasis][50]. It is also worth noting that in some locations significant progress has been made in increasing the resilience of the SRN (e.g., the raising of a stretch of the A66 in Cumbria following Storm Desmond and work with the Environment Agency to reduce flood risk along the A1 at Catterick)[63].

These adaptation objectives for the SRN all focus on using revised design and asset management standards to improve the hazard-resilience characteristics of new infrastructure, whilst also identifying and improving maintenance regimes for, and/or adapting (i.e., retrofitting), existing hotspots to be more resilient. This will take time, planning and resources. In the meantime, where these complex, designed, structures are likely to continue to flood during extreme events—due to their legacy design standards—grasping the need to further streamline contingencies for these *in extremis* conditions (i.e., delivering more *rapid* and *resourceful* flood response), should be seen as a first-step, proactive, climate adaptation in itself.

Unfortunately, not all highways can be managed in the same way as the strategic network. For example, some road links are irredeemably vulnerable to inundation during heavy rainfall (e.g., the A684 near Hawes in North Yorkshire, and increasing numbers of locations within our towns). The NaFRA analysis discussed above also highlights the magnitude of the challenge faced by highway operators, where ~38% of the network is already exposed to flood risk of some kind (Table 1).

Accordingly, whilst low points and links may feature on a precautionary salting network (i.e., we can realistically prioritise actions to keep them open during snow and ice events), taking an all-hazards perspective exposes a fundamental challenge in their being considered as 'resilient' in the context of an *All-Hazards* approach.

Do we need to consider contingencies where certain roads are understood as *in extremis* temporary flood storage and/or as flood pathways (i.e., as a route along which surface water can be steered to avoid unacceptable impacts)?

This is obviously contentious, because removing a road's primary function as a transport link, challenges the very idea of a resilient community *lifeline* (e.g., a route that provides guaranteed passage for Ambulance, Fire and Rescue, and Police vehicles). However, if the reality is that these assets, structures, and links are currently impossible to flood-proof without disproportionate expenditure, or simply because doing so would create a greater risk 'downstream', then it appears that a change of perspective is becoming increasingly necessary.

What does this mean? As a think piece I suggest that it means two things:

[nnn] For example: M62, (22/05/24); M5, (27/09/24) and (08/10/24); A1(M), (09/10/24); M62, (16/10/24); A5 (05/12/24); A55 (07/12/2024); M9 (07/10/24); A555 (31/12/2024)

[ooo] Footnote: the Strategic Network Operators in the Devolved Administrations have all expressed similar objectives in their climate adaptation and resilience strategies (Scotland, Wales, Northern Ireland).

1) The need for a methodology to underpin the reassessment of vulnerable highway assets, which focuses on understanding their respective values, as either critical lifeline highway assets that *must* be kept operational (e.g., routes to hospitals), or as those relatively few assets that—without adaptation—we know will, *in extremis,* inevitably transmute to a temporary SuDS function.

   This would need to involve Elected Members and concerted public outreach regarding the decision making and implementation processes, as well as engineering to apply any necessary adaptations to support the *dual* functioning (e.g., warning signage and safety measures, or revised cambers to retain flowing water in the highway 'channel').

   However, if once experienced and recorded, a function loss of this type is perceived as completely unacceptable, then a reassessment of the evidence required to support preventative adaptation *at this location* over and above other priorities will also need to be agreed.

2) A reassessment of the assumptions made in respect to what constitutes an all-hazards 'Resilient Network'. Such assumptions would not be based so much on the ease of commuter traffic flow but would focus on applying combined vulnerability and criticality analyses to identify the *fundamental* fall-back links and assets—the *real* lifelines—without which communities will struggle to function (i.e., including rural communities).

   Learning from earlier lessons, this should include the analysis of interdependencies between the highway, the subsurface (i.e., NUAR), and any connected infrastructure, which together comprise the roads' lifeline functionality (Box 1). Newly designated critical links and/or assets would also then attract enhanced levels of investment in adaptation, maintenance and emergency contingency planning, over and above all other routes: thus, ensuring they can remain operational or can be stabilised and reopened as *rapidly* as possible after impact from any hazard.

Returning to drainage, the limitations of contemporary drainage standards and design—which accept that even fully functioning drainage infrastructure will likely be overwhelmed in an extreme event—should not detract from the fact that ensuring these systems are operating at their design capacity can extend the *time* emergency services have available to safely access communities (e.g., to coordinate evacuation)[51] and also give communities the crucial additional *time* they need to avoid or to prepare for inundation (e.g., time to assemble and install property-level flood resilience measures, moving property out of the way). *Time* is something that poorly maintained pipes and culverts will not provide. This approach to drainage management (including SuDS), which focuses on "*proving the outfall*" to a much greater extent than basic, publicly visible but ultimately less effective regimes of gully-pot-only cleansing, was described to me simply as "*doing the basics well*".

In line with the *Lessons* review's focus on multi-agency collaboration, Box 5 describes an example of the type of multi-agency approach that can be taken to understand risk and to adapt local network serviceability for the future.

Recommendation 15: UKRLG should commission a task and finish group to review and refresh the *Well-Managed Highways* Code of Practice as it relates to resilience and, specifically, to the designation of Resilient Networks. The review should focus on providing guidance that defines an appropriate methodology and standards to:

... ensure—as far as is reasonably practicable—the maintenance of all-hazards resilience and essential functionality of key lifeline-designated routes

... underpin safe procedures (inc. communications) for the *in-extremis* sacrifice of asset function when managing hazard effects which overwhelm the network's drainage capacity (e.g., flood pathway management, temporary floodwater storage)

Box 5: The Worcestershire Network Resilience Forum

Following a review of the DfT *Lessons* recommendations, Ringway Infrastructure Services (RIS) approached Worcestershire County Council (WCC) with a suggestion to collaborate in establishing a Network Resilience Forum (NRF) as a direct response to the review's support of multi-agency collaboration.

The idea was approved and NRF was set up, with the purpose of coordinating three key focus groups – Proactive, Reactive and Communications - to make recommendations with regards to improvements that could be made and strategies employed. The NRF consists of senior Worcestershire County Council Officers and Ringway Infrastructure Services Senior Managers.

The Groups are focussed as:

- **Proactive** – contribute to asset management and help WCC to make well informed network decisions for capital investment (schemes) based on good data and knowledge of the county
- **Reactive** – what can be implemented to improve capabilities to 'restore' the network to 'normality' after an incident, based on data, but also recognising the fluid nature of a network in these circumstances—a dynamic approach
- **Resilient Comms** – what data is available and how can it be improved upon and how will it allow us to make best use to keep end users (the residents and travelling public of Worcestershire) informed and mitigate misinformation which is social media driven. Comms should also include recent technology in the forms of initiatives and trials (e.g., Emergency Alerts).

Case-study: The Sabrina footbridge

One issue deliberated by the group involved the pedestrian access to the Sabrina footbridge over the Severn in Worcester, which was being inundated at relatively low flood levels. As this footbridge provides essential access to the town for students it represented a chronic safety risk (i.e., slip hazard). Following input from WCC and the Environment Agency the group approved investment in works to raise the approach to the footbridge by 10cm. This work has resulted in the path now staying dry and remaining safe for significantly longer during flood events

Relationship outcome

The strength of WCC and Ringway's relationship has enabled the NRF to bring on board other stakeholders in a structured environment, resulting in real value being added to the challenge of achieving greater network resilience.

4.3 DfT as Lead Government Department during extreme events

Having discussed how 'doing the basics well' can be understood as an adaptation that offers to reduce some of the sector's lesser climate risks, it is important to now return to DfT's Lead Government Department role in respect to extreme-weather emergencies.

The Cabinet Office's current Lead Government Department (LGD) guidance on delivering integrated emergency management[52], places responsibility on DfT for managing risks affecting the transport network in England, and on the Devolved Administrations for their own risks[ppp]. However, emergency effects tend to be cross-cutting, so when emergencies require a central government response the designated LGD's (and/or Devolved Administration's) responsibility will include the identification of other departments, agencies, or arms-length bodies that may be required to collaborate. They will also need to ensure their partners' roles and responsibilities are clear, and that they are able to coordinate activities across all phases of Integrated Emergency Management (IEM).

