HS2

Climate Change Adaptation and Resilience

Adaptation Reporting Power Fourth Round

December 2024

Contents

Front cover image: Visualisation of HS2's Curzon Street station in Birmingham.

Introduction

1.1 Organisation profile

Overview of High Speed Two Ltd and High Speed Two

High Speed Two Ltd was established by the Department for Transport (DfT) to develop, build and bring into service Britain's new high-speed railway, High Speed Two (HS2). We are designing, constructing and managing HS2's infrastructure along a 140-mile route between London and the West Midlands.

HS2 will link London and central Birmingham and is the longest new railway built in Britain for more than a century. The new high-speed line will connect to the West Coast Main Line in Staffordshire to allow services to continue to the North West and Scotland on the existing rail network.

HS2's British-built bullet trains will provide zero carbon journeys for tens of thousands of passengers a day. This will not only provide fast, reliable travel between Britain's biggest cities: it will create new job opportunities and boost economic growth.

Crucially, HS2 will provide environmentally responsible travel, helping to combat the climate emergency and leave a legacy of technological innovation for major infrastructure projects.

We are building the railway with our future in mind: making HS2 climate resilient is fundamental to the project. This is our second report under the Adaptation Reporting Power (ARP), established under the Climate Change Act 2008 for organisations to show how they are adapting to climate change. It provides an update on our approach, the progress we've made since our previous ARP report made under the third reporting round, in 2021 (ARP3) and our action plan for the years ahead.

HS2 was the first stand-alone project in the design and construction stage to produce an ARP report and this latest report highlights our commitment to reporting on the achievements and challenges of our climate adaptation programme before services are launched.

The construction programme is a huge undertaking, supporting more than 30,000 jobs. In addition to laying the new track, it features 32 miles of tunnels, more than 50 major viaducts, four new stations and two depots.

Working under the deck of HS2's Curzon No 3 viaduct in Birmingham.

Since our first report, construction has progressed significantly. We've started building two-thirds of the viaducts and more than half of the tunnelling is complete. We are preparing for the project's next stage, HS2's huge rail systems programme, when we'll put in place the tracks, power, signalling and overhead lines for our trains.

There have been changes to the project since our previous ARP report. In October 2023, the then government decided to cancel the Phase Two route, which would have taken the railway to Manchester. It also set out a new approach to building HS2's Euston station, which followed a pause in construction activities to explore a more affordable station design. We remain on schedule to launch services between Old Oak Common, in west London, and Birmingham in the early 2030s. Old Oak Common will serve as HS2's London terminal while we extend the line to Euston. For historical reasons, the route is often called Phase One in this report and in our published risk assessments.

Our strategic goals

HS2 represents a significant investment by the taxpayer and the long-term benefits of the railway extend far beyond high-speed rail services. The benefits are captured in the project's seven strategic goals, which set out HS2's ambition to be a catalyst for economic growth, boost opportunities for all, promote prosperity and help to combat the climate emergency by providing sustainable, climate-resilient rail travel.

Introduction

The way we travel – and the way we build our transport networks – is critical to our response to the global climate emergency. Adapting to climate change is crucial to ensure the resilience of HS2 because the climate can affect the construction and operation of the railway, its customers, staff, local communities and the environment. Without appropriate mitigation, climate change and severe weather has the potential to affect HS2 in many ways. Some of the potential impacts are shown in the chart below. For this reason, climate adaptation remains at the heart of HS2's strategy including its Environmental Policy and Sustainability Policy.

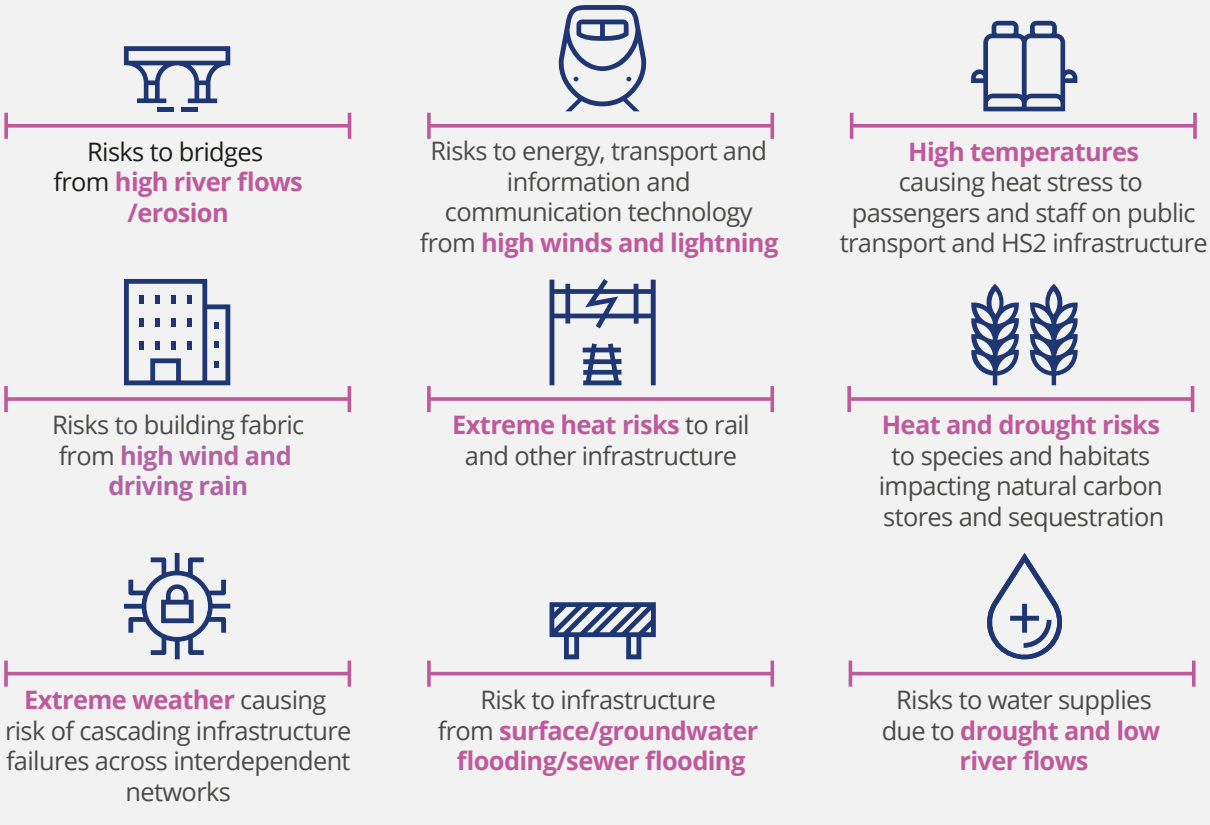
1.2 Governance, management and strategy

Our company, HS2 Ltd, is wholly funded by the Secretary of State for Transport, represented by the DfT. We are a non-departmental public body and we are treated as part of the central government sector by the Office for National Statistics. We were established to develop, build and promote HS2.

Our approach to climate change is embedded in project delivery. Our corporate governance ensures organisational oversight and provides structures and processes to manage risks and realise opportunities from climate change. We are also engaged in climate reporting, including in the previous ARP process and in our Annual Report and Accounts 2023 – 2024. In the latter, we provided initial climate-related financial disclosures consistent with the requirements of HM Treasury's guidance document[1], which interprets and adapts the Task Force on Climate-related Financial Disclosure (TCFD) framework[2] for the public sector.

Our environmental sustainability governance approach was summarised in our 2022 – 2023 Environmental Sustainability Progress Report (EPSR) and our ARP3 report, and it has remained largely unchanged. We are committed to ensuring we meet the challenges of climate change, for example, through work to understand our organisation's adaptive capacity maturity (see case study: Adaptive capacity maturity matrix).

Potential climate change risks to HS2



Introduction

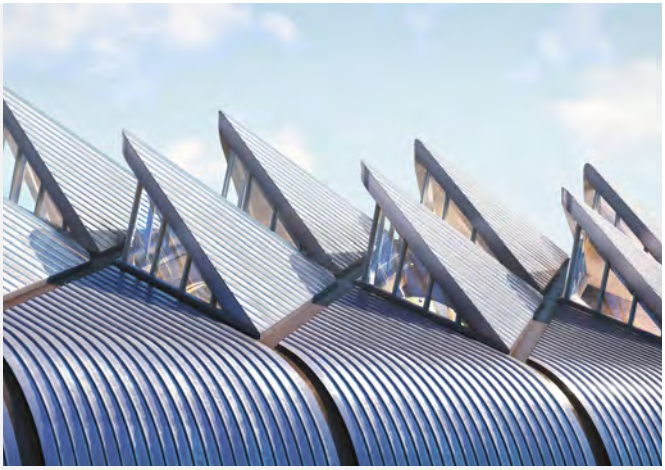
Case study

Adaptive capacity maturity matrix

As part of the Rail Safety and Standards Board (RSSB) Climate Change Adaptation Working Group, we have been looking at a new tool to assess climate resilience maturity in organisations and sectors including rail. Developed by Climate Sense working with RSSB, the tool aims to enable an industry-wide maturity assessment and development of improvement plans, fulfilling one of the actions in the RSSB Sustainable Rail Blueprint[3].

The tool requires you to input how the risks of climate change have been assessed, the extent to which climate change adaptation is embedded into decision-making, and the actions we are putting in place to protect HS2 against climate change risks. The questionnaire produces an adaptive capacity score describing our level of maturity across five states and a report with recommendations and observations. As part of the wider project, the scores can allow benchmarking across the rail sector.

Doogie Black, director at Climate Sense, said: "HS2 Ltd should be commended for their capability to make decisions that include an in-depth understanding of how best to respond to the risks posed by a changing climate. In a world that is often fixated with measuring risk, HS2 Ltd are one of the few who can demonstrate the capability of using climate risk information to build climate change resilience into their designs.



Visualisation of Interchange station roof

"This is what adaptation really is – it is about being adaptive to the risk. Information about risk characteristics is critical to adaptation, but it is not until there is a response to risk information that it can then truly be called adaptation."

We received an adaptive capacity score of Level 4 (Breakthrough Project). According to Climate Sense, a Level 4 score means we are undertaking significant experimentation to learn how to become resilient into the future. As a 'breakthrough project', we consider climate change in organisation-wide decision-making processes and climate adaptation is considered at a senior level.

More information about the tool can be found on the RSSB website[4].

Introduction

1.3 Benchmarking to standards

We have developed a set of internal design standards, including one for climate adaptation, to ensure climate adaptation and resilience are integrated into the design, construction and operational stages of HS2.

Our design standards are grounded in best practices from British and international engineering codes and standards, with modifications for nuances for HS2. We strive to develop improved climate change standards for the industry through collaborations with the British Standards Institution (BSI) as a stakeholder on the ISO 14090 Adaptation to climate change[5] standard and other emerging standards (see case study: PAS Adaption Pathways standard). The ISO 14090 standard offers a framework that allows organisations to consider climate change adaptation when developing and implementing policies, strategies, plans and activities. We have embedded its principles in our climate adaptation work. Our approach is also in line with British Standard 8631 Adaptation to climate change - Using adaptation pathways for decision making[6], and incorporates processes and requirements from HS2 technical standards.

Our wider environmental and sustainability practices are subject to external verification and audit processes. HS2's Environmental Sustainability Progress Reports are verified externally in line with the principles contained in ISO 14064-3:2019, ISO 14065:2020 and ISO 14016:2020[7] covering greenhouse gas requirements and environmental management principles. We also include annual reporting on our progress on climate adaptation. We undergo external audit covering ISO9001, ISO14001, ISO45001 and PAS2080[8] each year. Topics are selected by auditors for deeper focus sessions on rotation. In March 2023, our approach to climate adaptation was discussed.

Case study

Publicly Available Standard for adaptation pathways

We are continuing to work with the BSI and Institute for Civil Engineers (ICE), as sponsor to start to develop a new Publicly Available Standard (PAS) Adaptation to Climate Change – Adaptation Pathways for Infrastructure. The PAS, proposed by Alison Walker, climate change manager at HS2 Ltd, will provide a consistent methodology for developing and applying climate change adaptation pathways for infrastructure.

Adaptation pathways are an emerging tool for supporting good decision making to ensure infrastructure is adaptable and resilient to climate change. They allow infrastructure asset owners and managers to make decisions given uncertainty in climate change projections and can be used at various scales from large companies to smaller scale assets. This will be critical as we continue to see the unprecedented impacts of climate change. More information on work to develop adaptation pathways for HS2 is in Section 3.4 of this report.

There is limited uptake in using adaptation pathways across the infrastructure sector due to their complexity and lack of guidance. The proposed new PAS will address this gap and support wider uptake by providing an easy-to-follow methodology and case studies for retrofit and new builds. We are committed to supporting the development of guidance material and will provide expertise to steer the development of the PAS.

Climate adaptation and resilience

2.1 Climate adaptation at HS2

HS2 is being designed to operate into the 22nd century, which means it is crucial that it is resilient to a changing climate. It is critical the railway can withstand extreme hot and cold weather, heavy rain and droughts, high winds, and storms, which are becoming more common. Climate change adaptation and resilience is being integrated into each stage of the project.

Climate resilience is an evolving process. No single adaptation action or decision will deliver climate resilience. Instead, an iterative process of improvement in response to changes in environmental or socio-economic conditions, new scientific knowledge and greater understanding of processes is needed to build resilience. We are committed to evaluating and improving our work for climate adaptation, carrying out analyses and updating our climate risk assessments periodically. To align with the latest scientific evidence published in UK Climate Projections (UKCP18)[9], we've undertaken new assessments for emerging contract and programme areas. Our climate resilience and adaptation goals and targets haven't changed since our previous report, but work continues to enable evidence-based decisions that are best for the project.

2.2 Adaptation Reporting Power (ARP)

The Department for Environment, Food & Rural Affairs (Defra) has invited us to produce this report under the fourth round of Adaptation Reporting Power (ARP4) established in the Climate Change Act 2008[10]. The ARP allows the government to ask key organisations to report on the steps they are taking to prepare for climate change every five years. The reporting cycle timescale for this round has been reduced to allow for adaptation reports to be included in the analysis for the Climate Change Committee's (CCC's) independent risk advice to the government for the fourth Climate Change Risk Assessment[11] process. Recognising the shorter reporting window, Defra has advised that the focus of the ARP4 reports should be on reporting updates and progress on climate adaptation between 2022 and 2024, and providing an update to our risk assessment.

This is the second reporting round we've been involved in, having submitted HS2's first ARP report to Defra in 2021. We remain committed to climate adaptation reporting, even before HS2 is operational, as climate adaptation and resilience is fundamental to the planning consent, design, construction programme and into operations. We are proud to lead the way for large infrastructure projects in this area.