As an English example,

- whilst DEFRA bears overall LGD responsibility for managing *flooding* and
- MHCLG bears responsibility for coordinating *recovery*,
- where the emergency is affecting transport infrastructure, DfT is expected to have contingencies in place for coordinating those aspects of the emergency as required.

The author is aware that DfT has a mature emergency response mechanism in place for incidents that have been designated as within its remit[qqq], yet he has been told that this remit does not currently extend to local roads[rrr]. Yet, the LGD guidance does not differentiate responsibility between strategic and local roads, i.e., for "severe storms and weather" it simply designates DfT's responsibility as including "roads"[p.10]. By the wording of this guidance, therefore, it could be anticipated—at least by practitioners in the sector and by the public—that in the midst of a weather emergency that involves impacts on roads, other Departments (e.g., MHCLG) would expect to look to DfT to manage that aspect of the response.

Accordingly, it should be recognised that during a disaster or catastrophe, the handful of people expert in local roads management at DfT would naturally grip this responsibility (as occurred following Storm Desmond, Eva and Frank) and seek to deliver this coordination role through collaboration with a broader network of sector support.

This is one of the key areas of focus for the new UK ABC Board which is seeking to increase sector resilience by defining a process through which senior leadership can be mobilised to support the sector in direct conjunction with the DfT: *effectively helping the latter to discharge its LGD responsibility through those already well versed in the sector response to highway disaster management – including severe weather.* This will involve DfT developing a logical inter-connected network of key senior leaders such as John A. Lamb, Chair of UK ABC Board who was recently appointed by the DfT as the UK representative onto the World Road Association Disaster Management Committee. Select and targeted leadership, especially where resources are limited, has a vital role to play.

[ppp] Footnote: The Devolved Administrations are responsible for coordinating the response to incidents affecting the devolved nations

[qqq] Footnote: this includes the Transport Security Operations Centre (TSOC)

[rrr] Footnote: This perception appears to be supported by Defra, who in its 2015 *Flooding in England LGD Plan* state that the Defra duty officer should *only* consider alerting DfT in respect to flooding occurring on main railway line or *motorway* (NB. the guidance was published before Storm Desmond)

Weather hazards of increasing intensity and frequency will always require a fundamental level of local management, but as the magnitude of their impact starts to escalate (as they did in Germany and Belgium, and Spain), there is a need to know that preparation has gone into structuring coordination capabilities at higher levels.

In doing this, it is worth noting a finding of the UK COVID-19 Inquiry in respect to the Lead Government Department model. The COVID-19 Inquiry found the LGD model to be "*fundamentally unsuited to preparing for and building resilience to whole-system emergencies*"[sss] (p.51).

In effect, the Inquiry found that LGDs have a place in managing and coordinating what are described in doctrine[53] as *Significant* (Level 1) and *Serious* (Level 2) incidents directly affecting their sectors, and which are managed through the principle of subsidiarity[ttt]. However, when it comes to *Catastrophic* (Level 3) emergencies (whole-system emergencies), the Inquiry suggests a new approach is needed.

Considering this need to build resilience against the cross-government effects of future whole-system civil emergencies, the Inquiry recommended a simplified emergency management structure involving a single Cabinet level or equivalent Ministerial committee and a single cross-Departmental group of officials to oversee and implement policy on civil emergency preparedness and resilience.

In July 2024, the Prime Minister established a single ministerial committee to oversee action to build medium to long term resilience. In its response to the Inquiry recommendations the Government also agreed that the response to future whole-system emergencies would be coordinated through the Cabinet Office[54]. However, it also reaffirmed its commitment to the LGD model. This means that other departments still require the capability, and capacities needed to contribute both to managing risks within their remit, and also to up to and including whole-system-emergency response in respect to their respective departmental responsibilities, expertise, and connections.

For example, whilst the Government has only defined a limited set of 'Catastrophic' risks[uuu], any of these, if manifest, would require an element of transport coordination, including evacuation routing out of contaminated areas, and network management (e.g., if electricity network failure were to be caused by the cascading effects of extreme weather, such as fallen trees across local roads disrupting and preventing access to critical electricity infrastructure: as occurred to challenging levels during Storm Arwen[55])

In this sense it should be an expectation that DfT would still lead on managing the coordination of sector response to any such emergency's impacts on transportation, with this informed and delivered on the ground by the leaders and practitioners whose expertise is embedded across the practice community. Accordingly, both DfT and the broader sector need to be fit and ready to bear this responsibility.

Specifically, we need to reflect on where the objectively catastrophic impacts of the European floods of July 2021 may provide useful lessons for Government in respect to the

[sss] Footnote: The Inquiry describes the most complex civil emergencies as affecting "*the whole system of central, regional and local government across the UK and the whole of society. Whole-system civil emergencies impact on the whole society of the UK and require a cross-departmental approach within, as well as between, the UK government and devolved administrations*". (p.16)

[ttt] Footnote: *Subsidiarity* - the principle by which decisions should be taken at the lowest appropriate level, with co-ordination at the highest necessary level.

[uuu] The National Security Risk Assessment (NSRA) categorises five risks as comprising catastrophic potential: pandemic; regional electricity network failure; civil nuclear accident; radiological release from overseas site; and larger scale CBRN attack

Department's role in coordinating the response to potential future significant (Level 2) or catastrophic (Level 3) events when they occur in the UK.

To do this, it bears repeating that the overall cost of the July 2021 Storm Bernd floods amounted to >€32 billion to Germany alone[56], with €2 billion of that representing the impact on transportation infrastructure[16].

This returns us, fully, to the recommendation made in the *Lessons* review, that mutual aid contingencies "*and professional-networking arrangements need to be developed on a regional or national basis, thus negating the risk of neighbours being unable to aid each other because both have been impacted to their capacity by the same event.*" (p.44)

If we are to adopt the concept of whole-system emergencies, this recommendation takes on a new imperative. This is because when considering the potential for a European floods scenario to affect a large swath of the UK it becomes obvious that neighbouring authorities in the impact zone could be equally overwhelmed and would be unable to assist each other.

Given the whole-system impacts that such an event would manifest, it is also important to note the singular importance of maintaining transport connections during such events. As was discovered during the European floods, damage to roads "*significantly hampered relief deliveries and clean-up work in the affected area*"[57].

This finding further underpins the *lifeline* importance of the road network during emergencies and reaffirms the importance of integrating 'duration' as a key element of the impact equation (i.e. the longer the time it takes to get aid to impacted communities the greater the impact, stress, and trauma they experience).

Such an extreme event will inevitably require the mobilisation of regional and/or national support. Here, the highway sector should be able to *reach-back* to draw forward much of the incredible engineering capability, resource, and expertise that highway authorities hold, and which would be essential in managing catastrophic impacts[vvv]. To maximise response and recovery effects, Members and officers should also be able to *reach-across* to access similar or better capabilities and capacities from peer councils, and their supply chains, or other private sector entities.

Accordingly, in respect to the provision of effective disaster response, the question should be framed as, if not us, then who? The highway sector unquestionably needs to develop its own contingencies for these types of event.

At present, beyond certain Fire & Rescue capabilities[www] and the Environment Agency's framework for managing incidents within its own remit (e.g., flood defence), no structured, commonly recognised, national framework[xxx] exists for delivering these types of specialist engineering competencies, capabilities, and capacities to impacted areas at scale: noting that military contingencies (MACA) have strict rules and limitations and should not be taken for granted[yyy]. Nor (as far as the author can tell) are there any relevant local authority contract

[vvv] Footnote: It should be noted that the Cabinet Office's Mutual Aid short guide for local authorities exemplifies a simple model agreement based on mutual aid contingencies in respect to the sharing of *personnel*, rather than *capabilities*

[www] Footnote: https://fireengland.uk/national-overview/fire-and-national-resilience

[xxx] Footnote: This is not a discussion of the UK Central Government Concept of Operations (Conops)[52], it relates explicitly to a lack of planned, trained, and exercised, arrangements for delivering engineering capabilities owned, operated, or contracted by local authorities as mutual aid for their peers should they be impacted by disaster.

[yyy] Footnote: As discussed in the *Lessons* review, Military Aid to Civil Authorities (MACA) has provided capacity, capabilities, and niche capabilities to impacted councils during many previous emergencies and would undoubtedly do so again if tasked. However, as the UK Resilience Framework[43] makes clear: *"Armed Forces are facing pressure as risks multiply and diversify both at home and overseas, and they cannot be the first port of call whenever an emergency hits. The armed forces will continue to*

frameworks—beyond good faith interpretations of 'call off' arrangements—that will come near underwriting the delivery of such assistance as effectively and efficiently—as seamlessly—as would be required and expected by the public[zzz].

Yes, we are talking about a low probability / high consequence catastrophic risk here. However, given the orders-of-magnitude difference we are talking about in respect to the locally disastrous[58], compounding, impacts of Storm Desmond, Eva and Frank in 2015 and the catastrophic impact of the European floods in 2021, the idea that the sector, DfT (as LGD), and the Devolved Administrations, should discount the risk of such an event occurring in the future without developing any sort of national mutual aid response contingencies is becoming increasingly unconscionable.

The point to consider here is that precedent for national mobilisation of capabilities between areas already exists. In the United States, the Emergency Management Assistance Compact (EMAC) has provided a framework for the movement of extraordinary amounts of personnel, kit and resources between unaffected States to those impacted by disaster. Based on a set of straightforward templated forms the EMAC process provides the ability to move **any** resource one state wishes to utilize to assist another state, whilst also creating an auditable trail that allows the effective reimbursement of the lender if required.

Due to what was perceived as its primarily too 'highways focussed' bid into the recent LRF Innovation Fund competition, a project to develop a mutual aid system modelled on EMAC, but inclusive of elements to draw in key private sector capabilities that are omitted from the US model, failed. This is despite the EMAC framework having demonstrably transformed the US sector's ability to collaborate and to coordinate lifeline recovery following anything up to catastrophic level events.

Given the projections for future weather events becoming more extreme—potentially in the very near future—combined with the findings of the Covid-19 Inquiry, publication of the UK Resilience Framework and other committee findings, it appears prudent that this *Lessons* recommendation should be reemphasised and made more urgent.

Recommendation 16: The nature of contemporary extreme-weather events has reached a point where it is of utmost importance that DfT commission the development of an emergency mutual aid, supply chain, and professional-networking framework contingency. This should operate on a pan-regional basis to negate the risk of neighbours being unable to assist each other in an emergency because both have been impacted to their capacity by the same event (rephrased from Lessons Review)

play a vital supporting role to the civil authorities in resilience but will not be asked to take on an enhanced role." (p.29). This is an important statement within UKGRF, because it reinforces military Joint Doctrine in underlining the importance of designated civilian Cat 1 and 2 responders developing their own substantive plans and contingencies without an expectation that military assistance will be available.

[zzz] Reference has been made to the author in respect to the new Flood Resilience Taskforce, which has been convened by the new Government, as a possible mechanism for this coordination work. However, as this group has—to date—not issued any minutes or other outputs, it is not clear to the author how comprehensively highways issues are included in this group's mandate.

4.4 Suitably Qualified Experienced and Empowered Personnel (SQEEP)

In 2021 the Joint Committee on the National Security Strategy recommended:

> *"...that the Government oversees a programme of 'exercises' to plan for major regional extreme weather events with multiple cascading effects. It should involve local and regional actors in these exercises, including key CNI operators, and use them to clarify and communicate roles and responsibilities at a national, regional and local level"*[59]

In response to the JCNSS recommendation, in 2023 the UK Government Resilience Framework set out a plan for the development of a National Exercising Programme to "*validate plans; to develop competencies and give them practice in carrying out their roles in the plans; and to test well-established procedures and identify areas for refinement and improvement*" (p.62).

As was discussed in the *Lessons* review, exercising should only be undertaken in order to test already-trained competencies and prepared organisational structures, not to pressurise untrained individuals' or teams into improvised responses[60]. This point has recently been underlined with the publication by the UK Resilience Academy of its guidance on Organisational Resilience[61]. Whilst this output is aimed at government Departments and their arms-length institutions, the guidance it provides is equally useful for councils, highway authorities, and private sector contractors. Notably, the guidance advises on the importance of **preparation** for disruptions that may either evade or overwhelm existing risk controls. It suggests that this preparation should span the following elements of capability:

- Doctrine, powers, plans and procedures.
- Equipment, infrastructure, supplies and logistics.
- Information and communications.
- Suitably Qualified, Experienced and Empowered Personnel (SQEEP).

Whilst the first three points align with the preceding section's call for greater urgency in developing mutual aid contingencies, the fourth point, chimes precisely with the *Lessons* review's first observation:

> *"The concept of Suitably Qualified, Experienced and Empowered Personnel (SQEEP) appears to be useful in helping to understand how effectively Local Highway Authorities are able to engage in multi-agency integrated emergency management."* (p.18)

There is, undoubtedly, an admirable level of experience and competency within the UK highway sector to manage highway operations during weather events. There are also qualifications for winter service delivery (e.g., winter decision making). However, when it comes to interoperability, i.e., the ability of highways personnel to work effectively with other responders and their partner agencies in delivering Integrated Emergency Management (IEM), the picture since the publication of the *Lessons* review remains obscure.

The delivery of IEM requires SQEEP competencies at Gold (Strategic), Silver (Tactical), and Bronze (Operational) levels. This means that from the director and management cohorts down to the inspectors and field operatives, individuals and teams need to be trained in, and familiar with, key elements of emergency management and interoperability.

There are pockets where this is happening, as council directors are being encouraged to participate in Multi-Agency Gold Incident Command (MAGIC) courses. However, as

described in the *Lessons* review, in England these courses tend to be Police or Fire & Rescue led and cover key concepts and generic (often terrorism related) training scenarios, i.e., they are primarily designed for the emergency services. Accordingly, they tend to contain little input on how the impact assessment, stabilisation, and recovery of lifelines will be achieved.

Due to the devolved nature of emergency response legislation in Scotland and Wales, different approaches have been taken to delivering resilience training. In Scotland strategic training is currently delivered through the SMARTEU[aaaa] programme, which has been described, in similarity to England, as very 'Bluelight' focussed. However, a new 2-day strategic course is due to be launched by SMARTEU in early 2025, which has been specifically developed to be more inclusive of and relevant to the wider responder community.

Strategic-level training in Wales is delivered through the now well-established 'Wales Gold' course, which was developed against three bases of local contextualisation, accreditation, and cost[62bbbb]. During the preparation of this review the Wales Gold course was described to the author as having proven extremely valuable to those who have attended, as it is inclusive of local authorities, the 'basic structures' are well explained, and lines of communication are well established generally[cccc].

At the other end of the scale, as another example of leadership within the sector, but at the lower operational tier, the Tier 1 contractor Ringway has actively collaborated with the National Fire Service College to develop a LANTRA accredited course on first responder safety and dynamic decision making. This course, designed to make Ringway's operational teams' roadside activities safer, includes elements of extreme-weather incident response. This approach to using innovative training to reduce risks to frontline staff—driven by the *Resourcefulness* of a key sector contractor—should be seen as genuinely notable practice and a clear validation of the importance of understanding that strengthening sector resilience is everyone's responsibility and is in everyone's interest.

Returning to the Strategic and Tactical levels, following the drafting of the *Lessons* review, DfT did provide funding for the development of a bespoke course for highways senior management, but due to Covid-19 this course never progressed beyond its (successful) pilot stage. Accordingly, this training has never been tested in a major exercise.

In fact, the last time the sector was given the opportunity to test itself in a regional exercise was during FloodEx22 in November 2022 (Box 6)[dddd]. Whilst this exercise integrated and tested highway sector response in respect to Rapid Impact Assessment, in line with its highways focussed objective, it was clear that many participating authorities missed the opportunity to actively field test their highways contingencies. In addition to this, although National Highways—which purports to be a sector leader in resilience[63]—had participated in the planning, no NH representatives participated in the exercise at all.

This lack of resourcing of consistent training and exercising in the principles of Strategic, Tactical and Operational Integrated Emergency Management must be argued as representing a significant gap in sector resilience. One way to remedy this lacuna could be to develop a

[aaaa] Footnote: SMARTEU: Scottish Multi-Agency Resilience Training and Exercising Unit
[bbbb] Footnote: Local contextualisation – to Welsh legislation; Accreditation – the course provides opportunity as a component of an optional Masters-level qualification; Cost – it is much cheaper to deliver the course locally than at the Emergency Planning College.
[cccc] Footnote: Personal communication - Darren Thomas (14/11/2024)
[dddd] Notice of conflict of interest: the author of this review Dr Hugh Deeming is the principal designer of the Stormchain Highway Rapid Impact Assessment process and a director of Stormchain Global Response Ltd.

sector Emergency Management Manual to provide a mechanism for realising the sector's critical importance in managing emergency and disaster risk. Such a manual (based on the PIARC Disaster Management Manual)[eeee] would provide a framework for strengthening and supporting sector IEM competency development tailored to the sector's critical function of delivering lifeline resilience.