This ARP4 report is an opportunity to report on the progress in climate adaptation and resilience for HS2, supporting efforts to raise awareness for adaptation, build adaptive capacity, and make examples of good practice publicly available. It covers the following:

- Progress on climate adaptation and resilience in the last three years, grouped into three categories:
  - embedding climate adaptation and resilience (Section 3)
  - understanding new risks and challenges (Section 4), and
  - interdependent and cascading risks (Section 5).
- Progress updates on our ARP3 Action Plan based on implementation experience (see Appendix A).
- An updated ARP4 action plan for the next five years and beyond (Section 6).
- Evidence best practice case studies for shared learning.

Climate adaptation and resilience

2.3 Scope of this report

In October 2023, the then government cancelled Phase Two of HS2 in the Network North command paper. As the company charged with developing and promoting the scheme, we are responsible for bringing the work on Phase Two to a stop in a safe and efficient way while ensuring value for money. We are working with the DfT to review and refine the scope of the London – West Midlands railway, also known as Phase One, to ensure delivery of the scope required for the reduced HS2 programme.

We remain on track to launch high-speed services between our HS2 stations at Old Oak Common, in west London, and Curzon Street, in Birmingham, in the early 2030s. This section of the railway, during the design and construction stages, is the focus of our report.

The report focuses on physical climate risks and adapting to them. Further details of our work on reducing emissions and creating zero carbon journeys can be found on the HS2 carbon webpage. For more information on how we're also creating additional value, such as creating habitats, improving flood resilience for communities and carrying out nature-based solutions, see our Environmental Sustainability Progress Reports.

We are committed to reporting on risks and opportunities associated with the transition to a lower carbon economy in reporting aligned to the Task Force on Climate-related Financial Disclosures (TCFD) recommendations in our Annual Reports and Accounts.

The cutterhead of the tunnel boring machine being lifted into the east box at Old Oak Common station

Embedding climate adaptation and resilience

Climate change adaptation and resilience is integrated into each stage of the project. We consider it in business-as-usual planning as we push beyond existing standards to develop best practice for the industry. This work requires ongoing commitment and integration across HS2, the supply chain and the transport sector.

3.1 Working with HS2's supply chain

Working with our colleagues and supply chain is key to ensuring climate change adaptation and resilience is embedded in the railway. We've developed a bespoke process to assess the resilience of HS2 designs to climate change and support our contractors with design developments. This process is described in more detail in our ARP3 report. It is based on the bespoke HS2 design standard for climate change adaptation and resilience which outlines requirements contractors must follow to ensure adaptation to climate change risk. To ensure that climate change risks are considered and managed in all stages of design, the climate standard is supported by evidence-based climate assessments. The Climate Change Design Impact Assessment (CCDIA) assesses the suitability of HS2 design standards to future climate change and identifies where additional allowances may be required (see Section 4.3). The Climate Change Resilience and Interdependencies Assessment (CCRIA) categorises, assesses and priorities risks arising from climate change impacts on HS2's interdependent infrastructure.

The HS2 climate change technical standard also requires HS2 designers and contractors to provide a Climate Change Adaptation and Resilience Report (CCARR). The reports must demonstrate that the design, as far as reasonably practicable, maximises resilience to climate change, maximises the potential for adaptation to climate change and minimises the risk of loss of performance due to the impacts of climate change on interdependencies. This report remains active during the design and construction process with requirements for reviews to be carried out as the design develops and/or where there is a change in design of assets.

Case study

Designing resilient cross-passage tunnels

HS2's 10-mile Chiltern tunnel, the longest on the route, will contain 40 cross passages, short tunnels for evacuating passengers in an emergency. They need to be durable as they will have a design life of 120 years and climate resilience is critical to the design.

Most of the passages will be built under the water table so groundwater levels were considered to prevent water entering the tunnels, leading to possible flooding. Many different levels were considered as part of the design. The highest groundwater level expected over the course of the 120-year design life, including the effects caused by climate change, were used. Changes in groundwater levels can also affect the durability of underground structures. We included an additional five millimetres of concrete cover to the steel reinforcement to combat climate change and increased durability by reducing the risk of steel corrosion.

We also considered the impacts of climate change on carbon dioxide (CO_2) levels as high levels can increase the risk of carbonation of concrete structures, leading to their deterioration.The burning of fossil fuels is leading to higher atmospheric levels of CO_2 so it is important to consider future levels and how the durability of the passages might be affected. Ultimately, we concluded future projected CO_2 levels over the HS2 design life are not expected to cause accelerated deterioration of materials. We also ruled out any possible risks posed by humidity levels affected by climate change.

For more information on designing our cross-passage tunnels and the design challenges, see our Learning Legacy paper.

Embedding climate adaptation and resilience

Our main works civils contractors (MWCCs), main works station contractors (MWSCs) and onboarded rail systems contractors completing Stage 1 designs, continue to submit CCARRs. Since our last report, we have assured 10 CCARRs, covering five separate contract areas. We have provided enhanced training and guidance to ensure contractors provide design mitigation measures to address route wide residual risks at a site-specific level.

Our architects, engineers, environmental specialists and many others are working together to innovate across the HS2 project and build a resilient railway. The HS2 Climate Change Adaptation and Resilience Forum was established in 2014 and shares knowledge across the project on climate change resilience and associated issues.

The forum raises challenges and develops solutions and is part of our internal operational governance to ensure, at the delivery level of the organisation, HS2 is resilient to climate change.

In early 2022, we established the HS2 Contractor Climate Resilience Collaboration Group, one of our actions from our previous report. The group has met seven times so far. It encourages MWCC contractors to share best practice using innovation case studies and examples of how they have embedded climate resilience at a site-specific level.

Case study

Realigning the River Cole

Faced with the challenge of realigning a river, we set out to enhance the local landscape, promote nature recovery and boost HS2's climate resilience.

Our work linked to the River Cole in north Warwickshire features two large viaducts, embankments and landscape enhancements including flood compensation areas and habitat creation.

New structures and assets must be built to be resilient to the risks of flooding, so the railway can operate safely. In designing the watercourse crossings, including viaducts and abutments, we've made sure they will cope with high water levels caused by climate change.

We've designed our infrastructure to cope with a 100-year return period flow, including an additional flow allowance for climate change.

Two replacement floodplain storage areas will be created around the river to ensure it can flood and recede safely after a storm event without causing a bigger flood.

Aerial view from the northern side of River Cole

Realigning the river will also benefit the local area and enhance biodiversity. Ecological mitigation and habitat creation features will boost biodiversity while new footpaths and cycle paths will forge stronger community connections.

An HS2 Learning Legacy paper describes the wider benefits of our work on the River Cole.

Embedding climate adaptation and resilience

3.2 Working with industry and academia

We work with the transport industry, standards bodies and academic partners to better understand climate change adaptation including technical engineering issues and emerging research areas. We also share experiences of embedding climate adaptation. These partnerships help us to improve adaptation and resilience, and contribute to a learning legacy for future infrastructure projects. Our work includes the following.

- **Transport Infrastructure Efficiency Strategy Living Lab (TIES LL) Climate Adaptation Community of Practice (Completed)**

The TIES LL aimed to create performance benchmarks and agreed metrics for the transport sector. We were able to share data on climate resilience that we collected during the planning and design stage, and understand best practice, especially from operational projects, on other relevant climate metrics. The project provided important insights into potential data collection options for HS2. We are committed to supporting the industry to develop and implement a sector-wide metric for resilience.

- **National Hub for Decarbonised, Adaptable and Resilient Transport Infrastructures (DARe) (Ongoing)**

We are one of the funders for the national hub for DARe[12], which brings together UK universities and industry, policymakers and other partners to find viable pathways and solutions for a transition to a resilient, net zero transport system that works for all. Together with our construction partners, we are involved in ongoing research projects as part of the DARe project.

- **Working with stakeholder groups to share knowledge (Ongoing)**

We participate in supply chain and industry collaboration groups, discussion forums and stakeholder steering groups to share best practice. We are a member of the Infrastructure Operators Adaptation Forum (IOAF), the RSSB's Climate Change Adaptation Working Group and the Transport Adaptation Working Group. The groups have representatives from other major infrastructure sectors including transport, energy and water companies – working towards a vision for infrastructure assets and services that are resilient to natural hazards and prepared for the future climate.

- **Climate resilient railways paper (Completed)**

Our climate change team published a research paper in the Institute of Civil Engineering's journal Civil Engineering in 2024. The paper explained how climate adaptation and resilience has been embedded at every stage of planning, designing and building HS2.

- **UK Green Building Council (UKGBC) partnership on physical climate risks (Completed)**

We partnered with the UKGBC through their Physical Risk Labs Compendium of Experience[13] to help develop and test its new framework, which aims to provide a consistent methodology for assessing climate-related physical risks to buildings. Using workshops, we successfully demonstrated the application of UKGBC's framework on new build assets on a major infrastructure project and shared lessons learned.

- **Industry working group to develop rail sector climate scenarios with RSSB and DfT (Completed)**

As part of the RSSB's Climate Change Adaptation Working Group, our climate change team contributed to a sector-wide effort to agree unified climate change scenarios for the rail sector[14]. This standardised approach to climate change scenarios will be used across risk assessments and adaptation planning in the sector, ensuring consistency and effective management of future climate risks. The agreed scenarios are embedded in our processes.

- **Industry collaborations and sharing knowledge for a resilient, net zero future (Ongoing)**

We are a member of the Construction Leadership Council (CLC), working with government and across the sector to support growth, improve productivity, attract and retain talent and transition to net zero. We collaborate in the ConstructZero arm, chairing the Zero Diesel Sites Delivery Group. We contribute to workstreams under the Climate Task Group in the Infrastructure Client Group (ICG), which brings together economic infrastructure clients.

Embedding climate adaptation and resilience

3.3 Addressing climate-related construction risk

Climate resilience is embedded in the construction of HS2 through measures in the Code of Construction Practice (CoCP) and our health and safety standards. Extreme weather events in the UK have demonstrated the pace of climate change. In July 2022, the UK experienced record-breaking temperatures[15] above 40C. This followed a series of severe winter storms[16] that caused widespread damage in early 2022. Additionally, the winter and spring of 2023/24 were the wettest 18 months on record[17]. If we don't do anything, the impacts of extreme weather, worsened by climate change, could affect our construction sites, workers and our programme.

We have worked with our contractors to understand the impacts of recent events on their sites to strengthen our response to climate change and our resilience to extreme weather.

We are committed to undertaking a renewed risk assessment for the HS2 construction stage, building on the results of the Phase One Environmental Impact Assessment and including consideration for unprecedented events going beyond historic data observations. We are also committed to capturing lessons learned from the construction sector that are directly applicable to HS2 operations and maintenance works that can be shared for best practice. This work is ongoing from 2024 – 2026 and the results will be reported in future Adaptation Reporting Power reports.

First completed sections of the Chipping Warden 'green' tunnel.

Embedding climate adaptation and resilience

Innovative solutions
In the construction sector, weather management is crucial due to its potential to affect a site's productivity, performance and safety. Traditional methods to tackle this issue include considering weather forecasts in project planning, work schedules and method statements for activities. Processes are reactive and typically based on previous experience of historic weather events.

Historic weather is an imperfect representation of future trends due to climate change. Recognising the increased risk that extreme weather presents to construction sites, we have been supporting efforts to create a step-change in the processes and tools available to the industry. HS2 construction sites have been involved in research projects, innovation solutions and public challenges to identify ways to manage the impact of climate change on sites.

Our contractors are working towards a step change in the way weather is managed in the construction sector. MWCC Align has been working with an external partner, MetSwift, to develop a forecasting tool to enhance real-time and planned management of weather impacts with increased understanding of localised site conditions and artificial intelligence (AI) learning (see case study: Align JV innovative weather forecasting tool). Another MWCC, EKFB, is working with an external partner, EHAB, to improve understanding of weather impacts, integrating historical and predictive analyses of climate change. We have provided innovation funding for these initiatives and we are sharing the outcomes across MWCCs and MWSCs.

A visit to Align's site at Colne Valley Viaduct

Case study

Data hackathon to provide real-world solutions

Climate change is leading to more extreme weather events, carrying a greater risk to people's safety onsite, possible delays and higher costs. To find solutions, our innovation team sponsored a data hackathon, organised by Projecting Success, to bring together business analysts, project delivery experts and data scientists.

The teams were set real-world challenges. For HS2, they were asked to design a tool to provide real-time insight into weather events to manage decisions and optimise productivity, cost and safety. The challenge was supported by our main works contractor Align, who provided data from their onsite weather stations.

Prototype solutions developed during the two-day event included a weather tool to support day-to-day project management, where activities onsite were linked with thresholds in weather impacts. The tool was able to provide real-time warnings and forecasts of potential disruptions, and develop quantified impact management metrics for cost and time delays. Another design featured a dashboard that showed which sites were most likely to be affected by weather by using Met Office and onsite weather station data from along the HS2 route.

The hackathon was part of our wider efforts to drive innovation and progress on climate adaptation, including sharing solutions in a public forum. The solutions provided insights on methods to harness the data being collected and use it to improve decision-making.

Embedding climate adaptation and resilience

Case study

Align JV innovative weather forecasting tool

MWCC Align worked with MetSwift, through HS2's innovation programme, to gain more accurate forecasts about the weather conditions on construction sites. MetSwift uses AI and machine learning to analyse weather models and data from Align's six onsite weather stations. The resulting site-specific forecasts are found to be more accurate than traditional methods.

Many of Align's construction activities are affected by certain weather conditions: for example waterproofing can only be done in dry conditions; lifting operations can only be carried out when wind speeds are low; and concrete pouring can only take place in specified temperature ranges.

Align determined thresholds for construction activities that are affected by weather variables. It then used site-specific forecasts generated by MetSwift to more accurately plan when activities can take place, adjusting scheduling based on forecasted weather. This reduced work 'downtime' and increased safety levels on their construction sites.

By tracking site-specific weather conditions and producing more accurate forecasts, Align's sites are more resilient to changing weather conditions. For further details, listen to our HS2 podcast.

An aerial view of Colne Valley viaduct under construction. The launching girder lifts 140 tonne deck segments into place as the viaduct crosses the Grand Union Canal, which can only be conducted during periods of low wind speeds.

Embedding climate adaptation and resilience

Understanding recent experiences
Following recent extreme weather events, including the 40C heatwave in July 2022, a series of severe winter storms in early 2022, and the long wet winter and spring of 2023-24, we have been working with our contractors to understand the impacts of these events on their site activities, through the collection of evidence describing the impacts and reviewing proactive and reactive mitigations across the programme to promote sharing of best practice and learnings. Results have been presented at the HS2 contractor climate resilience collaboration group and disseminated to contractor organisations for consideration.

Collecting incident data and developing guidance
We use a data management system to report incidents, observations and operational assurance for construction. It is called HS2's Online Reporting Assurance CoSSH Environment system, or HORACE.

We've developed a dashboard in HORACE that allows us to identify and monitor environmental incidents caused by, or affected by, adverse weather during the construction phase. The dashboard uses information input by HS2 contractors to filter incidents affected by adverse conditions. The information feeds into our work programme, helping to identify focus areas to reduce risks during construction. The lessons we learn will be transferred into HS2's operational stage and we will report on progress in future iterations of the Adaptation Reporting Power cycles.