Irrespective of the current lack of a comprehensive manual, as a means to increase the sector's knowledge of how it can contribute to the delivery of multi-agency Integrated Emergency Management, a successful bid into the DfT Transport Research and Innovation Grant (TRIG) competition in 2022 did result in the creation of new resources to support highways practitioners facing 'their worst day'.

The *Virtual Operations Support (VOS) for Rapid Impact Assessment* project, was led by The East Riding of Yorkshire, with support from Dumfries and Galloway, Derbyshire, Staffordshire, Westmorland and Furness, and Cumberland.

These authorities were all keen to develop processes to support their operations during major incidents and following the data collection, a framework was developed to inform the way highway authorities can harvest relevant information in real time. This involved the development of a functional GIS display[64], which aggregated in one place the key sources and types of information that had been identified as potentially most important in supporting highway managers' situational awareness (e.g., public reports to call centres, CCTV, field operatives, and weather-forecast suppliers).

[eeee] Footnote: https://disaster-management.piarc.org/en

Box 6: FloodEx22 - deployment of Stormchain Highways Rapid Impact Assessment

FloodEx22 (FX22) was a major exercise focussed on testing the response of 20 participating Local Resilience Forums to scenarios based on major coastal and river flooding. The major 5-day exercise was a collaboration between the Local Resilience Forum (LRF) members of the Trent and East Coast Flood Groups, with support from Cabinet Office (CO), Defra and DLUHC.

Despite two unavoidable delays—occasioned initially by the COVID-19 pandemic and then by the death of HM Queen Elizabeth—the exercise went ahead in November 2022. However, due to the upheaval some LRFs were unable to participate as fully as they had planned, with only 55% of the exercise's planned injects being instigated.

The exercise was based on a scenario of two storms (Isaac and Janet) traversing the country over two days, with the LRFs along the River Trent catchment tested by Storm Isaac, then the remaining east coast LRFs involved in the response to Storm Janet.

Exercise activity included live play (e.g., testing National Fire and Rescue Hi-volume pumping capabilities) and table-top elements, dependent on each LRFs' exercise objectives. Whilst National Highways had participated in exercise preparation activities, the organisation did not participate on the day. This is a concern, because the SRN will undoubtedly have a role to play in any major coastal flood event (e.g., evacuation of communities, coordination of Strategic Holding Areas (SHA))

The inclusion of one specifically highways-focused objective was directly informed by discussion in the *Lessons* review in respect to the importance of using exercises to fully test highways contingencies, rather than simply as 'injects' (e.g., as an inject, "local bridge has been damaged", can be 'managed' by the coordinating group simply agreeing that the road should be closed, whereas testing a contingency will involve the validation of a full highways response).

The *Lessons* review proposed that "*objectives focussed on evaluating how highways-related scenarios are managed add value to injects because they provide a substantive framework for the sector to test itself, and its collaboration with partners, within the parameters of the broader exercise.*" [p.62]

As an additional incentive to test highways related contingencies, DfT provided funding to onboard 7 participating authorities onto the Stormchain Rapid Impact Assessment system:

- Derbyshire (Storm Isaac)
- Staffordshire (Storm Isaac)
- Hull City Council (Storm Janet)
- East Riding of Yorkshire (Storm Janet)
- North-East Lincolnshire (Storm Janet)
- North Lincolnshire (Storm Janet)
- Cambridgeshire (withdrew from exercise)

Through the course of the exercise's main two days, Stormchain was used to create a series of Rapid Impact Assessments to provide situational awareness for participating highway managers, Tactical and Strategic Coordinating Groups and Exercise Control (FxCON) in London.

The reports generated by Stormchain were also shared with the team from the National Situation Centre (SitCen) at FXCON, to provide them with an indication of the quality and consistency of highways data that *could* be available during a major incident. *NB. SitCen is the arm of the Cabinet Office/COBR incident coordination function that generates situational awareness at national scale.*

Over the course of the exercise over 30 Rapid Impact Assessments were created and validated by highway managers, before being shared with the respective coordinating groups. As each Rapid Impact Assessment was conducted in a consistent way, this offered unprecedented situational awareness of highways impacts to exercise participants and observers.

Following debriefing in the days after the exercise:

> *Lt Col Andy McCombe stated "as Exercise Director for FloodEx22 I am delighted to note how successful Stormchain was during the exercise, offering a step change in the management of highways incidents. Having spoken to colleagues since the exercise I noted that the capability met their needs, and they are keen to progress the roll-out of the programme."*

> *A Staffordshire County Council user stated "Overall, the use of Storm Chain was simple and effective. We printed out the event summary report and used this in our own Authority Reporting during the event. I feel you and the developers should be very proud of a software system which achieved everything required during this one-day Exercise."*

When participants who had used Stormchain were asked to rate the statement "*I think Stormchain adds a useful capability to the way emergencies can be managed by the highway sector?*" it received a 92% positive rating.

Across the wider exercise cohort, which didn't have access to Stormchain, the lack of an alternative to this consistent rapid impact assessment process was highlighted as a specific gap which needed to be filled if LRFs are to be able to effectively prioritise recovery operations in the future.

This was a revealing finding given how much effort had been put into creating the 'Flooded Properties' [which only counted flooded properties], reporting system for the *ResilienceDirect*™ (the Government's preferred IT-platform for sharing emergency information), but which was subsequently discontinued. This had left LRFs to create their own, inherently inconsistent, and usually generic or property-focussed RIA processes.

When SitCen asked for a list of prioritised and geo-located incidents, Stormchain output took 90 seconds. This contrasted with anecdotal evidence from related work where a participant stated "*if* [that storm] *was to happen again we would still revert to paper, pens and spreadsheet*"

Previous major exercises have only rarely integrated substantive *tests* of highways operations directly into exercise objectives. Accordingly, what the inclusion of Stormchain into the activity was able to seed, was a realisation amongst the user cohort of the value of a nationally consistent Rapid Impact Assessment. FloodEx22 confirmed, that consistent RIA creates invaluable Shared Situational Awareness, seamlessly, from local teams within an authority or multi-agency coordinating group, up to the national-level coordination structures and groups.

During the development of the Dashboard two principal challenges were identified, which clearly illustrated why it was important to develop a framework methodology, rather than to expect that a single method would be sufficient for creating an operational dashboard that would work for everyone. These challenges were:

1) The current lack of consistent/complementary approaches to data management within councils, with different systems (e.g., ArcGIS, MapINFO) and different data formats (e.g., WFS, DATEX II, .CSV, .SHP) being used by different data suppliers, different councils, and even within different departments within the same councils across the country.

2) Closely related to challenge 1, is the general tendency for councils not to see resilience and emergency planning considerations as pertinent to the use cases put forward to justify types of data collection by other teams.

A good example here is the collection of CCTV footage which tends to be focused on enforcement, so clear protocols often exist between CCTV centres and the Police and any council enforcement teams. Whereas, beyond the Strategic Road Network's operation centres, CCTV's obvious potential to inform highway managers' situational awareness in real time during major incidents on their local networks can be neglected (although there are good examples of CCTV being used in this way, e.g., Derbyshire's new control centre).

In terms of less technical outputs, the project also adopted a recommendation of the Manchester Arena Inquiry[65] in respect to the importance of checklists in supporting

individuals and teams needing to operate in high pressure environment of incident response. Two outputs, a *Major-Incident Support Tool* and *Highway Operations Manager Major-Incident Checklist*, are intended to begin to normalise the notion, that highway managers who have been trained and equipped with checklists will be more effectively empowered to respond to major incidents in the future.

Given the evolving nature of the extreme weather risks that have been discussed in this retrospective, and the mixed progress made by the sector in embedding the *Lessons* review recommendations, this section on Suitably Qualified Experienced and Empowered Personnel (SQEEP) bears particular relevance.

In the 3 years since its publication there are many councils who have still not integrated its findings into practice (Figure 3). This suggests that there are still people working within the sector who do not fully appreciate the critical importance of understanding how their work supports national resilience by protecting community lifelines against climate change and extreme weather risks.