In 2024, we set up an internal Extreme Heat Task and Finish Group including our climate change team, occupational health and safety teams and HS2 contractor health and safety specialists. The group produced occupational health guidance to ensure there was a consistent approach to working in extreme heat across HS2 sites (see case study: Learning lessons from the 2022 heatwave).

Surveyor working at an HS2 construction site

Embedding climate adaptation and resilience

Case study

Learning lessons from the 2022 heatwave

We face a collective challenge to keep people safe and well on the UK's biggest infrastructure project. We have a workforce of more than 30,000, based across 350 sites, with an evolving risk profile. Our programme-wide approach and philosophy, Safe at Heart, guides our actions and behaviours, and sets out accountabilities.

In July 2022, the UK experienced an unprecedented heatwave that saw record-breaking temperatures of over 40C. Extreme weather events have the potential to cause significant impacts to the construction sector including increased safety risk for outdoor workers, work delays and site shutdowns.

HS2 contractors have an obligation under the Code of Construction Practice to mitigate the impacts of extreme weather. As July 2022 was unrivalled and it is likely that extreme hot weather will increase with climate change, we wanted to understand its impacts and support new best practices for the sector.

First, we collected qualitative data from HS2 contractors to capture lessons learned. Common impacts included outdoor activities being stood down, stopping concrete and steel fixing works, additional water permits being needed, and safety concerns for workers overheating. Mitigation strategies included rescheduling activities, providing summer-specific personal protective equipment, additional shaded areas, health and safety talks on heat, and adapting work patterns and physical activity expectations.

We identified a series of key lessons for similar weather events which were discussed at our HS2 contractor climate resilience collaboration group.

- Forecasting: Having advance warning of a heatwave and its likely magnitude and length allows planning of key activities and minimises the potential impacts of the heatwave.
- Consistency: Having a consistent, well-communicated response for events is useful. In July 2022, this was done at a site-by-site basis but we have since taken steps to progress this.
- Flexibility: The temperatures seen during July 2022 were significantly above UK averages and need to be taken seriously to avoid potential health and safety risks. Stopping activities where needed and providing flexible working arrangements, including increased breaks and welfare areas, reduces risk.

The HS2 Safety Forum established a Task and Finish Working Group in 2024 to create principles for working in extreme heat across HS2 sites in preparation for summer working. It was a response to climate change making heatwaves more likely and more severe, increasing the risk of heat illness among workers.

The Task and Finish Working Group produced a guidance document setting out the principles for working in extreme heat incorporating these lessons learned. The guidance highlights the range of risk factors which can influence the extent of the impact of hot weather on personnel health and safety. It provides direct recommendations of risk levels for extreme heat periods based on indicative air temperatures, aligned to the Met Office heat-health alert service. The guidance document highlights other additional risk factors that should be considered including the type of works being conducted, the working environment and individual factors. It also sets out general principles of best practice for managing periods of extreme heat.

Embedding climate adaptation and resilience

3.4 Developing new approaches to climate resilience

We have taken a proactive approach to integrating climate change adaptation throughout the project. The process was described in detail in the ARP3 report and further information is provided in this report. The HS2 design standards have been written and assessed with consideration of multiple future climate change scenarios where relevant.

It is highly unlikely that our future climate will be in line with one future scenario, and it is widely acknowledged there are many sources of complexity in climate change impact assessments. How climate risk will emerge, the speed at which it will do so, and the magnitude of the risk we face are uncertain. While HS2 designs have been reviewed against a range of future scenarios, the railway's assets will remain vulnerable to inherent uncertainties associated with climate change and assumptions that have been made at the design stage. As designs become set through the construction phase, and we look to HS2's operational processes, we need a complementary, dynamic and adaptable method to evolve climate adaptation thinking for the project's assets.

We are developing guidance and case studies of adaptation pathways for HS2 assets. Adaptation pathways are a growing decision-making approach in climate adaptation research and planning. They will give HS2 the flexibility to continue building resilience over the long-term. Adaptation pathways are recognised as a pathway of sequential actions which can be implemented progressively dependent on future conditions. They specify which actions should be taken now, and which can be delayed until conditions occur in the future. The conditions can relate to a physical condition – for example, reaching of a certain temperature threshold – or knowledge development – for example, policy implementation, updated climate modelling or emission trajectories.

Finemere Woods site, showcasing scale, growth and environmental diversity

Adaptation pathways for HS2 will build on principles in international climate adaptation standards and the British Standard 8631 Adaptation to climate change - Using adaptation pathways for decision making[6], integrating considerations for a major infrastructure project. The work will initially develop an HS2 specific guidance approach document, detailing best practice methodology and applying this approach to a series of case studies of asset-specific adaptation pathways covering flood risk and 'green' assets. We anticipate this work will develop between 2024 – 2026 with full details presented in future iterations of our climate adaptation reporting.

We will use our experience of developing adaptation pathways and applying these to a major infrastructure project to support the development of a new publicly available standard (PAS) Adaptation to Climate Change – Adaptation Pathways for Infrastructure in partnership with the British Standards Institute (BSI) and the Institute for Civil Engineers (ICE) (see case study: PAS Adaption Pathways standard).

Understanding new risks and challenges

4.1 Recent progress

In our previous report, we published a comprehensive risk assessment combining assessments delivered in the planning and consent stages coupled with implementation experience during the early design stage for initial HS2 contract awards of enabling works contracts and MWCCs. The ARP3 risk assessments set out the potential impacts of climate change on HS2 infrastructure and assets using the UK climate change projections (UKCP) available at the time, UKCP09. It considered our embedded approach to resilience including work to develop design standards based on best practice engineering codes and adapted to consider climate change risk and projections.

Our understanding of climate science continues to evolve. Since these assessments were conducted, a new suite of climate change projections for the UK (UKCP18) was released by the Met Office between 2018 and 2022[9]. Additionally, new HS2 design and construction contracts have been awarded for HS2's West Midlands' stations at Curzon Street Birmingham, in 2021, and Interchange at Solihull, in 2022. We have reviewed the potential implications for our climate risk assessment and MWCC design standards arising from the new climate change projections and resulting guidance; and we've carried out detailed analysis where residual risks have been identified. Some of this work is ongoing but this report presents the results so far. The risk assessment presented in Appendix B builds on our previous risk assessment, highlighting where risks have been reassessed or new risks and opportunities that have been identified.

4.2 Risk assessment methodology

Our approach for conducting risk assessments for climate change has largely remained consistent with that reported previously, with our methodology evolving with advances in global understanding of climate science and increased detail available on HS2 designs.

Our risk assessment is based on the likelihood of a climate hazard occurring and resulting in an impact on HS2, coupled with the consequence of the impact.

The potential likelihood and consequence of impacts to infrastructure and assets are scored using a five-point scale, which aligns with our corporate risk management procedure scoring matrix. It uses quantitative definitions of likelihood based on the probability or frequency of the risk occurring and impacting HS2, taking account of existing or embedded resilience measures in place or in development for HS2 infrastructure and assets. The consequence is based on criteria for cost, safety, operational performance and public perception and environmental impacts. Risk is then defined as the likelihood of the impact occurring multiplied by the consequence of the impact of the hazard. The resulting risk level can then be assessed in line with HS2's Risk Management Policy.

The climate risk assessment considers the climate change resilience for all HS2 infrastructure and assets to the end of their design life. The temporal scope of the assessment includes considering risks in both the design and construction stages (the 2020s) to the operation stage of HS2 (represented by the last time period available for UKCP18 projections, the 2080s). Where applicable, a mid-century (the 2050s) has also been used to help understanding of climate projections.

Weather events and average climatic conditions that could potentially worsen or improve due to projected climate change and could affect HS2 infrastructure and assets are both considered within the climate risk assessment. There is significant uncertainty about future climate projections based on socio-economic and political factors with assumptions made within a set of future climate scenarios. The UKCP18 projections are based on Representative Concentration Pathways (RCPs) future emissions scenarios used in the Intergovernmental Panel on Climate Change's (IPCCs) previous 5th Assessment Report (IPCC AR5)[18]. The RCP pathways represent a broad range of climate outcomes and include a wide range of assumptions regarding population growth, economic development, technological innovation and attitudes to social and environmental sustainability.

Understanding new risks and challenges

To capture some of this uncertainty in the climate risk assessments, we consider two UKCP18 emission scenarios: a planning assumption of RCP6.0 (equivalent to a central estimate of about 2.8C global temperature rise at the end of the century relative to pre-industrial levels, a medium emission scenario); and a scenario for sensitivity testing, RCP8.5 (considered a realistic worse-case scenario, equivalent to a central estimate of about 4.3C global temperature rise, a higher emission scenario).

4.3 Gap analysis for new climate projections

Background

We have developed a bespoke assessment process, the Climate Change Design Impact Assessment (CCDIA), to ensure climate change risks are considered and managed in all stages of design. The assessment considers the suitability of HS2 design standards to future climate change and identifies where additional allowances may be required to ensure climate resilience. We give this information to our contractors to inform their designs. The initial instruction of the CCDIA for MWCCs only was based on work conducted in 2015/16 using now superseded Met Office UK climate projections (UKCP09).

The CCDIA is a route-wide assessment and considers each asset type in isolation considering the asset's anticipated design life. Designers can assess risks for specific sites, with more detailed information about their exposure to hazards, and the sensitivity of specific systems or assets to local climate conditions in their Climate Change Adaptation and Resilience Reports (CCARR). The CCARRs provide evidence that climate change has been considered in design, including any differences from the route wide assessment or requirements for further analysis of specific risk and asset combinations. More information on the CCARR can be found in ARP3. The process is unchanged.

Rationale for update

Between 2018 and 2022, the UK Met Office released a new set of climate change projections for the UK (UKCP18)[9]. They are based on the latest versions of the Met Office Hadley Centre climate models and provide an update to the previous set of projections (UKCP09). Over the last three years, we have carried out extensive work to align the risk assessment with these new projections. This involved conducting a gap analysis to assess the impacts of the new climate change data – and associated changes in regulatory guidance for flood risk – on the HS2 asset types; and additional climate analyses to investigate, minimise and address any residual risks. All future iterations of the CCDIA will be based on the new climate information.

The methodology remained consistent with previous analysis. It reviewed climate change evidence for various locations along the route, then considered how climate change is incorporated into the existing technical standards to assess the potential design impacts on each asset. Residual risks were addressed through our internal risk management processes (Section 4.5).

Results of the gap analysis

The new UKCP18 climate projections highlight the impacts of different rates of emissions, different climate responses and improvements in modelling of the climate system relative to the previous UKCP09 projections. While there are variations in the details, general climate change trends projected for the UK are broadly consistent with earlier projections. They suggest the UK is likely to experience warmer, wetter winters and hotter, drier summers with an increase in the frequency and intensity of extremes[19]. The CCDIA gap analysis reflected on the variety of data available in the UKCP18 suite with a focus on the extreme ends of the climate outcomes which are typically more extreme with greater impacts in the new projections.

Understanding new risks and challenges

A review of the CCDIA analysis was undertaken based on the analysis of UKCP18 projections, information in existing HS2 design standards and discussions with relevant technical leads. The review recommended that the majority of MWCC asset/hazard combination noted in the CCDIA are unchanged following the new climate projections. However, in a few cases, there were changes that needed to be highlighted and addressed in our climate risk assessment. These risks related to areas where the climate projections suggested increased or decreased impact, or where advances in HS2 design had resulted in an update to the risk narrative due to embedded mitigations included in the project designs (see table, Appendix B).

Updated risks for main works contractors due to the gap analysis conducted for the new UKCP18 climate projections

Risk reference	Risk description	Update risk narrative / description due to UKCP18 gap analysis	Risk score
ARP4.1	Risk of failure or damage to highway signs and lightning columns due to increased stress on infrastructure due to extreme winds.	UKCP18 projections still warn of the uncertainty associated with wind projections. However, during the UKCP18 gap analysis it was noted that this risk is lower for wind damage to highway signs and lighting columns since the assets have a short design life of about 15 years and will be replaced in the short term. It is assumed further analysis will be conducted during asset replacement cycles.	Very low (See Appendix B)
ARP4.2	Increased risk of thermal expansion joints being pushed beyond their design capability, presenting a direct risk of damage to bridge structures and indirect damage of other assets dependent on bridges.	UKCP18 projections are hotter than UKCP09. The design of HS2 expansion joints includes consideration for climate change to allow expansion and contraction in response to temperature. We undertook further analysis to understand the impacts of these higher temperatures as this posed a residual risk.	Low (See Section 4.5)
ARP4.3 / ARP4.4	Mechanical and electrical equipment may fail to operate properly under extreme heat, causing reduced electrical loading capability, failure to operate properly or damage, ultimately resulting in overheating in infrastructure including tunnels, tunnel shafts, portal buildings, stations and depots.	HS2 design standards integrate consideration for climate change based on superseded projections. Analysis of updated climate projections, UKCP18, suggest more extreme temperatures may be experienced. There is a residual risk at the extreme temperature range and further analysis was conducted to address the designs sensitivity to these new projections.	Low / Medium (See Section 4.5)

Understanding new risks and challenges

Updated risks for main works contractors due to the gap analysis conducted for the new UKCP18 climate projections

ARP4.5	Increased risk of flooding from river, surface and groundwater sources could increase the risk of inundation of tunnels.	Our design standard requires contractors to ensure HS2 remains operational during a present day 1-in-1,000-year event. While this is a high resilience requirement, it does not include a consideration for climate change, and there remains a residual risk. Given the level of maturity of Phase One designs, further work is ongoing to address this risk as part of our work on adaptation pathways.	Medium (See Section 4.4)
ARP4.6	Increased risk of flooding from river, surface and groundwater sources.	The HS2 flood risk and drainage design standards require contractors to embed climate change allowances in flood and drainage designs to protect the railway and minimise the railway's impact on third parties. The Environment Agency (EA) published revised guidance[20] for flood risk assessment and drainage design in July 2021 and May 2022 in response to the UKCP18 projections. In response, we have updated guidance to contractors, allowing them to use the latest EA guidance where possible in a well progressed design and construction programme.	Low (See Section 4.4)

Understanding new risks and challenges

4.4 Review of updated flood risk guidance

The Environment Agency (EA) provides guidance on how to take climate change into account in flood risk assessments and design, providing a climate change allowance for anticipated changes in peak river flow and peak rainfall intensity[19]. HS2 design standards consider climate change and flood risk, in line with available EA guidance. For Phase One, this was initially aligned with the 2016 EA guidance for climate change allowances.

In July 2021, just before we published our previous report, the EA published an update to its guidance based on the UKCP18 projections. The updated guidance included revised allowances for anticipated changes in peak river flow based on the UKCP18 data. In May 2022, the EA provided a further update to the guidance with updated allowances for peak rainfall intensity allowances. As reported in the ARP3 report, we've conducted a review into the implications of this update for HS2 designs.

Peak river flows guidance

The EA's July 2021 guidance update for peak river flows changed the way allowances were applied, using management catchments instead of river basin districts. It also recommended using the 'higher central' allowance for essential infrastructure, such as HS2, where previously the more conservative 'upper end' allowance was recommended.

In many places, the maturity of HS2's design and construction meant updating climate change allowances to reflect the guidance would have incurred disproportionate redesign costs. HS2 design standards were already applying the most conservative design allowances from the EA's 2016 guidance (based on UKCP09) and in all locations reviewed, adoption of the July 2021 EA guidance (based on UKCP18) would have resulted in a lowering of the allowances for flood risk assessment and design. As such, HS2 remained aligned with, or more conservative than, the latest UKCP18 guidance from the EA for peak river flow allowances.

Peak rainfall intensity allowances

The EA update highlights that where allowances used for approved/progressed schemes are within 5% of the new updated allowance, the EA suggests the assessments don't need to be re-run as they are within rounding assumptions made in the research. For HS2 Phase One designs, the allowances applied based on the previous guidance were considered appropriate; and for all locations the 40% allowance already applied by HS2's contractors was more conservative than the recommended allowances in the May 2022 guidance.

Artist's impression of the Edgcote Viaduct, showing an aerial view of the viaduct and the flow of the River Cherwell underneath it

Understanding new risks and challenges

4.5 Addressing residual risks with analytical deep dives

Following the review of the implications of the UKCP18 new climate projections (Section 4.3), we commissioned 'deep dives' to address specific engineering challenges and assess residual risks. This highlights how our understanding of climate science and the implications for HS2 are evolving and being updated.

Temperature thresholds

Tunnel ventilation systems are integrated into HS2 tunnel and portal building design. They aim to control air temperature during normal train operations and allow for safe operations in tunnels in an emergency. As is typical, the systems are designed to operate in typical annual temperatures ranges, up to so-called exceedance temperature thresholds. These thresholds represent temperatures that will only be exceeded for a small portion of time, 88 hours in a typical year or less. Understanding how ambient temperatures may change in the future is crucial to informing the design of tunnel ventilation systems to ensure they are resilient to climate change.

Our designs considered climate change by setting future climate exceedance temperatures based on 2080s future scenarios. They were modelled using the now superseded UKCP09 projections. The UKCP18 MWCC gap analysis, with more extreme temperature changes, highlighted a potential climate risk from increasing high and extreme temperatures leading to overheating in tunnels, shaft and portal buildings, and having a potential impact on heating, ventilation and air conditioning (HVAC) systems. It was also recognised that this risk has implications for other HS2 assets outside the MWCC scope, such as stations and depots (Section 4.6).

We commissioned work to obtain updated thresholds from the latest climate change projections and determine the magnitude of the residual risk and potential impact.

Inside HS2's tunnel at Long Itchington Wood in Warwickshire

The analysis showed that the exceedance temperature thresholds have increased under the new climate projections. However, under HS2's design scenario the magnitude of potential impacts is low as the ventilation system will accommodate the projected future temperatures. With sensitivity testing under a high emission future scenario, and considering the heat released from the railway system equipment, the ventilation system is expected to remain effective. It is also expected to have adequate cooling potential at the highest exceedance temperature.

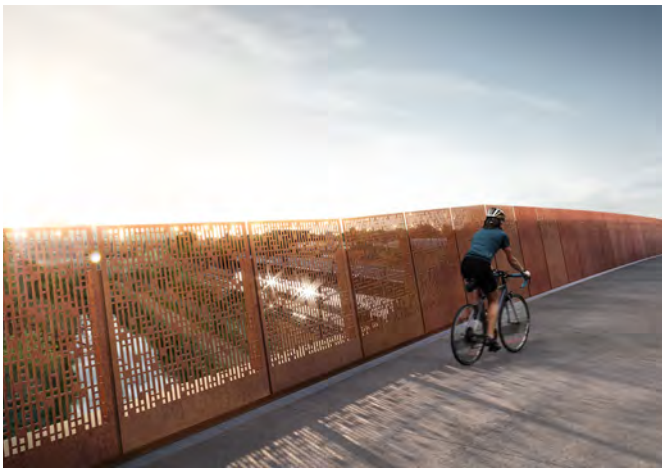
Within the HS2 design specification, mechanical ventilation systems were specified as they use less energy to operate relative to mechanical refrigeration options. Following the detailed climate analysis, further work was conducted to explore the viability of alternative options that could be implemented at a later stage, and to understand co-benefits and costs, including implications for carbon emissions. This work will be used to develop an adaptation pathway (Section 3.4) to ensure the resilience of the ventilation system during the HS2 operational period. It highlights the importance of updating the exceedance temperature and associated assumptions during regular asset renewal cycles.

Understanding new risks and challenges

Research to develop UK maximum temperature maps for structural calculations

Many UK and international engineering standards are based on historic weather observations and typically do not consider climate change. To increase HS2's resilience, we are developing world-class engineering standards that integrate climate change into HS2 design standards. This is usually done by either specifying higher levels of resilience, integrating mandatory sensitivity testing for more extreme future climate scenarios or integrating climate uplift factors in engineering calculations and sizing decisions.

The HS2 Bridge Design Basis shows how an HS2 engineering standard increases resilience compared to British Standards. Due to thermal dependent effects, bridges expand as temperatures increase and contract as temperatures drop. Bridge designs include bearings and expansion joints that typically are sized in line with observed temperatures defined in British Standards. The British Standard for structures (BS EN 1991-1-5)[21] doesn't consider climate change so we integrated an additional uplift for climate change into HS2 designs, allowing accommodation for 40C temperatures in our design calculations. This threshold was selected in the early stages of design as representative of a low-likelihood, high-impact extreme event, which, at the time, had not been seen in the observational record. With the release of the more extreme UKCP18 projections – and the unprecedented widespread 40C heatwave in July 2022 – we tested whether the threshold, although already more conservative than the requirements of the British Standard, was sufficient for our long-life railway.



CGI visual of a cyclist riding over Saltley viaduct in Birmingham

In 2022, we commissioned a project to undertake a technical climate analysis to produce updated temperature maps for the UK, replicating those presented in the British Standard but including climate change using the latest available climate projections and incorporating recent record-breaking observations. The analysis showed the shift to higher, and more frequent, extreme temperatures across the UK. It recommended considering new temperature thresholds when designing new structures vulnerable to high temperatures.

Given the advanced design stage of MWCC designs, and the implications to programme and cost associated with making significant changes, the sensitivity of the existing calculations were assessed in this new context. We confirmed the original uplifts included in HS2 bridge design allowed for thermal expansion and contraction under future climate change projections anticipated under our design scenario for the end of the century.

Understanding new risks and challenges

Embedding climate change in our standards
As stated previously, many UK and international engineering design standards do not consider climate change so we've modified these to integrate climate change into HS2 design standards. We are also reviewing climate change assumptions to ensure the resilience of our designs, and to update design standards.

Conducting detailed climate analysis, such as that described within the previous sections, is highly technical, complex and potentially a barrier for smaller, individual projects. We've shown the benefit of integrating climate thinking into project design standards early in the process, supported by detailed technical studies when appropriate.

While engineering standards need to integrate climate change consideration formally, we've shown that in the meantime designers can take proactive steps to integrate adaptation and drive progress on resilience. We are committed to sharing this learning while encouraging standards bodies to integrate robust climate change requirements and considerations.

Another example of how we are embedding additional climate consideration into design standards based on general climate trend information relates to stress-free temperature requirements for our track systems.

Track view of Curzon No 2 viaduct in Birmingham

Case study

Developing world-class engineering standards for HS2

HS2 will predominately use a precast slab track system, similar to several high-speed railways across the world. The system will reduce maintenance costs, increase resilience and improve performance compared with traditional ballasted track.

Steel tracks are particularly vulnerable to temperature extremes due to thermal expansion. During high temperatures, they can expand, starting to curve or buckle; and under low temperatures, rails are more susceptible to breaking. It is essential that HS2's track can cope with a range of temperatures including future summer highs and winter lows.

To reduce the risk of buckling, the rails will be 'stressed' as they are installed, ensuring expansive stresses only start to develop above a certain temperature. Network Rail's standards for stressing temperatures have been in place for over 50 years. They provide for setting temperatures based on historic annual temperature variability. To account for climate change, we have applied a nominal uplift to the stress-free temperature for our slab tracks and can uplift further the specification used during maintenance of the infrastructure through its life.

The uplift is moderate to minimise any additional risk at the colder end of the rail temperature range, but it will increase the resilience of HS2's track system as average temperatures increase in the future. The magnitude of the uplift is based on analysis of high-level global climate trend information and engineering expert judgment. Our work is a proactive step to integrate adaptation into HS2 track design. We welcome industry collaboration on developing our understanding and identifying suitable updates to UK standards and best practice.

Understanding new risks and challenges

4.6 Expanding the scope of our assessment: HS2 stations

Since our previous report, we have awarded new contracts for HS2's West Midlands stations at Curzon Street Birmingham, in 2021, and Interchange at Solihull, in 2022. In November 2024, we confirmed our rail system contract winners, collectively worth around £3bn. We are committed to assessing the impact of climate change in new contract areas using the latest available climate change projections (UKCP18), embedding these into technical standards and asset-level, routewide, climate risk assessment provided in the bespoke Climate Change Design Impact Assessment (CCDIA). While initial work has started to assess the impacts on rail systems contacts, it is being developed while contracts are being signed and contractors onboarded. For this reason, this section focuses on work covering the new station contracts.

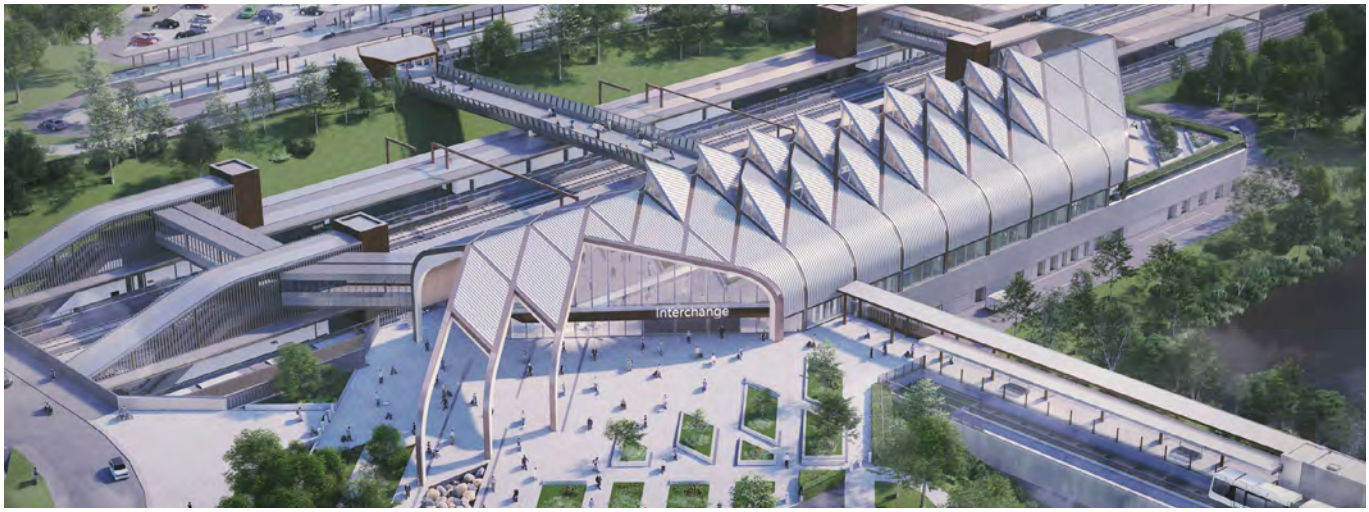
We have set requirements for sustainable design for HS2 stations based on the Building Research Establishment Environmental Assessment Method (BREEAM) scheme[22], a recognised environmental sustainability rating scheme for buildings. BREEAM credits can be made up of several themes including climate change adaptation and resilience. Credits count towards designs being awarded different levels of achievement. All HS2 stations must achieve a minimum of BREEAM 'excellent' rating, and requirements have been set to ensure that HS2 designers and contractors obtain the credits for climate change adaptation and resilience for stations designs.

Two HS2 stations have been officially accredited as being 'outstanding' at the design stage, with one achieving an exemplary credit for climate resilience (see case study: Old Oak Common station).

Using the same methodology as the CCDIA update described in Section 4.3, we reviewed climate risks with the potential to affect HS2 stations. In most cases, the risks were mitigated by existing HS2 design standards for stations. The results are shown in Appendix B.

A limitation of the data needed to complete thermal modelling requirements presents a potential risk for stations. HS2 technical standards require thermal modelling to be conducted for all stations including platforms and concourses. The modelling is based on industry standards that require the use of weather files[23] provided by the Chartered Institution of Building Services Engineers (CIBSE). These are based on now-superseded UKCP09 projections. Although the findings of more recent climate projections, UKCP18, are broadly consistent with the previous climate projection trends, there are some differences in findings, including temperature extremes. Suitable weather files based on the new climate projections are not yet available. Once released, as part of our standard review of new climate information we will work to understand any potential implications on our designs, and mitigate if required.

Visualisation of Interchange Station in Solihull



Understanding new risks and challenges

Visualisation of Old Oak Common station

Case study

Exemplary climate resilience design at HS2's Old Oak Common station

HS2's Old Oak Common station in west London will be one of the busiest in the country and has been designed with our future climate in mind.

The design has been recognised as 'outstanding' under the internationally recognised Building Research Establishment's Environmental Assessment Method (BREEAM) assessment. This is higher than the 'excellent' required through the project's Environmental Minimum Requirements. BREEAM is the sector's principal indicator for excellence in building design, construction, and sustainability, and the award puts Old Oak Common in the top 1% of UK buildings for sustainability. As part of the rating, Old Oak Common designs were awarded an exemplary credit for climate change adaptation, recognising a holistic approach to integrating resilience across the station.

The changing climate is likely to have far-reaching impacts on HS2 infrastructure: rising temperatures may cause increased risk of overheating in buildings; changing rainfall patterns could lead to an increase risk of flooding and water scarcity; and rising carbon dioxide atmospheric concentrations coupled with extreme weather could lead to the faster degrading of construction materials.

Thermal modelling of Old Oak Common integrates industry-standard climate change projections to demonstrate that it will not overheat. The design includes passive design measures which help achieve significant energy and emission savings while managing climate change impacts such as increased solar gains through external shading, vegetation and natural ventilation solutions. Passive provision has also been made in the design to accommodate a future platform cooling system that could be used to mitigate against higher levels of warming and changing passenger expectations for thermal comfort.

Durability and protective measures for vulnerable and exposed parts of the station have been incorporated into the design to avoid increased risks of deterioration and higher maintenance demands.