These reviews have introduced new ideas (e.g., highways as *lifelines*), but as with the *Lessons* review, the findings of this report, including the analysis of the first *Hazards* survey, suggests there is a need for driven engagement with these ideas. In order to create the cultural change required to achieve this, the sector's leaders need to understand for themselves this new climate-risk space into which the sector is currently being pitched. It is only through leading the sector through a period of familiarisation, training, and subsequent regular exercising that this pitching into risk will transform into the required confident strides to create a well-adapted and climate resilient highway sector.

Recommendation 17: DfT and UKRLG should develop a sector specific *Emergency Management Manual*, based on best UK civil protection practice (e.g., JESIP[ffff]), but tailored to inform and structure the sector's critical roles in both collaborative emergency management and in leading the delivery of critical lifeline resilience.

Recommendation 18: DfT should collaborate with the UK Resilience Academy (UKRA) to set criteria for sector senior leadership roles that must include focussed competency development in the delivery of Integrated Emergency Management (IEM).

[ffff] https://www.jesip.org.uk/

Summary

5. Summary

This retrospective was commissioned by UKRLG in order to identify key gateways or barriers to strengthening sector resilience that have been identified since the publication of the DfT *Lessons Review* in 2021. **This retrospective does not negate the need for highway operators and owners to address the observations made in the *Lessons* review** (Appendix 5). Rather, the additional recommendations made here reinforce the urgency with which the sector needs to learn from and adapt to the increasing prevalence and impacts of extreme weather events, both in the UK and overseas.

Whilst the nation's legal duty to decarbonise by 2050 is driving a range of critically important work to reduce the sector's carbon footprint, this is only half of the story. Increasingly, extreme weather events that are occurring today are impacting highways and cutting communities' lifeline connections already. This means that as well as decarbonising, we need to apply equal effort to adapting to climate effects by reducing our infrastructure and systems' vulnerabilities to hazard events. This will require a shift in approach, from the sector's traditional understanding of extreme weather as meaning *snow and ice*, to an encompassing all-hazards approach to delivering business-as-usual.

Understanding resilience as a system property across six key domains (2.1.2), allows us to take a perspective on highways that encompasses not just the tarmac and highway structures, but all aspects of the system: from bridges to on-call rotas.

Since 2020 there have been a series of extreme events (2.2), which demonstrate the challenges we face. The European floods of 2021 should be seen as the precedent for the type of high consequence regional-scale catastrophe that this review is focused on preparing the UK highway sector to experience.

In order to understand how best to enhance the sector's resilience, however, there is a need to understand the baseline from which we are working. The Climate Change Committee, the National Infrastructure Committee, and the National Audit Office, have all identified the paucity of consistent data that exists in respect to local roads (2.3.1). Without this data it is impossible to understand the nature and local complexities of the adaptation challenge.

In November 2023 UKRLG circulated its initial *Hazards Survey*, which for the first time sought to explore Highway Authorities' experiences of a range of hazards and their initiatives to mitigate them. This retrospective presents a preliminary analysis of survey responses by a representative sample of sixty English and Scottish councils.

It was found that the findings of the 2021 *Lessons* report were still under review by the majority of the respondents. Worryingly, one explanation for this is that under the pressures presented by delivering Business as Usual, councils are simply struggling to grasp opportunities for implementing important and beneficial change.

In respect to flood hazards (3.1.2), it was found that the different approaches councils have to recording flooding effects on their infrastructure meant that it was difficult to obtain a clear understanding of their relative hazard exposure. Here the survey exposed an issue with data collection, in that respondents had reported difficulty in collating consistent information in respect to hazard effects, because the data—if it was collected at all—was held within

different silos within the council (e.g., Highways, Adaptation, Lead Local Flood Authority (LLFA), making it hard to access.

The review then discussed flood hazards specifically from the perspective of their risk-to-life effects (3.1.3). Here river fords and crossings, underpasses, and aquaplaning were discussed as presenting hazards that could be enhanced by climate change, thus amplifying litigation and reputational risks if not effectively managed.

When asked about their asset inspection regimes (3.1.4), it was found that a majority of councils operated a risk-based approach that should be capable of identifying hazard hotspots very effectively, making their reporting straightforward. Yet, of all the survey respondents only two provided information that suggested they had a precise (easily interrogated) dataset of individual flood incidents on their networks.

In respect to councils' ability to respond to the Met Office daily Flood Guidance Statements, only 65% of the respondents using the risk-based inspection regime also had processes in place to proactively react to Red, Amber and Yellow warnings (3.1.5).

In discussing landslides and other geohazard risks, the survey really started to draw out potential inequities in respect to councils' hazard exposure (3.1.6). Here it was found that 55% of the reporting 'Pennine 17' authorities had experienced landslides during the year, compared to 23% of the whole sample. It was proposed that this may be creating inequitable costs for those authorities needing to manage them. This question can only really be answered through applied research, so it has been good to see that the British Geological Survey is keen and willing to work with the sector on this (e.g., the NIVAR project).

The survey identified significant variability in respondents' take up of new technologies and best practice. For example, the majority stated having no intention to adopt either of the LiveLabs 1 projects' climate adaptation innovations (i.e., smart gully sensors, winter service). A minority reported adopting either climate zone or route-based weather forecasting to support their winter decision makers. There was also a minority with membership of the NWSRG, the leading group responsible for developing the sector's winter service code of practice.

Despite these low figures, it is known that there are countless innovations being trialled and implemented around the country. Of which, Section 3.1.7 focused on the CReDo project and the roll out of the National Underground Asset Register (NUAR). These two innovations are focused on increasing our understanding of the subsurface, particularly in respect to interdependency risks. As highways ultimately host, carry, or connect, all our critical infrastructure it was suggested that concerted effort should be applied to collaborations with these project teams, principally to better understand extreme weather risks from an 'aligned lifelines' perspective (e.g., 'lifeline bottleneck' bridges such as Tadcaster).

The range of Asset Management Systems currently in use was identified as a barrier to consistent data collection, because they all use client-defined attributes and metrics (3.1.8). Accordingly, as a vital step toward standardisation, it was suggested that the key sector groups agree a set of precise operational metrics for these systems, allowing the measurement and recording of extreme weather impacts and their remediation costs in a consistent way.

Although this review has an all-hazards focus, respondents were asked questions in respect to traditional winter service (3.1.9). Whilst innovative use of salt alternatives and other technologies were identified, the uncertainty in respect to what a warming climate means for winter service in the medium to long term led to a proposal that the NWSRG should be empowered to carry out regular reviews of the service, to identify potential cost or efficiency savings that could be redirected into all-hazards risk reduction.

Section 3.2.1 identified an opportunity for 'extreme weather' metric development across the sector to be informed by the requirements of the Climate Change Act's, Adaptation Reporting Power (ARP). This would ensure that if the ARP is rolled out more fully, the sector will be ready in advance. The NaFRA analysis that identifies that 38% of the network is exposed to flood risk only emphasises the importance of this.

Having presented the initial *Hazards Survey* findings, the review then shifted its focus onto more substantive subjects, framed through the importance of DfT as the sector's principal resilience facilitator.

In discussing adaptation (4.2) from the perspective of SuDs, it was agreed that there are many impressive on-going projects focused on delivering benefits at the site, source, and regional scales. Such projects are undeniably important in reducing local risks. However, recent extreme events have begun to reveal that whilst such schemes can provide additional *time* to react, there is a growing need to understand the increasing risk of roads acting as floodwater pathways or as unplanned stores for exceedance flows during extreme events. This becomes a balance, where surrender of some network function to direct water away from people's homes and businesses may become inevitable.

There are other links and assets that should be genuinely regarded as community *lifelines* and designated accordingly as critical components of a resilient network. Here again, the need to collect and collate consistent data is underlined, as without such data it will be impossible to inform and deliver effective and proactive adaptation.

Section 4.3 then returned to DfT as the sector's resilience facilitator, whilst understanding that the sector itself bears equal responsibility to develop and implement resilience good practice. DfT's on-going development of *Hazard Profiles* was identified as providing potentially very useful resources to support councils in understanding their full risk portfolios.

The importance of DfT's re-emphasised Lead Government Department (LGD) role in emergencies was highlighted as an impetus for the Department to actively develop contingencies and arrangements for helping the sector prepare for European-Floods scale emergencies (e.g. a national Mutual Aid framework).