In the UK, summers are likely to become drier while winters will become wetter. To minimise the risk of localised flooding on and offsite, a climate change allowance has been included in the drainage design. To reduce the consumption of potable water, and increase resilience during periods of water scarcity, the station roof includes rainwater harvesting, which is expected to cover 100% of the demand for flushing toilets.

Interdependent and cascading risks

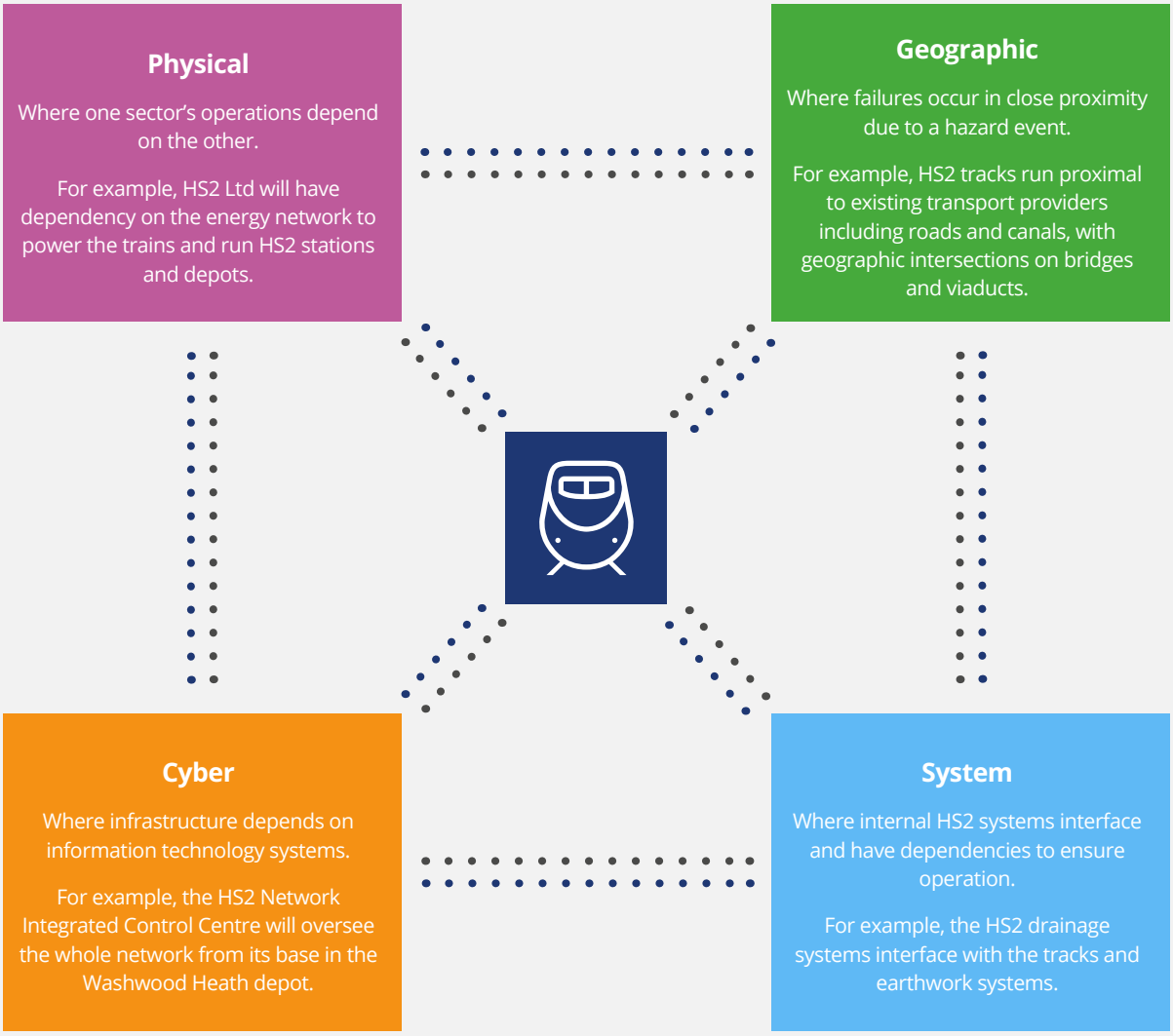
HS2's adaptation and resilience is interwoven with other systems and sectors. The interconnected and dependent/interdependent nature of the UK transport and infrastructure sectors and HS2 asset systems means there are risks to HS2's construction works and future services from impacts from external organisations. These include our supply chains, transport to HS2 sites, water supply to sites as well as other assets, such as drainage, and services that HS2 interfaces with, or relies on.

For example, HS2 operational services will have climate change interdependencies with:

- the power network;
- where HS2 systems connects to Network Rail's systems; and
- where HS2 assets interact with each other, such as drainage, track and earthworks.

The key interdependencies for HS2 are shown in the graphic below.

Interdependencies for HS2 Ltd



Interdependent and cascading risks

Interdependencies can also lead to 'cascading' risks where disruptions caused by extreme weather could cause a chain of impacts across HS2 assets as well as other sectors and systems. We require our designers and contractors to understand HS2 systems, their interdependencies and the risks that HS2 systems face.

We undertook a Climate Change Resilience and Interdependencies Assessment (CCRIA), described in ARP3, to identify interdependent infrastructure, namely: energy; information and communications technology; water; waste management; and other transport systems.

We ask designers and contractors to review the CCRIA and consider where their designs may be vulnerable to the impacts of climate change from interdependent systems, services or assets. This is reported in a Climate Change Adaptation and Resilience Report (CCARR). Risks and opportunities are recorded in our risk management system to ensure they are managed throughout design. Where necessary, designers and contractors are required to propose design solutions to improve resilience to these interdependencies.

There are also risks associated with compounding impacts. For example, a heatwave followed by extreme rainfall could lead to high levels of surface water flooding due to the impermeability of the ground. We plan to undertake further work to understand the nature of all interdependency risks and compounding impacts (see Section 6).

To ensure HS2 continually improves resilience efforts and sharing knowledge, we've set up a contractor collaboration group for climate resilience, using it to discuss interdependencies and communicate impacts across the project. The work is supported by our involvement in industry peer collaboration groups such as the Infrastructure Operators Adaptation Forum (IOAF), RSSB's railway focussed Climate Change Adaptation Working Group (CCAWG) and the Transport Adaptation Steering Group (Section 3.2). We support sector-wide initiatives and have recently been involved with Transport for London (TfL) on its interdependencies project to further understanding across land-based transport services (see case study Working with Transport for London on interdependencies).

Two tunnel boring machines completed their 10-mile drives in spring 2024, creating the longest tunnel on the route. We addressed water supply dependency during HS2 tunnelling in the Chilterns by improving the water efficiency of construction machinery, increasing water reuse to ensure supplies and protect construction from potential impacts of drought.

A view of the Chiltern tunnel South Portal, July 2024

Interdependent and cascading risks

Case study

Working with Transport for London on interdependencies

We were involved in a project, led by Transport for London (TfL), to improve our understanding of the capital's road and rail sector and their interdependencies. The project took a collaborative approach to climate adaptation and resilience involving partners including Network Rail, National Highways, High Speed 1 (HS1), High Speed Two (HS2) and the Department for Environment, Food and Rural Affairs (Defra) as part the Transport Adaptation Steering Group (TASG).

The project combined system mapping with a climate interdependency risk assessment for the London land-based transport sector. It focused on upstream interdependencies, where rail infrastructure assets are dependent upon other services, for example power or water sectors, to continue functioning. It drew on guidance from the government and Defra. Stakeholder engagement across multiple sectors was used to develop our understanding of existing interdependencies, climate hazards and potential actions to reduce climate interdependency risks. Further detail on the project method and the approach can be found in the TfL ARP4 report[24].

A total of 114 climate interdependency risks were identified. They were scored against the likelihood of a particular pathway occurring and the potential magnitude of an impact or consequence across three time periods: present-day; the 2050s; and the 2080s. The climate interdependency risk assessment highlighted key interdependencies with the power sector, urban drainage and telecoms. The potential for climate interdependency risks to increase in the 2050s was also noted as decarbonisation, electrification and changes in climate hazards lead to greater impacts from the power sector.

Visualisation of Old Oak Common station

Although not the focus of the risk assessment, downstream interdependencies were also discussed. Downstream interdependencies could arise from HS2 if our rail services are impacted by a climate hazard and are unable to deliver services for other users, affecting their functionality. Downstream interdependencies for the rail sector include supply chain impacts, access to health services and impacts on staff availability.

A total of 52 actions were created by the stakeholders to reduce the risk from climate hazards to the key organisational interfaces.

We believe many of the findings and actions will apply outside London and we will work to apply the new knowledge to HS2. We are committed to working with other partners across the rail sector and wider industries to reduce the risk of interdependencies.

HS2 Adaptation Action Plan

HS2's infrastructure is being designed to withstand the impact of climate change and extreme weather and we are taking action to limit the impact on communities and the environment. We're also creating additional value, such as creating habitats, improving flood resilience for communities and carrying out nature-based solutions.

Our work is ongoing and our action plan, covering the next five years and beyond, is presented in the following table. More details are provided in Appendix C. We will use the plan to measure our progress in future reporting rounds.

Action	Action to address risks	ARP4 status
1. Governance and risk management	Ensure climate risks are managed throughout the project with governance and risk management.	Current
2. Collaborations	Host regular meetings to bring together engineers, designers and environmental managers including the HS2 Climate Change Adaptation and Resilience Forum and HS2 Collaboration Group.	Current
3. Climate Change Adaptation and Resilience Reports (CCARRs)	Ensure designers and contractors develop and submit CCARRs.	Current
4. ARP reporting	Provide updates on the adaptation progress across the project in future ARP reports.	Current
5. Task Force on Climate-related Financial Disclosure (TCFD)	Provide annual disclosures covering climate adaptation in HS2 Ltd's Annual Reports and Accounts, in line with the requirements for TCFD reporting for arm's-length bodies, as set out in HM Treasury sustainability reporting guidance.	Current
6. Metrics	Develop metrics for climate adaptation and resilience for the construction and operation phases of HS2.	Current / Planned
7. Construction	Ensure the impacts of climate change on construction are assessed and monitored, meeting the requirements in the Phase One HS2 Code of Construction Practice.	Current
8. Operational planning	Undertake operational planning to ensure resilient HS2 operations including risk management of weather and climate change as well as extreme weather and seasonal changes. This includes the ability to monitor performance during operation to provide insight and allow further adaptation of HS2 assets to climate change.	Current / Planned
9. Adaptive capacity	Build organisational adaptive capacity for climate resilience.	Current / Planned

HS2 Adaptation Action Plan

Action	Action to address risks	ARP4 status
10. Adaptation pathways	Develop adaptation pathways guidance for HS2 assets and case studies, including monitoring requirements. Support industry-wide initiatives to develop pathways and provide feedback and learnings from implementation experience.	Current
11. Interdependencies	Work with partners, supply chain and stakeholders to achieve our climate change adaptation and resilience objectives, including managing interdependent climate risks.	Current / Planned
12. Innovation	Engage in industry and academic partnerships to develop understanding of climate change adaptation and resilience. Seek opportunities to innovate and share knowledge.	Current / Planned
13. Engineering design standards	Continue to embed climate change considerations in engineering design standards where practicable given HS2 design stage, and share lessons learned to improve industry standards.	Current

Appendix A
Progress made against the ARP3 action plan

ARP3 action number	ARP3 action	Project stage	ARP3 status	ARP4 status	ARP4 progress update
1	Ensure climate risks are managed throughout the Project with appropriate governance and risk management.	All	Ongoing	Current	Climate risks continue to be managed through our risk management processes, which remain unchanged from those reported in ARP3. This is a continuous action throughout the project's planning, design and construction.
2	Assess the impact of climate change on future phases of HS2 and consider the resilience of all phases to climate change.	Planning and consent	Planned	Completed	Climate change consideration has been embedded into all active phases of HS2. In October 2023, the then government cancelled Phase Two of HS2. Our focus is now delivery of Phase One between London and the West Midlands.
		Design	Planned	Completed	Since depositing ARP3, we have awarded new contracts for HS2's stations at Curzon Street in Birmingham and Interchange, Solihull. In November 2024, we confirmed our rail system contract winners, collectively worth around £3bn. We have assessed the impact of climate change in the new contract areas using the latest available climate change projections (UKCP18) within HS2 design standards and the asset-level, routewide, climate risk assessment, the Climate Change Design Impact Assessment. The resulting updated understanding of the climate risks, challenges and opportunities presented to these contract areas is described in Section 4.
3	Review and update HS2 standards and supporting documents as climate change evidence and data evolves and develop new standards where appropriate.	Design	Ongoing	Completed	Understanding of climate science continues to evolve. Since our designs and standards for civil contracts were started, a new suite of climate change projections for the UK (UKCP18) have been released. At the time of writing the ARP3 report, a review of the potential implications arising from the new climate change projections was underway. We have developed an extensive gap analysis for the MWCCs and commissioned analytical deep dives to address specific engineering challenges. Details of these works are presented in Section 4.
4	Undertake climate change design impact assessments and interdependencies assessments as necessary.	Design	Ongoing	Completed	Developments to our climate change design impact assessments have taken place in the last three years as a result of new contracts being awarded in the recent past or upcoming procurement (see Action 2) and updated climate information (see Action 3). We have conducted asset-level, route-wide assessment of climate change impacts for UKCP18 climate projections and updated guidance material provided to contractors to highlight any residual risks. The progress with respect to this is detailed in Section 4. Our Climate Change Resilience and Interdependencies Assessment (CCRIA) highlights the vulnerability of interdependent infrastructure services, operations and assets to those aspects of climate change that could affect the long-term climate resilience of HS2. We have been involved in cross-sector interdependency work lead by TfL to investigate interdependencies across the rail sector. This work is presented in Section 5.

continued overleaf

Appendix A

ARP3 action number	ARP3 action	Project stage	ARP3 status	ARP4 status	ARP4 progress update
5	Ensure designers and contractors develop and submit Climate Change Adaptation and Resilience Reports for Phase One and Phase 2a.	Design	Ongoing	Current	In October 2023, the then government cancelled Phase Two of HS2. Our focus is now delivery of Phase One between London and the West Midlands. Our MWCC and rail systems contractors continue to submit Climate Change Adaptation and Resilience Reports (CCARRs) during the design and construction phases. These are iterative reports – they develop as the detailed design and construction occurs. Since January 2022, we have assured the production of 10 CCARRs covering five contract areas (Section 3.1). We expect to receive updates to the MWCC reports and new CCARRs for new contract areas during the design and construction period. We've provided training and guidance to ensure contractors provide design mitigation measures to address routewide residual risks at a site-specific level.
6	Establish a climate change resilience collaboration group with contractors.	Construction	Planned	Completed	The HS2 contractor climate resilience collaboration group was established in early 2022 and seven meetings have been convened to date. The group encourages contractors to share best practice by presenting innovation case studies and examples of how they have embedded climate resilience at a site-specific level (Section 3.1).
7	Ensure the impacts of climate change on construction are assessed and monitored, meeting the requirements in the HS2 Code of Construction Practice.	Construction	Ongoing	Current	Climate change and extreme weather are affecting our day-to-day lives. Following extreme weather events, including the 40C heatwave in 2022, severe winter storms in early 2022, and the wet winter and spring of 2023/24, we have been working with HS2 contractors to understand the impact on their sites. We've collected evidence of impacts and reviewed proactive and reactive mitigations across the programme to share best practice and learnings (Section 3.3). Recognising the risk extreme weather presents to construction sites, some HS2 contractors have taken an innovative approach to develop a step change in the way weather is managed in the sector. Align and EKFB have been working with external partners to use innovative weather forecasting tools to enhance real-time and planned management of weather impacts on site. We have provided innovation funding and endorsement for these initiatives. We've also been involved in research projects and challenges to identify solutions to manage the impact of climate change on sites (see Action 12). Ahead of summer 2024, an internal Extreme Heat Task and Finish Group was established. The group, which included our climate change specialists, developed occupational health guidance to ensure a consistent approach to working in extreme heat across our sites (Section 3.3).

continued overleaf

Appendix A

ARP3 action number	ARP3 action	Project stage	ARP3 status	ARP4 status	ARP4 progress update
8	Develop metrics for climate adaptation and resilience for the construction and operation phases.	Construction	Ongoing	Current	Our data management system, HORACE, records and identifies environmental incidents caused by, or affected by, adverse weather during the construction phase. The information feeds into our work programme to identify focus areas to improve climate resilience. We expect this work to continue during construction.
		Design / Operation	Planned	Current / Planned	During the design stage, we monitor the number of Climate Change Adaptation and Resilience Reports submitted by HS2 designers and contractors (see Action 5). This metric demonstrates that our requirements on climate change are being delivered by designers and contractors. We will continue to monitor this. We recognise that the development of operational metrics for climate resilience and adaptation will be critical for reviewing the organisation's adaptive capacity, progress and identify thresholds for action, especially as part of adaptation pathways planning (see Action 9). We have been part of the climate resilience community of practice formed under the Transport Infrastructure Efficiency Strategy Living Lab (TIES LL), which aimed to create performance benchmarks and metrics for the sector. Unfortunately, no single climate resilience metric was developed, highlighting the complexity of the challenge. However, the project provided important insights into potential data collection options. We will continue to support the industry to develop a metric.
9	Develop adaptation pathways, where applicable, including monitoring requirements.	Design / Operation	Planned	Current	Work has begun to develop adaptation pathways for HS2. We are producing HS2 specific guidance detailing best practice methodology and resources to be used for the HS2 project based on existing best practice and established standards. Additionally, a series of case studies of asset-specific adaptation pathways will be developed. This work is summarised in Section 3.4. Adaptation pathways are an emerging tool for supporting good decision-making to ensure infrastructure is adaptable and resilient to climate change. There is limited uptake in using adaptation pathways across the sector due to their complexity and lack of guidance materials. We have partnered with British Standards Institute (BSI) and the Institute for Civil Engineers (ICE) to support the development of a new publicly available standard (PAS) Adaptation to Climate Change - Adaptation Pathways for Infrastructure. We're committed to supporting the development of new guidance material and will provide expertise and experience of developing adaptation pathways on a major infrastructure project to steer the development of the PAS. For further details see case study: PAS Adaption Pathways standard.

continued overleaf

Appendix A

ARP3 action number	ARP3 action	Project stage	ARP3 status	ARP4 status	ARP4 progress update
10	Undertake operational planning to ensure we are ready for resilient operation and ready to manage risks from climate change, such as extreme weather. This includes the ability to monitor performance during operation to provide insight and allow us to adapt to climate change.	Operation	Ongoing	Planned	HS2 is in peak construction. Unlike many organisations submitting ARP reports and/or considering climate adaptation, HS2 infrastructure is not yet operational. HS2 climate resilient design and our operational planning will ensure HS2 can operate at a high level of resilience, including during potential disruption from extreme weather and climate hazards. Our work on operational planning is in its initial stages but it is accelerating ahead of initial HS2 services being launched between 2029 and 2033. Operation of HS2 is excluded from the scope of this report but work is underway to embed climate change considerations, including for extreme weather events, into operational procedures. This action will remain in the ARP4 action plan (see Section 6) and will be reported on in future reporting rounds.
11	Work with our partners, supply chain and stakeholders to achieve our climate change adaptation and resilience objectives including managing interdependent climate risks.	All	Ongoing	Current	We work across the industry to understand technical engineering issues, emerging research areas and shared experiences on embedding climate adaptation. Our collaboration efforts are reported in Section 3.2. We have also been involved as a partner in new work, led by TfL, to understand and manage interdependent climate risks. The project involves colleagues at TFL, Network Rail, HS1 and other organisations to better understanding climate risks between rail systems and across other sectors such as energy and water. The project's results and the implications for HS2 are presented in Section 5.
12	Engage in industry and academic partnerships to develop our understanding of climate change adaptation and resilience. Seek opportunities to innovate and share knowledge.	All	Ongoing	Current	We participate in supply chain and industry collaboration groups, discussion forum and stakeholder steering groups to share and collate best practice and learnings. Our collaboration efforts are reported within Section 3.1. We have provided partial funding for the National Hub for Decarbonised, Adaptable, and Resilient Transport Infrastructure (DARe). The hub brings together leading UK universities and industry, policy-makers and other partners to find pathways and solutions for a transition to a resilient, net zero transport system that works for all. Along with our construction partners, we are actively involved in research projects as part of the DARe project.
13	Host regular meetings of the HS2 Climate Change Adaptation and Resilience Forum, bringing together engineers, designers and senior environmental managers.	All	Ongoing	Current	The HS2 Climate Change Adaptation and Resilience Forum was established in 2014 and disseminates knowledge from the project on climate change resilience and associated issues. The group brings together disciplines to share knowledge, raise challenges and develop solutions, ensuring HS2 is resilient to climate change (Section 3.1).

continued overleaf

Appendix A

ARP3 action number	ARP3 action	Project stage	ARP3 status	ARP4 status	ARP4 progress update
14	Provide updates on our adaptation progress and new phases of HS2 in future Adaptation Reporting Power reports.	All	Ongoing	Current	We provide this update on climate adaptation progress as part of APR4 and will continue to report in future rounds. We also report on climate-related financial disclosures in our Annual Report and Accounts 2023 – 2024.

Appendix B
Our risk assessment

B1 Our ARP4 risk assessment

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	Narrative updates for ARP4 where risk was previously identified	ARP4 risk score	Confidence (high/ medium/ low)
APR4.1	Wind: Likely increase in the frequency and intensity of high wind events (with some uncertainty).	Risk of failure or damage to highway signs and lightning columns due to increased stress on infrastructure due to extreme winds.	Structures; auxiliary components; signs	Operations	Head of civil engineering structures	Yes: ARP3.32	I1, I12	While HS2 structures are generally deemed not to be sensitive to wind loading – as there are no slender/ suspension bridge types – auxiliary components such as parapets may be vulnerable to wind events. With long design lives, building roofs may be vulnerable to wind events. These risks will be considered and mitigated through measures to be developed during the design. Consideration for wind exposure to sign design is included within HS2 design standards.	UKCP18 projections still warn of the uncertainty associated with wind projections. However, during the UKCP18 gap analysis it was noted that this risk is lower for wind damage to highway signs and lighting columns since the assets have a short design life of about 15 years and will be replaced in the short term. It is assumed further analysis will be conducted during asset replacement cycles.	Very low	Low

*The UK Climate Change Risk Assessment 2022 (CCRA3) is the third assessment of key climate change risks and opportunities. It identifies 61 UK-wide climate risks and opportunities across many sectors of the economy. Each risk is given a risk code, categorised by areas of policy or societal interest.

B – Business and Industry
H – Health, Communities and Built Environment
I – Infrastructure
ID – International Dimensions
N – Natural Environment and Assets

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Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	Narrative updates for ARP4 where risk was previously identified	ARP4 risk score	Confidence (high/ medium/ low)
APR4.2	High temperatures: Very likely increase in summer maximum temperature and number of hot days.	Increased risk of thermal expansion joints being pushed beyond their design capability, presenting a direct risk of damage to bridge structures and indirect damage of other assets dependent on bridge.	Structures – bridge expansion joints	Operations	Head of civil engineering structures	Yes: ARP3.15	I12	Climate change and high temperatures are incorporated into HS2 bridge design. The Bridge Design HS2 standard goes beyond the requirements of the UK engineering standard, which are only based on historical weather observations from 2007 or before (contained within the UK National Annex to BS EN 1991-1-5).	UKCP18 projections are hotter than UKCP09. The design of HS2 expansion joints includes consideration for climate change to allow expansion and contraction in response to temperature. We undertook further analysis to understand the impacts of these higher temperatures, described in Section 4.5 which found the allowance included in designs to be sufficient for our design scenario climate projections.	Low	Medium
APR4.3	High temperatures: Very likely increase in summer maximum temperature and number of hot days.	Mechanical and electrical equipment may fail to operate properly under extreme heat, causing reduced electrical loading capability, failure to operate properly or damage, ultimately resulting in overheating in infrastructure.	Mechanical and electrical	Operations	Head of mechanical and electrical engineering	Yes: ARP3.14	I12, H1	Tunnel ventilation for HS2 designs is controlled by both natural and M + E ventilation systems. M + E assets will be designed to be resilient to climate change with future environmental conditions for the end of the century provided in the HS2 design standard. For MWCC designs, these are based on UKCP09 modelling.	The MWCC is responsible for the design and sizing of the tunnel structure and ventilation shafts with a known interface with the rail systems ventilation systems. Ongoing work across HS2 Ltd will consider interface risks including those exacerbated by future climate conditions.	Low	Medium

Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	Narrative updates for ARP4 where risk was previously identified	ARP4 risk score	Confidence (high/ medium/ low)
APR4.4	High temperatures: Very likely increase in summer maximum temperature and number of hot days.	Mechanical and electrical equipment may fail to operate properly under extreme heat, causing reduce electrical loading capability, failure to operate properly or damage, ultimately resulting in overheating in infrastructure.	Mechanical and electrical	Operations	Head of mechanical and electrical engineering	No: Linked to ARP3.14	I12, H1	Tunnel ventilation for HS2 designs is controlled by both natural and mechanical and electrical ventilation systems. Mechanical and electrical assets will be designed to be resilient to climate change with future environmental conditions for the end of the century provided in the HS2 design standard. For Phase One MWCC designs, these are based on UKCP09 modelling.	HS2 design standards integrate consideration for climate change based on superseded projections. Analysis of updated climate projections, UKCP18, suggest more extreme temperatures may be experienced. Further analysis was conducted to understand the sensitivity of our designs (Section 4.5) and further assessment will be conducted using our adaptation pathways process.	Medium	Medium
APR4.5	High precipitation: Likely increase in projected mean daily rainfall, especially in winter months.	Increased risk of flooding from river, surface and groundwater sources could increase the risk of tunnels being inundated.	Structures: tunnels	Operations	Head of tunnel engineering, head of water resources, waste and flood risk	Yes: ARP3.4	I2, I4	Many HS2 design standards give consideration for designing resilient tunnels. This includes railway drainage, earthworks, cut-and-cover tunnels and tunnel portals. All critical systems infrastructure for HS2 is designed to remain operational during a 1-in-1,000 year return period flood event. These standards will ensure resilience against high precipitation events.	Our design standard requires contractors to ensure HS2 remains operational during a present day 1-in-1,000-year event. While this is a high resilience requirement, it does not include a consideration for climate change, and there remains a residual risk. Given the level of maturity of Phase One designs, further work is ongoing to address this risk as part of our work on adaptation pathways.	Medium	Medium

Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	Narrative updates for ARP4 where risk was previously identified	ARP4 risk score	Confidence (high/ medium/ low)
APR4.6	High precipitation: Likely increase in projected mean daily rainfall, especially in winter months.	Increased risk of flooding from river, surface and groundwater sources	All assets	Operations	Head of water resources, waste and flood risk	Yes: Linked to ARP3.1	I2, I4	The HS2 flood risk design standard requires consideration for climate change in line with Environment Agency guidance. Flood risk assessments are required for all sites at flood risk and include appropriate allowance provided by the Environment Agency on climate change uplifts.	The HS2 flood risk and drainage design standards require contractors to embed climate change allowances in flood and drainage designs to protect the railway and minimise the railway's impact on third parties. The Environment Agency published revised guidance for flood risk assessment and drainage design in July 2021 and May 2022 in response to the UKCP18 projections. In response, we have updated guidance to contractors, allowing them to use the latest EA guidance where possible in a well progressed design and construction programme.	Low	High

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Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.7	High precipitation and flooding	Increased likelihood of flooding or pooling of water in station assets including access routes and car parks caused by extreme rainfall events.	Stations: access	Design, Operations	Head of water resources, waste and flood risk	No: new risk identified as part of ARP4	I2	The HS2 design standards for stations and their surroundings include requirements to include climate change allowances in flood risk modelling. Our guidance to contractors has been updated to reflect the most recent guidance provided by the Environment Agency.	Very low	High
APR4.8	High precipitation and flooding	Increased likelihood of flooding in station assets including platforms and buildings and underground boxes, leading to disruptions to services and performance.	Stations: building structures	Design, Operations	Head of water resources, waste and flood risk	No: new risk identified as part of ARP4	I2	The HS2 design standards include requirements to include climate change allowances within flood risk modelling, based on the most recent guidance provided by the Environment Agency. HS2's critical infrastructure is required to be protected against a low likelihood, high magnitude 1-in-1,000 year flood event. Work is ongoing to understand the implications of this high resilience standard not including consideration for climate change. Climate change allowances must be applied to the design of eaves gutters and valley and parapet gutters for buildings (or parts of buildings) and protection to guard against groundwater ingress where necessary.	Low	High
APR4.9	High precipitation and flooding	Potential for wet conditions to impact the flooring material leading to increased risk of unsafe conditions, for example, slips, trips and falls.	Stations: building structures	Design, Operations	Head of water resources, waste and flood risk	No: new risk identified as part of ARP4	I2	Appropriate material selection will reduce the risk of slips, trips and falls during peak rainfall events. Operational procedures will also further reduce this risk.	Very low	High