Returning to the primary observations of the *Lessons Review* the final section restated the importance of highway practitioners at all tiers of authority and delivery being Suitably Qualified, Experienced, and Empowered (SQEEP) to deliver their roles when required, through the institutions of Integrated Emergency Management (IEM) (e.g. interoperability). This included the importance of resourcing, training, and exercising individuals and teams so they can perform as well as possible on their worst day.

The three principal priorities, which carry forward from the Lessons review remain, the importance to the sector of:

1) ...Suitably Qualified Experienced and Empowered Personnel (SQEEP) to manage the resilience of our lifeline highway network.
2) ...consistent Rapid Impact Assessment to inform effective response/recovery and adaptation (Appendix 4).
3) ...developing pan-regional Mutual Aid contingencies (inc. the private sector)

Finally, to support and direct all lines of activity focused on reducing risk from extreme weather hazards, it was proposed that UKRLG should develop a dedicated Emergency Management Manual as a component part of a revised sector Code of Practice.

Recommendations

6. Recommendations

Recommendation 1: Sector professional bodies and DfT should review whether the current after-the-event approach to "Wet weather funding/flood resilience" payments, which follows acute extreme weather impacts, should be re-formalised to create a substantive budget and funding framework for adaptation to, reduction of, and recovery from chronic and acute extreme weather risks.

Recommendation 2: DfT and Highway Authorities should jointly agree the frameworks necessary for councils to conduct Climate Change Risk Assessments that are not wholly future looking but encompass the full range of contemporary risks for which greater resilience is needed *now*.

Recommendation 3: DfT and the professional bodies should commission a review, led by UKRLG, on whether the legislation and regulations in respect to flood water management and safe use of highways in flood conditions (e.g., warning signage) are fit for purpose.

Recommendation 4: UKRLG to lead sector bodies in a collaboration with the Met Office to develop principles and techniques for consistent and more location specific geographic domain and weather hazard forecasting for application in extreme weather planning and response.

Recommendation 5: As part of an update of the *Well-Managed Highways* code of practice, UKRLG should work with the British Geological Survey (BGS) and relevant Local Highway Authorities to assess and define the data and insight on highway network geohazards that should be consistently collected and shared by Local Highway Authorities as a matter of course.

Recommendation 6: DfT should work with MHCLG / UKRI to extend the remit of the CReDo project and apply it to local highway sector. Defining the scope / nature and brief would be a logical first step to understand and describe the logic and locus of highway asset criticality assessment, and with it provide a compelling case to fill what is clearly a sector void in understanding and application.

Recommendation 7: DfT should collaborate with DSIT in the development and operationalisation of a resilience use-case for the National Underground Asset Register (NUAR), which includes the development of a methodology through which NUAR can inform multi-agency situational awareness and decision making in respect to the integrated management of emergency risks (e.g. potential impacts on 'lifeline-bottleneck' assets).

Recommendation 8: DfT should define the essential criteria for the broad sector adoption of consistent Rapid Impact Assessment (RIA) as part of all Local Highway Authorities' emergency planning contingencies.

Recommendation 9: DfT should act to improve Local Highway Authority 'Step-in' access in respect to property adjoining highway assets, to allow the stabilisation and restoration of lifeline function to critical assets following damage resulting from extreme weather events. This should include exploring the feasibility of changing the law to allow this.

Recommendation 10: Led by UKRLG, the sector should define template contract clauses, whose function is to allow term contractors to carry out work under emergency conditions or as an exigency for their clients following extreme events, without compulsory recourse to a competitive process.

Recommendation 11: Led by the UK Bridges Board and supported by DfT, the aims and objectives of the original Temporary Bridges Portal initiative should be reassessed. New focus should be placed on outlining, developing, and delivering a portal that is able to support expert-agreed contingencies and a national (Mutual Aid) response capability for lifeline bridge loss.

Recommendation 12: Led by the UKRLG ABC Board, the Asset Management Group and other boards should develop consistent metrics and technical methodologies for recording the impacts and remediation costs of extreme weather hazards in accordance with asset information management principles.

Recommendation 13: Led by the UKRLG ABC Board, NWSRG should work with the Met Office to develop an iterative 5-yr review process to ensure winter service delivery is fit for purpose in the context of climate change risks. Considering the sector's increasing need to understand extreme-weather risk management this process should drive an all-hazards resilience approach, rather than solely snow-and-ice focus.

Recommendation 14: Led by UKRLG, sector national groups should collaborate to agree key variables (i.e., questions) and mechanisms (e.g., surveys) for the collection and consistent quantification of highways specific extreme weather / impact data. These should be developed in collaboration with Defra to ensure that the data collected are consistent with and usefully inform any future sector Adaptation Reporting Power (ARP) requirements.

Recommendation 15: UKRLG should commission a task and finish group to review and refresh the *Well-Managed Highways* Code of Practice as it relates to resilience and, specifically, to the designation of Resilient Networks. The review should focus on providing guidance that defines an appropriate methodology and standards to:

- … ensure—as far as is reasonably practicable—the maintenance of all-hazards resilience and essential functionality of key lifeline-designated routes
- … underpin safe procedures (inc. communications) for the in-extremis sacrifice of asset function when managing hazard effects which overwhelm the network's drainage capacity (e.g., flood pathway management, temporary floodwater storage)

Recommendation 16: The nature of contemporary extreme-weather events has reached a point where it is of utmost importance that DfT commission the development of an emergency mutual aid, supply chain, and professional-networking framework contingency. This should operate on a pan-regional basis to negate the risk of neighbours being unable to assist each other in an emergency because both have been impacted to their capacity by the same event (rephrased from *Lessons* Review).

Recommendation 17: DfT and UKRLG should develop a sector specific Emergency Management Manual, based on best UK civil protection practice (e.g., JESIP), but tailored to inform and structure the sector's critical roles in both collaborative emergency management and in leading the delivery of critical lifeline resilience.

Recommendation 18: DfT should collaborate with the UK Resilience Academy (UKRA) to set criteria for sector senior leadership roles that must include focussed competency development in the delivery of Integrated Emergency Management (IEM).

Appendices

Appendices

Appendix 1: The condition and maintenance of local roads in England

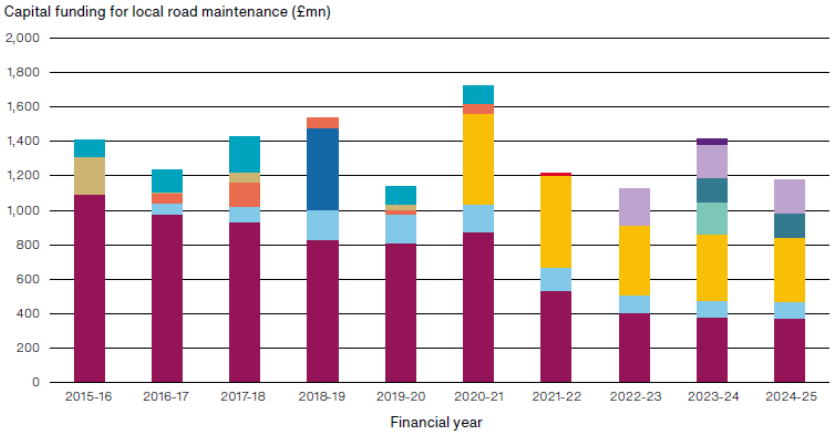
Appendix 2: Hazards Survey: Method limitations

Appendix 3: Desktop analysis of fatalities from vehicle/water-hazard interactions

Appendix 4: The Five-Stage Rapid Impact Assessment Process

Appendix 5: Observations reproduced from Lessons from Extreme-Weather Emergencies (Deeming, 2021)

Appendix 1



	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25
Total highways maintenance (£mn)	**1,410**	**1,232**	**1,425**	**1,539**	**1,139**	**1,722**	**1,218**	**1,125**	**1,413**	**1,176**
Highways Maintenance Block (needs)	1,093	979	935	829	810	874	534	407	382	375
Highways Maintenance Block (incentive)	0	59	88	173	169	160	134	102	96	94
Local Highways Maintenance Funding (Budget 2018 top up)	0	0	0	480	0	0	0	0	0	0
Potholes Fund	0	0	0	0	0	530	534	407	382	375
Pothole Action Fund (PAF)	0	59	141	57	28	53	0	0	0	0
Wet weather funding/flood resilience	217	11	58	0	28	0	0	0	0	0
Pothole repair funding (one off top up in 2023-24)	0	0	0	0	0	0	0	0	188	0
Network North uplift	0	0	0	0	0	0	0	0	141	138
Highways Maintenance Challenge Fund	101	123	203	0	105	106	0	0	0	0
CRSTS funding settlements adjustment	0	0	0	0	0	0	0	209	196	193
Traffic signals maintenance scheme awards	0	0	0	0	0	0	16	0	0	0
Traffic signals maintenance	0	0	0	0	0	0	0	0	28	0

Source: Figure 7 in National Audit Office report: *The condition and maintenance of local roads in England* (NAO, 2024: p.25)

Original title: "*The Department for Transport's (DfT's) provision of capital funding to local authorities in real terms, 2015-16 to 2024-25*

Since April 2015, DfT has reduced the funding it provides in real terms through its Highways Maintenance Block (needs) fund and has had 11 other funds through which is has provided funding"

Note: *"Wet weather funding/flood resilience"* payments total £314m between 2015 and 2020.