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Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.10	High precipitation and flooding	Potential for water ingress to exposed electrical equipment during periods of intensive rainfall.	Stations: building structures	Design, Operations	Head of water resources, waste and flood risk	No: new risk identified as part of ARP4	I1, I2, I7	In line with HS2 design standards, key electrical infrastructure in stations will be designed and located to prevent water ingress and flooding above and below ground. All external equipment is required to be protected from the effects of the weather. The HS2 design standards include requirements to include climate change allowances in flood risk modelling. Our guidance to contractors has been updated to reflect the most recent Environment Agency guidance.	Low	High
APR4.11	High precipitation and flooding	Potential for overtopping of drainage systems or overwhelming of storage capacity in Sustainable Drainage Systems (SuDS) infrastructure and other rainwater attenuation features.	Stations: drainage	Design, Operations	Head of water resources, waste and flood risk	No: new risk identified as part of ARP4	I1, I2	The HS2 design standards include requirements to include climate change allowances within flood risk modelling. Our guidance to contractors has been updated to reflect the most recent Environment Agency guidance. The HS2 design standards require that drainage is resilient to extreme rainfall events. Eaves gutters and valley and parapet gutters must be designed in line with British Standard requirements including additional consideration of climate change allowances.	Very low	High
APR4.12	High precipitation and flooding	Earthwork failures due to flooding causing secondary impacts on structures and buildings (for example, damage) or access (for example, movement of signs and fencing).	Stations: earthworks	Design, Operations	Head of water resources, waste and flood risk; head of geotechnical engineering	No: new risk identified as part of ARP4	I5, I12	The HS2 design standards require climate change to be considered in the design of earthworks, particularly changes to groundwater conditions, prolonged periods of precipitation and prolonged drought. It is challenging to attribute individual climate variables to a particular geotechnical impact and as such HS2 Ltd recommend that designers include allowances for climate change following a cautious approach (for example, selecting the worst credible groundwater conditions and characteristic strength values, or applying partial factors) to account for the uncertainty created by climate change.	Low	Medium

Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.13	High precipitation and flooding	Risk of water ingress into underground station boxes during peak river flow events.	Stations: Underground structures	Design, Operations	Head of water resources, waste and flood risk	No: new risk identified as part of ARP4	I2, I7	Underground boxes are protected from flooding by raising the entrance by 300mm above the 1-in-1,000 year flood level from all sources without the need for intervention. This high resilience requirement for protection of critical infrastructure against a low likelihood, high magnitude 1-in-1,000 year flood event, does not include consideration for climate change. Work is ongoing to understand the implications of this high resilience standard not including consideration for climate change.	Low	High
APR4.14	High precipitation and flooding	Potential for increased surface water run off affecting planting and soil conditions during flooding and peak rainfall events.	Stations: vegetation	Design, Operations	Head of water resources, waste and flood risk	No: new risk identified as part of ARP4	I2, N4	The HS2 design standards include requirements to include climate change allowances in flood risk modelling. Our guidance to contractors has been updated to reflect the most recent guidance provided by the Environment Agency. HS2 design standards require stations and their surroundings to be resilient to the impact of flooding arising from climate change. Trees, 'green' walls and 'green' roofs and other planting around HS2 stations are used to provide flood attenuation support, supporting resilience to climate change. It is considered that the plant strategy for vegetation in stations will be resilient to climate change based on existing HS2 design standards.	Very low	High
APR4.15	High temperature / heatwaves	Public realm spaces around stations could experience increased external temperatures, resulting in an increased likelihood of heat stress to passengers.	Stations: access	Design, Operations	Landscape assessment manager; head of stations	No: new risk identified as part of ARP4	N1, N18, I5, H1, B5	The location and design of public realm spaces include consideration for shade. Introducing shade in public realm spaces will provide increased comfort to station users as temperatures increased due to climate change.	Very low	High

continued overleaf

Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.16	High temperature / heatwaves	Heat impacts on surfacing materials affected by differential expansion leading to heave and displacement of elements such as tactile paving.	Stations: building structures	Design, Operations	Lead material engineer - durability	No: new risk identified as part of ARP4	I5, I12, H1	HS2 design standards sets out that the materials used in stations should be robust and durable, ensuring future flexibility. Consideration for climate change is embedded in these standards.	Very low	High
APR4.17	High temperature / heatwaves	Increased risk of fire due to high temperatures.	Stations: building structures	Design, Operations	Operations and maintenance director	No: new risk identified as part of ARP4	N1, I5, H1	All switch and plant rooms will be provided with environmental controls to maintain optimum conditions for the equipment. These are designed with climate considerations in mind. It is assumed that increased temperatures due to climate change are unlikely in themselves to cause a fire within a controlled temperature environment. Fire safety is addressed in the HS2 design documentation and will be integrated into operational procedures.	Very low	High
APR4.18	High temperature / heatwaves	Increased likelihood of electrical equipment overheating and failing or running at a degraded performance level.	Stations: building structures	Design, Operations	Head of mechanical and electrical engineering	No: new risk identified as part of ARP4	I1, I5, I12, H1, B5	Thermal modelling of stations is a requirement of HS2's BREEAM design requirements for station designs. Following industry standards, this modelling is performed based on weather files provided by the Chartered Institution of Building Services Engineers (CIBSE). These are based on now-superseded UKCP09 projections. Although the findings of more recent climate projections, UKCP18, are broadly consistent there are some differences in findings, including in temperature extremes. It is not considered to be proportionate to update these weather files on a project-by-project basis due to their complexity. This remains a potential risk that requires sector-wide action to address.	Low	Low

continued overleaf

Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.18 (contd.)								Heating, ventilation and air conditioning (HVAC) systems will also be incorporated into the station design where required to provide additional cooling in periods of higher temperatures. HVAC systems will be sized using thermal modelling taking account of future maximum temperature ranges as a result of climate change. Mechanical building services systems must be designed so they perform satisfactorily during operation with effects of climate change considered.		
APR4.19	High temperature / heatwaves	Station buildings could experience an increased internal temperatures, resulting in an increased likelihood of heat stress to passengers and staff including unsafe working conditions for staff.	Stations: building structures	Design, Operations	Head of building services	No: new risk identified as part of ARP4	I1, I12, H1, B5	Thermal modelling of stations is a requirement of HS2's BREEAM design requirements for station designs. Following industry standards, this modelling is performed based on weather files provided by the Chartered Institution of Building Services Engineers (CIBSE). These are based on now-superseded UKCP09 projections. Although the findings of more recent climate projections, UKCP18, are broadly consistent there are some differences in findings, including in temperature extremes. It is not considered to be proportionate to update these weather files on a project-by-project basis due to their complexity. This remains a potential risk that requires sector-wide action to address. To conduct sensitivity testing, the design criteria for HS2 platforms and concourses are more onerous with a sensitivity assessment conducted against a low-likelihood, plausible 'high-end' climate change scenario (referred to as the H++ scenario).	Medium	Low

continued overleaf

Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.20	High temperature / heatwaves	High temperatures could lead to expansion in structures.	Stations: underground structures	Design, Operations	Head of civil engineering structures	No: new risk identified as part of ARP4	I12	Climate change and high temperatures are incorporated into HS2 design standards. These go beyond the requirements of the UK engineering standard, which are only based on historical weather observations from 2007 or before (contained within the UK National Annex to BS EN 1991-1-5). While the values included in Phase One designs are based on the now-superseded UKCP09 projections, analysis described in the ARP4 report was conducted to update this. Combining the above analysis with engineering judgement, the climate factors included in our designs were found to be sufficient.	Low	High
APR4.21	High temperature / heatwaves	Increased stress on planting and ecosystem services due to increased heat.	Stations: vegetation	Design, Operation	Landscape assessment manager; head of stations	No: new risk identified as part of ARP4	N1, N4, I12	It is considered that the planting strategy for vegetation in HS2 stations will be resilient to climate change based on existing design standards. The planting is designed to improve the micro-climate around stations, provide shade during warm and hot days and therefore plays a critical role in the health and wellbeing of people using the public realm. The HS2 Plant Procurement Strategy (described in ARP3) provides guidance on species that should be selected taking into account the need for climate change resilience and seasonal variety.	Low	High
APR4.22	Low rainfall / drought	Risk of failure of planting due to low water availability especially on green roofs or walls	Stations: vegetation	Design, Operations	Landscape assessment manager	No: new risk identified as part of ARP4	N1, N4, B3	It is considered that the plant strategy for vegetation in stations will be resilient to low rainfall / drought due to climate change based on provenance requirements embedded within the strategy, as described in ARP3. Maintenance and monitoring procedures will be developed to ensure successful planting, with consideration for climate change.	Very low	Medium

continued overleaf

Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.23	Low rainfall / drought	Potential for reduced water availability affecting services that use potable water.	Stations: building structures	Design, Operations	Head of stations	No: new risk identified as part of ARP4	B3	Consideration for water consumption, as required by the HS2 design criteria, aims to reduces water demand which will inherently increase resilience of the station environments to drought conditions. Operational procedures will be developed for stations to ensure resilience during periods of drought.	Low	High
APR4.24	Low rainfall / drought	Risk of fluctuating soil moisture content leading to instability in soils.	Stations: earthworks	Design, Operations	Head of water resources, waste and flood risk; head of geotechnical engineering	No – new risk identified as part of ARP4	N4	The HS2 design standards requires climate change to be considered in the design of earthworks, In particular, changes to groundwater conditions, prolonged periods of precipitation and prolonged drought. It is challenging to attribute individual climate variables to a particular geotechnical impact; and as such, HS2 Ltd recommends designers including allowances for climate change follow a cautious approach (e.g. selecting the worst credible groundwater conditions and characteristic strength values, or applying partial factors) to account for the uncertainty created by climate change.	Low	Medium
APR4.25	Low temperature / cold spells / snow	Potential for snow and ice to cause hazardous conditions on access routes to the station including reduced visibility of signs.	Stations: access	Design, Operation	Head of stations; lead material engineer - durability	No: new risk identified as part of ARP4	I12	Material selection at HS2 stations will be appropriate for adverse weather conditions. This risk will also be further mitigated in operational procedures at stations for periods of adverse weather.	Very low	High

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Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.26	Low temperature / cold spells / snow	Reduced performance of equipment and services due to low temperatures.	Stations: building structures	Design, Operation	Head of stations	No – new risk identified as part of ARP4	I12	Climate change will generally reduce the risk of cold weather events although extreme events may still occur. Building services are designed to be able to operate at very low temperatures, below those typically seen in the UK, and mitigations are embedded into the design including frost protection heating where required.	Very low	High
APR4.27	Low temperature / cold spells / snow	Station buildings could experience reduced internal temperatures, resulting in an increased likelihood of cold stress to passengers and staff including unsafe working conditions for staff.	Stations: building structures	Design, Operation	Head of building services	No: new risk identified as part of ARP4	H1	Thermal modelling of stations is a requirement of HS2's BREEAM design requirements for station designs. Following industry standards, this modelling is performed based on weather files provided by the Chartered Institution of Building Services Engineers (CIBSE). These are based on now-superseded UKCP09 projections. Although the findings of more recent climate projections, UKCP18, are broadly consistent there are some differences in findings, including in temperature extremes. It is not considered to be proportionate to update these weather files on a project-by-project basis due to their complexity. This remains a residual risk that requires sector-wide action to address. Climate change projections show a trend towards increased average temperatures in both summer and winter. Therefore, this risk is deemed to be lower for low temperature events but it should be noted that extreme cold spells will still occur.	Low	Medium
APR4.28	Low temperature / cold spells / snow	Risk of snow loading on buildings.	Stations: building structures	Design, Operation	Structural engineering lead	No: new risk identified as part of ARP4	H5	The British Standard for snow loading (BS EN 1991-1-3:2003 General actions. Snow loads UK National Annex) does not include any consideration for climate change and was last updated in 2010. While climate projections suggest a general increase in temperature in the future, there is still a likelihood of snow vents. Conservative design snow loads are applied over the design life and will therefore be accounted for in the structural design including a significant safety allowance.	Very low	Medium

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Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.29	Low temperature / cold spells / snow	Increased weathering of earthworks due to freeze and thaw cycles.	Stations: earthworks	Design, Operation	Head of water resources, waste and flood risk; head of geotechnical engineering	No – new risk identified as part of ARP4	I5	The HS2 design standards requires climate change to be considered in the design of earthworks. In particular, changes to groundwater conditions, prolonged periods of precipitation and prolonged drought are noted as areas for consideration with respect to climate change. It is challenging to attribute individual climate variables to a particular geotechnical impact and as such HS2 Ltd recommends that designers including allowances for climate change follow a cautious approach (e.g. selecting the worst credible groundwater conditions and characteristic strength values, or applying partial factors) to account for the uncertainty created by climate change.	Low	Medium
APR4.30	Low temperature / cold spells / snow	Increased movement provision in expansion joints may be needed to accommodate the change in temperatures against the reference level.	Stations: underground structures	Design, Operation	Head of civil engineering structures	No: new risk identified as part of ARP4	I12	UKCP18 projections suggest that average temperatures are increasing. However, colder than average winters will still occur but will become less likely in the future. Climate change consideration is incorporated into HS2 design standards. These go beyond the requirements of the UK engineering standard, which are only based on historical weather observations from 2007 or before (contained within the UK National Annex to BS EN 1991-1-5). While the values included in Phase One designs are based on the now-superseded UKCP09 projections, analysis described in Section 4.5 was conducted to update this analysis and the climate factors were found to be sufficient.	Low	High
APR4.31	Low temperature / cold spells / snow	Increased stress on planting and ecosystem services due to extreme low temperature.	Stations: vegetation	Design, Operation	Head of landscape	No: new risk identified as part of ARP4	N1, N4	It is considered that the HS2 planting strategy for vegetation in stations will be resilient to low temperatures due to climate change based on existing design standards and provenance requirements, as described in ARP3. Operation, maintenance and monitoring procedures will be developed to ensure successful planting, with consideration for climate change.	Very low	High

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Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.32	Subsidence or ground movement	Increased risk of damage to retaining structures and earthworks due to shrink-well and soil creep processes.	Stations: earthworks	Design, Operations	Head of geotechnical engineering	No – new risk identified as part of ARP4	I5	The HS2 design standards requires climate change to be considered in the design of earthworks, particularly changes to groundwater conditions, prolonged periods of precipitation and prolonged drought. It is challenging to attribute individual climate variables to a particular geotechnical impact and as such we recommend that designers follow a cautious approach (e.g. selecting the worst credible groundwater conditions and characteristic strength values, or applying partial factors) to account for the uncertainty created by climate change.	Low	Medium
APR4.33	Sun	Increased solar gain from sunlight driving increases in internal temperatures and/ or causing large amount of glare.	Stations: building structures	Design, Operation	Head of mechanical and electrical engineering	No – new risk identified as part of ARP4	n/a	The station buildings are designed to balance solar gain from sunlight and have appropriate mitigations in place to manage heat gain via cooling systems.	Very low	Medium
APR4.34	Wind, storms and lightning	Damage to traffic signs, lighting columns, fencing and any public way signs.	Stations: access	Design, Operation	Head of highways	No – new risk identified as part of ARP4	n/a	The UKCP18 wind projections are associated with significant uncertainty. However it should be noted that no climate change projections are included in available British and international standards. Given that signs and lighting columns have a short design life of about 15 years, these assets will be replaced in the short-term. This would provide an opportunity to install assets that are more resilient to wind impacts in the future if necessary.	Very low	Low