Appendix 2

Hazards Survey: Method limitations

Methodological limitations and opportunities in respect to data standardisation

During the period the survey link was live it became clear that the questions being asked were in many cases challenging for individuals within councils to answer. The *Winter* survey's format had clearly become institutionalised, so the questions could be answered each year relatively easily by the winter service manager who had the data to hand.

Issues around administrative burden

In the case of the *Hazards* survey, this was asking questions that were either more detailed than normal or fell outside that individual respondent's area of expertise and/or ability to answer. Representations were made that copies of the survey needed to be sent across councils to other teams (e.g., Lead Local Flood Authority, Drainage, Assets), making survey completion a team enterprise.

This may explain people's reticence to complete the survey, given the perceived additional burden this level of collaboration would have required over and above that expected for the *Winter* survey.

The National Audit Office too, has identified concerns over placing additional administrative burden on councils as a justification for DfT having not been collecting a range of data that would be useful in understanding road condition and maintenance challenges.[19] However, it should be seen as encouraging that DfT has now accepted the need to work with the sector to develop standard metrics as a stated goal in its (draft) Adaptation Strategy.

Issues around data standardisation

As a pointer to inform this work on metric development, differences emerged in the survey in respect to the level of detail in which some respondents were able to answer the questions. A primary example of this was identified in respect to the question "*During 2023, have you had any surface water flooding events that has/have affected your network with direct impacts or potential to cause serious harm/damage/risk to life?*"

Of 34/64 who responded 'Yes' to this question the average of surface water flooding incidents given was 4, with a range of 1-27. This indicated that these council's records referred to weather events (e.g., Storm Babet counting as 1), despite the fact that any single major storm would likely have caused flooding at numerous locations across the network.

However, for 2/64 authorities the answers provided suggested that flood data was collated in a very different way. These two responses (Wigan – 205 and Lancashire – 11,196) resulted from these councils having set up detailed reporting processes which logged all reports of flooding by location, rather than by incident. This was clarified and it was found that Lancashire collates all its public reports of flooding using the Performance Management Framework (PMF) offered by NHT[gggg], which has been set up to provide precise information in report form.

[gggg] https://nhtnetwork.org/nht_product/performance-management-framework/

Analysis of this question alone clearly illustrates the importance of data and question standardisation. Given this is something that the NHT member groups have been working towards across a range of indicators they are developing to monitor their own and peer authorities' performance, there is an opportunity to work with those groups to develop some expectations and indicators to inform, and to form consensus around, subsequent rounds of the *Hazards* and other adaptation and resilience surveys.

Appendix 3

Desktop analysis of fatalities from vehicle/water-hazard interactions

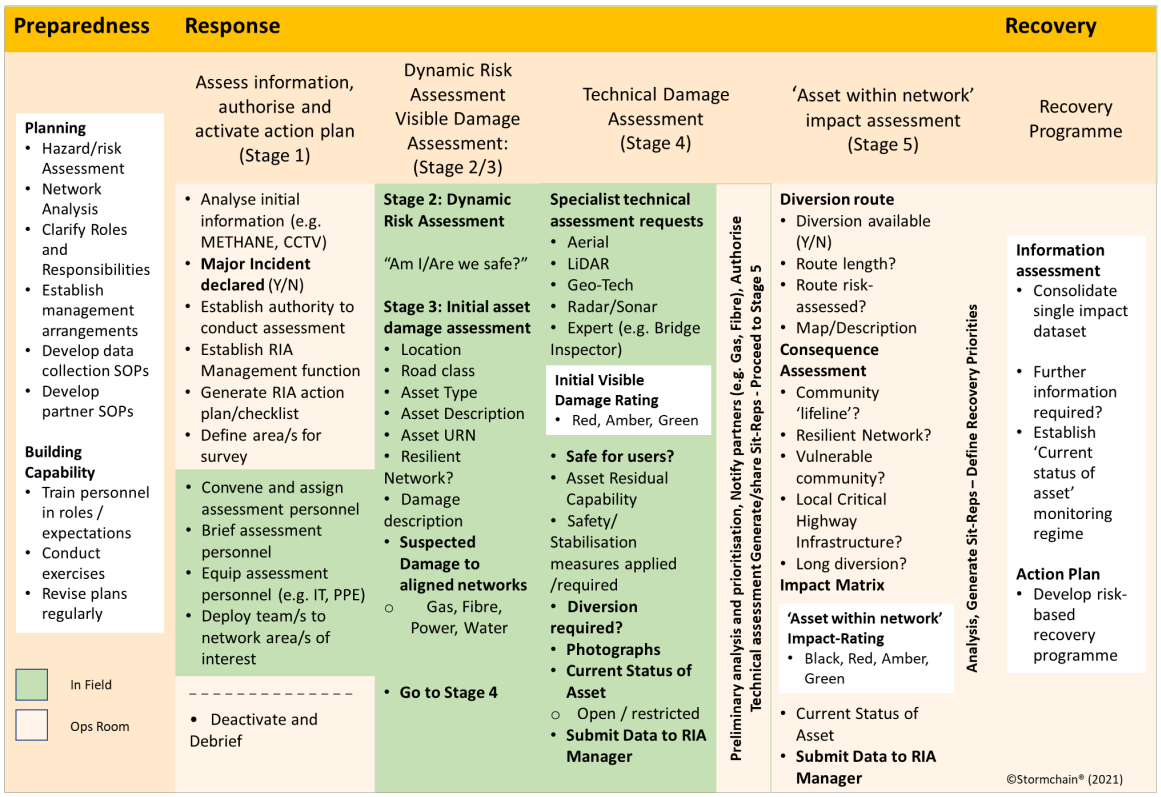
Results of a provisional desktop review of media articles and coroners' inquest reports in respect to deaths due to vehicle/ water-hazard interactions during a twelve-year period (2012 – 2024)

7	**Fatal incidents at river ford**
9	**Fatalities at river ford**
1	**Fatal incidents at flooded underpass**
2	**Fatalities at flooded underpass**
4	**Fatal incidents along flooded road**
4	**Fatalities along flooded road**
12	**Fatal incidents with vehicle leaving carriageway into water course**
18	**Fatalities where vehicle leaves carriageway into water course**
3	**Fatal incidents with vehicle leaving bridge into water course**
4	**Fatalities where vehicle left bridge into water course**
5	**Fatal incidents caused by surface water (aquaplaning)**
5	**Fatalities due to surface water (aquaplaning)**
1	**Fatal incidents where vehicle driven into water whilst evading Police**
1	**Fatalities where vehicle was driven into water whilst evading Police**
43	**Total**

Appendix 4

The Five-Stage Rapid Impact Assessment Process

(Source: Deeming and Lamb, 2023)



Appendix 5

Observations reproduced from *Lessons from Extreme-Weather Emergencies* (Deeming 2021) – for this review's Recommendations see page 82

Observation 1: The concept of Suitably Qualified, Experienced and Empowered Personnel (SQEEP) appears to be useful in helping to understand how effectively Local Highway Authorities are able to engage in multi-agency integrated emergency management.

Observation 2: The development of multi-agency information cell (MAIC) and virtual operations support team (VOST) capabilities by extreme weather affected local resilience partnerships clearly illustrates good practice in improving information management processes during emergencies

Observation 3: ResilienceDirect (RD) is the Government's preferred IT platform for sharing emergency management related information. However, the current system is not yet able to support key additional GIS map layers which identify a number of highways critical information streams, e.g., known-vulnerable structures (and information related to their intervention trigger points), assets containing multiple utilities infrastructures, live traffic data. This is a significant lack of capability. Accordingly, it appears that Local Highway Authorities need to either: 1) work with the Cabinet Office to suitably increase the capability of the RD platform, or 2) continue to develop other contingencies for dynamically sharing their information with partners (including within Strategic Coordination Centres and, trans-boundary, with neighbouring Highway Authorities).

Observation 4: The role of VM/Matrix signage during emergencies appears to be an issue that would benefit from focussed research to assess how it can best be used to reduce risks to the travelling public during extreme weather.

Observation 5: Local authority and partner agency communication strategies, which encompass and encourage active social media usage have proven that they provide both, a useful service for the public and an additional information source, which can help responders develop situational awareness during emergencies and recovery.

Observation 6: Stabilisation appears to be a useful concept for Local Highway Authorities to adopt in order to help them to understand and to explain to the public, their intentions, plans and activities following physical damage to highways assets.

Observation 7: Local Highway Authorities need to proactively manage the expectations of their partners in respect to how the highway network will be managed during emergencies. Partners should be supported in carrying out their own risk-assessments to identify appropriate (e.g., private sector) contingencies for mitigating the impact of extreme-weather effects on their assets and services.

Observation 8: Extreme-weather effects can manifest in ways that challenge 'resilient network' plans. Effective Local Highway Authorities maintain the flexibility to iteratively reassess risks in order to adjust resilient networks as circumstances require.

Observation 9: Effective prevention and mitigation of single-point failures within paralleled critical infrastructure networks during extreme-weather events (and the cascading risks they present) can be achieved through dynamic information sharing between Category 1 and Category 2 responders. Rather than detailed mapping of potential network complexities and vulnerabilities, what appears to have been critical to resilience partnerships' abilities to manage these risks during major incidents, have been the relationships developed between these organisations during the planning and day-to-day operational management stages. One aspiration that should be taken forward from this point, however, is that despite the challenges presented by the sharing of potentially sensitive data, these partnerships should be seeking to coordinate even more effectively, to develop shared understandings of all vulnerabilities in their integrated-systems prior to an event, not just in the heat and confusion of response.

Observation 10: Network prioritisation during extreme weather is an inherently political issue. Local Highway Authorities can face considerable challenges in managing the expectations of the public in relation to this. Accordingly, it is critically important that risk-based management approaches are understood and supported by suitably trained, experienced and empowered team members in corporate, strategic and elected-member cadres.

Observation 11: Responsibility for strategic and resilient-network closures during extreme-weather events should not be borne by a single agency alone. Multi-agency justification should be sought as soon as practicable, in order that a collaborative risk-based approach can be applied to the decision (e.g., to ensure the safety of motorists is not further compromised by pushing them from the strategic roads onto more vulnerable networks).

Observation 12: Local Authority and Local Highway Authority personnel who deal with extreme weather event preparedness and response need to have sufficient training and support to ensure they have the competency, and the confidence required and that they are empowered to declare a major incident, and activate a multi-agency response, when appropriate.

Observation 13: It appears that uncertainty exists about Highways England's current attitude toward supporting Local Highway Authorities in the management of designated diversion routes.

Observation 14: Given recent examples of effective collaboration between local Highway Authorities and other highways infrastructure 'owners' in repairing extreme-weather damage (e.g., the A591 in Cumbria), it appears strange that no formal mutual-aid based relationship has been proposed by the Department for Transport to develop a framework for managing future critical-repair partnerships.

Observation 15: The nature of contemporary extreme-weather events appears to be leading to a point where emergency mutual aid and professional-networking arrangements need to be developed on a regional or national basis, thus negating the risk of neighbours being unable to aid each other because both have been impacted to their capacity by the same event.

Observation 16: The military has provided critically important capabilities and capacities to hazard-affected local authorities under existing Military Aid to the Civil Authorities (MACA) arrangements. However, experience has shown that local authorities can clearly illustrate and positively affect their own resilience by developing response and recovery contingencies that do not, and should not need to, include a military component.

NB. Where conditions do dictate military input, the Joint Regional Liaison Officer, can activate the Military Assessment Team or Infrastructure Response Force, (currently at zero cost), thus providing Tactical Coordinating Groups access to significant specialist knowledge and reach-back to impressive infrastructure/engineering capabilities.

Observation 17: The Department of Transport (DfT) should engage directly with the Civil Contingencies Secretariat to design and put in place a substantive Crisis Management Excellence Programme. This would comprise suitable competency, learning, and peer-support components to ensure consistent delivery of resilience plans and contingencies by a cadre of suitably qualified, experienced, empowered, and respected personnel.

Observation 18: It is important for hazard-impacted authorities to present DfT, or in extreme circumstances the Ministerial Recovery Group, with a coherent 'ask' following emergencies. Therefore, that DfT has provided seed funding for the development of Rapid Impact Assessment (RIA) guidance and a methodology for creating a consistent information picture that provides shared situational awareness and supports the development of repair/funding priorities should be welcomed (x-ref observation 24).

Observation 19: The example of the A9 trunk road plan illustrates the critical importance of Local Highway Authority personnel's collaboration with their own authorities' resilience units to develop effective working relationships and effective emergency plans.

Observation 20: Multi-agency planning activities for extreme-weather emergencies should be regarded as opportunities to extend the 'make friends before you need them' mantra to consider potential partners from across the statutory, private, voluntary and community sectors. The goal should always be the integration of all capabilities and capacities that may help to shorten emergencies and reduce harmful consequences.

Observation 21: Cumbria Local Highway Authority's decision to operate a health-and-safety based approach to asset and personnel management during the 'Beast from the East' extreme-weather response, should be regarded as an illustration of sound practice.

Observation 22: Under current out-sourcing frameworks Highway Authorities may wish to push the operational risks of managing extreme-weather response away from themselves and toward their contractors and sub-contractors. However, it should not be forgotten that some extreme-weather scenarios bear a high risk to life. Accordingly, Highway Authorities should consider developing contractual conditions with their suppliers to ensure operator health and safety is prioritised.

Observation 23: Projections suggest that extreme-weather emergencies may occur with increasing intensity and/or frequency in the future. Preparing personnel for their role during all types of extreme-weather emergency (i.e., not just winter weather) should be regarded as a fundamental component of any authority's continual professional development programme.

Observation 24: Whilst there are useful courses currently available for preparing personnel for multiple respective roles within integrated emergency management, it is apparent that these course materials need to be reviewed to better integrate the needs of responders outside the 'blue light' community.

Observation 25: It is notable that the Rapid Impact Assessment (RIA) process used by Cumbria County Council, using trusted independent contractors, technology and 'Cumbria Ask' spreadsheet approach to documentation, has been identified as good practice and

used as a case-study by DfT to support the development of consistent Rapid Impact Assessment guidance for the sector (x-ref observation 17).

Observation 26: Cumbria's Infrastructure Recovery Programme presents a clear case study of how careful planning and innovative thinking when recovering from disaster can present genuine opportunities for local growth and for enhancing resilience.

Observation 27: Cumbria's Infrastructure Recovery Programme was made possible by the government lump-sum grant of £120m. However, the process through which this money was awarded, whilst clearly illustrative of good practice, was used because no consistent set of criteria for such applications has yet been developed (contrary to Brown et al.'s recommendation 30). Whether other Local Highway Authorities have missed out on funding opportunities because they did not use the same structured approach to impact assessment and funding requests as Cumbria is an area of uncertainty. Accordingly, to ensure fairness for those who will be dealing with future emergencies it seems appropriate to repeat Brown et al.'s recommendation that *"Government should consult Local Highway Authorities on a set of criteria to be applied consistently to emergency highway repair funding through the DfT whenever such funding is made available."*

Observation 28: Building resilience to extreme weather is best understood as a process. Accordingly, it is important that local Highway Authorities expend effort and resources in consistently striving to learn from their and from others' experiences of emergencies and by instilling these lessons into practice through a process of planning, training, exercising and validation.

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Emergency Preparedness, Response, & Recovery

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