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Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.35	Wind, storms and lightning	Damage to buildings and equipment due lightning strikes. Potential impacts include damage to station roofs and canopies, power surges and fires from lightning strikes and unsafe working conditions.	Stations: building structures	Design, Operation	Head of stations	No – new risk identified as part of ARP4	n/a	The vulnerability of buildings to lightning caused by storms is considered adequately addressed by existing standards. They include provision of a dedicated lightning protection system (LPS) at all stations and a surge protection system. Any potential change in frequency of lightning strikes as a result of climate change would not impact the effectiveness of this mitigation.	Very low	Medium
APR4.36	Wind, storms and lightning	Damage to buildings due to high winds or storms. Potential impacts include damage to station roofs and canopies from high winds, and unsafe working conditions.	Stations: building structures	Design, Operation	Head of stations	No – new risk identified as part of ARP4	H5	HS2 Ltd requires stations to achieve the BREEAM credit for adaptation to climate change, which includes considering the resilience of structure, fabric, building services and renewable installation to hazards including storms (including high winds). It is noted that the British Standard for wind loading does not include any consideration for climate change, although the calculations are conservative with additional safety factors applied. Although climate projections for winds are associated with significant uncertainty, projections highlight increasing wind speeds and storminess for the second half of the 21st Century. This is modest compared with the interannual variability and there is not an increase in peak velocity projected for the UK or western Europe.	Very low	Low

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Appendix B

Risk code	Climate variable (and trend)	Risk (including indirect and interdependency risks)	Function / Services / Assets	Location	Risk owner	Risk identified under ARP1-3?	Risk identified in CCRA3?*	Embedded adaptation and resilience measures for Phase One	ARP4 risk score	Confidence (high/ medium/ low)
APR4.37	Wind, storms and lightning	Potential for high winds to result in trees to fall causing secondary damage.	Stations: vegetation	Design, Operation	Landscape assessment manager	No – new risk identified as part of ARP4	H5	UK climate projections are associated with considerable uncertainty regarding wind conditions. The current design standards include requirements for consideration of wind conditions in planting design in public realm spaces and adaptation to climate change. HS2 design standards require the microclimate, including exposure to wind, to be considered in the design and location of planting and ecology in the public realm spaces. Planting will be selected to ensure adaptability to climate change.	Very low	Medium

Appendix B

B2 Adjustments made to the risk assessment template

We are still in the design and construction phase of HS2 but the Department for Environment Food and Rural Affairs (Defra) template for risk assessment is based primarily on operating companies and organisations. We have made the following changes to the reporting template so it is fit-for-purpose for our reporting needs and also allows comparison with other organisations.

- Removed the decision threshold, process or trigger point for action on the risk. We have embedded climate adaptation and resilience from the start of the project and we're committed to building a railway that is resilient for the long-term. Consideration of necessary action to address risk is triggered in the design stage for any medium to high risks that are identified.
- Added a column on embedded adaptation and resilience measures. HS2 is built to world-class engineering standards which include enhanced measures for climate adaptation and resilience. To align with our previous risk assessments, details of the embedded adaptation and resilience measures included in our design documents have been included. For some organisations, the description described here may be comparable with the narrative column but we've found it helpful to separate these descriptions to address the risk.
- Removed various risk scoring columns to combine results into one overarching risk score. For a project organisation with defined phases of construction and operation, risks needs to be considered on appropriate timescales. For example, construction risks only need to be considered in the short term while operational risks don't have a risk until they are built and functioning. We think a single overarching risk score is more appropriate for the project organisation and this considers the risk at the end of the design life for the asset. Climate change risks are considered in the design and construction stages (the 2020s) to the operation stage (represented by the last time period available for UK climate projections, the 2080s). Where applicable, a mid-century (the 2050s) has also been used to help understand climate projections.
- Removed various columns detailing risk scoring under different scenarios. We consider two emission scenarios: a planning assumption of RCP6.0 (equivalent to a central estimate of approximately 2.8C global temperature rise at the end of the century compared with pre-industrial levels) and a higher emissions scenario, RCP8.5 for sensitivity testing (equivalent to a central estimate of approximately 4.3C global temperature rise) when developing HS2 design standards. While these do not align exactly with the +2C and +4C scenario recommended by the Defra guidance, they align with the agreed rail sector standard climate scenarios and are an appropriate representation of the range of future climate outcomes we may experience.

Appendix C: ARP4 Action Plan

Action number	Actions to address risks (including ARP3 actions)	Category of action*	Monitoring and evaluation (what does success look like?)	Project stage	Ownership/ business function	Implementation timetable**	Status of actions (planned, current or completed) ARP3	Status of actions (planned, current or completed) ARP4
1	Governance and risk management: Ensure climate risks are managed throughout the project with appropriate governance and risk management.	3 / 4	• Complete assurance of contractor Climate Change Adaptation and Resilience Reports (CCARRs) promptly. • Provide updates to our Environmental Sustainability Committee (ESC). • Ensure risks identified in the climate change risk assessments are integrated in our management processes.	All	Carbon and climate change team	Continuous	Current	Current

*Category of action from Defra guidance:
1 – scoping, monitoring and identifying impacts / risks.
2 – consideration of impacts, risks and likely actions with stakeholders.
3 – implementation of actions to address impacts / risks and maintain delivery of the organisation's functions.
4 – monitoring actions, evaluation against original plans, reassessment of risks, management system audit (against adaptation best practice).
Note: 1, 2, and 4 are management system actions; 3 is more closely associated with the actions necessary to deliver outcomes.

** The implementation timescales for actions are based on Defra guidance with an additional category added to represent our project status. Action timetables are: short-term implementation (i.e. by 2030); longer-term implementation (beyond 2033); or continuous (will be actioned throughout the design and construction stages).

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Appendix C

Action number	Actions to address risks (including ARP3 actions)	Category of action*	Monitoring and evaluation (what does success look like?)	Project stage	Ownership/ business function	Implementation timetable**	Status of actions (planned, current or completed) ARP3	Status of actions (planned, current or completed) ARP4
2	Collaborations: Host regular meetings to bring together engineers, designers and environmental managers including the HS2 Climate Change Adaptation and Resilience Forum and HS2 Climate Collaboration Group.	2	• Host meetings of the HS2 Climate Change Adaptation and Resilience Forum and HS2 Climate Collaboration Group. • Share best practice and lessons learned.	All	Carbon and climate change team; environmental delivery teams; engineering teams; Learning Legacy team	Continuous	Current	Current
3	Climate Change Adaptation and Resilience Reports (CCARRs): Ensure designers and contractors develop and submit Climate Change Adaptation and Resilience Reports.	1 / 3	• Complete assurance of contractor CCARRs promptly. • Ensure risks identified in CCARR are integrated in our risk management procedures. • Provide training on our process and requirements to new supply chain organisations as contracts are awarded.	Design / Construction	Carbon and climate change team; contractor organisations	Continuous	Current	Current
4	ARP reporting: Provide updates on the adaptation progress across the project in future ARP reports.	4	• Deliver a rolling five-year programme tracking the ARP4 action plan to ensure it is evaluated and monitored. • Complete an ARP5 report in December 2029 with increased focus on operational planning (timings to be confirmed by Defra).	All	Carbon and climate change team	Continuous	Current	Current

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Appendix C

Action number	Actions to address risks (including ARP3 actions)	Category of action*	Monitoring and evaluation (what does success look like?)	Project stage	Ownership/ business function	Implementation timetable**	Status of actions (planned, current or completed) ARP3	Status of actions (planned, current or completed) ARP4
5	Task Force on Climate-related Financial Disclosure (TCFD): Provide annual disclosures covering climate adaptation in HS2 Ltd's Annual Reports and Accounts, in line with the requirements for TCFD reporting for arm's-length bodies, as set out in HM Treasury sustainability reporting guidance.	4	• Reporting in line with public sector guidance from HM Treasurt phased reporting requirements in HS2 Ltd's Annual Report and Accounts, including following the guidance for Phase 2 disclosure in our 2024/25 report, and Phase 3 in our 2025/26 report. • Develop the strategy to integrate TCFD reporting in business-as-usual preparations for annual reporting.	All	Carbon and climate change team; financial teams	Continuous	n/a	Current
6	Metrics: Develop metrics for climate adaptation and resilience for the construction and operation phases of HS2.	3 / 4	• Use HS2 Ltd's HORACE dashboard to record and identify risks during the construction phase and establish a metric (construction action). • Report on the number of CCARR reports assured by HS2 Ltd (design action). • Develop a resilience target for HS2 (operations action).	Construction / Design / Operation	Carbon and climate change team; infrastructure management team	Short- / Long-term	Current / Planned	Current / Planned
7	Construction: Ensure the impacts of climate change on construction are assessed and monitored, meeting the requirements in the Phase One HS2 Code of Construction Practice.	2 / 3 / 4	• Conduct risk assessment for construction sector involving contractor organisations and focused on extreme weather risk. • Use HORACE dashboard to record and identify risks during the construction phase and establish a metric.	Construction	Carbon and climate change team; environmental delivery teams; corporate sustainability; benefits team	Short-term	Current	Current

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Appendix C

Action number	Actions to address risks (including ARP3 actions)	Category of action*	Monitoring and evaluation (what does success look like?)	Project stage	Ownership/ business function	Implementation timetable**	Status of actions (planned, current or completed) ARP3	Status of actions (planned, current or completed) ARP4
8	Operational Planning: Undertake operational planning to ensure resilient HS2 operations including risk management of weather and climate change, as well as extreme weather and seasonal changes. This includes the ability to monitor performance during operation to provide insight and allow further adaptation of HS2 assets to climate change.	1 / 2 / 3 / 4	• Conduct risk assessment for relevant elements of infrastructure management to assess weather and climate risks to HS2 during the operational stage (current). • Host regular progress meetings with a focus on weather and climate resilient operations (current). • Support development of capability, governance, strategies, standards and guidance documents for operational procedures, integrating consideration of climate and extreme weather (current/planned). • Model climate resilient operations (planned). • Engage with groups working to integrate conventional and HS2 rail infrastructure to ensure joined up approaches and consideration of climate change and extreme weather to help to ensure reliability and performance (planned).	Operation	Carbon and climate change team; infrastructure management team	Short- / Long-term	Current / Planned	Planned
9	Adaptive Capacity: Build organisational adaptive capacity for climate resilience.	2 / 3	• Participate in industry-wide climate resilience maturity assessment and develop plans in line with learning to build adaptive capacity (current). • Provide a future training programme for climate change adaptation and operational weather resilience. • Build governance and capability in new contract areas (for example, rail systems) and stages of the project (for example, operations).	All	Carbon and climate change team	Long-term	n/a	Current / Planned

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Appendix C

Action number	Actions to address risks (including ARP3 actions)	Category of action*	Monitoring and evaluation (what does success look like?)	Project stage	Ownership/ business function	Implementation timetable**	Status of actions (planned, current or completed) ARP3	Status of actions (planned, current or completed) ARP4
10	Adaptation Pathways: Develop adaptation pathways guidance for HS2 assets and case studies, including monitoring requirements. Support industry-wide initiatives to develop pathways and provide feedback and learnings from implementation experience.	2 / 3 / 4	• Complete an internal project to develop guidance for applying adaptation pathways to HS2 assets including developing two case studies. • Apply our new guidance to at least one additional adaptation pathways case study. • Implement adaptation pathway plan from guidance note for flood risk and 'green' assets. • Engage with external partners to support the development of industry-wide approaches to adaptation pathways including development of new infrastructure publicly available standard.	Design / Operation	Carbon and climate change team; infrastructure management team; engineering teams; British Standards Institute (BSI); Institute for Civil Engineers (ICE)	Short- / Long-term	Planned	Current
11	Interdependencies: Work with partners, supply chain and stakeholders to achieve our climate change adaptation and resilience objectives, including managing interdependent climate risks.	1 / 2 / 3	• Building on the work from the Transport for London project (Section 5), develop internal understanding of interdependencies to/from HS2 and risk of cascading impacts. • Develop a risk assessment of climate-related interface risks between HS2 assets. • Conduct risk assessment for HS2 supply chain.	All	Carbon and climate change team; engineering teams; infrastructure management team; communication team; wider-transport sector networks	Short-term	Current	Current

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Appendix C

Action number	Actions to address risks (including ARP3 actions)	Category of action*	Monitoring and evaluation (what does success look like?)	Project stage	Ownership/ business function	Implementation timetable**	Status of actions (planned, current or completed) ARP3	Status of actions (planned, current or completed) ARP4
12	Innovation: Engage in industry and academic partnerships to develop understanding of climate change adaptation and resilience. Seek opportunities to innovate and share knowledge.	1 / 2 / 3	• Develop a climate change innovation strategy to address key challenges. • Support the development of new standards for climate change adaptation including the PAS Adaptation Pathways for Infrastructure. • Engage with DARe Research Hub and integrate findings into our project.	All	Carbon and climate change team; innovation team; British Standards Institute (BSI); Institute for Civil Engineers (ICE)	Short-term	Current	Current
13	Engineering Design Standards: Continue to embed climate change considerations in engineering design standards where practicable given HS2 design stage, and share lessons learned to improve industry standards.	2 / 3	• Share lessons learned and methodologies for integrating climate considerations into engineering design standards. • Engage with industry and the rail sector to push for climate considerations in standard design, going beyond today's requirements.	Design / Operation	Carbon and climate change team; engineering teams	Continuous	n/a	Current

Endnotes

1 HM Treasury guidance document: https://www.gov.uk/government/publications/tcfd-aligned-disclosure-application-guidance/task-force-on-climate-related-financial-disclosure-tcfd-aligned-disclosure-application-guidance#annexes

2 TCFD recommendations: https://www.fsb-tcfd.org

3 RSSB Sustainable Rail Blueprint: https://www.rssb.co.uk/sustainability/sustainable-rail-blueprint

4 RSSB Climate change maturity: https://www.rssb.co.uk/sustainability/climate-change-maturity

5 ISO 14090: https://www.iso.org/standard/68507.html

6 British Standard 8631: https://knowledge.bsigroup.com/products/adaptation-to-climate-change-using-adaptation-pathways-for-decision-making-guide?version=standard

7 ISO Standards: https://www.iso.org/standards.html

8 PAS 2080: https://www.bsigroup.com/en-GB/insights-and-media/insights/brochures/pas-2080-carbon-management-in-infrastructure-and-built-environment

9 UK Climate Projections: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/index

10 Climate Change Act 2008: https://www.legislation.gov.uk/ukpga/2008/27/contents

11 Climate Change Committee CCRA4-IA: https://www.theccc.org.uk/publication/proposed-methodology-for-the-ccra4-advice

12 DARe Research Hub: https://dare.ac.uk

13 UKGBC Physical Risk Lab: https://ukgbc.org/resources/physical-risk-labs-compendium-of-experience

14 RSSB Climate projections for rail: www.rssb.co.uk/sustainability/prepared-for-a-changing-climate/climate-projections-for-rail

15 Met Office Unprecedented Temperatures: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2022/2022_03_july_heatwave_v1.pdf

16 Met Office severe winter storms: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2022/2022_02_storms_dudley_eunice_franklin.pdf

17 Wettest 18 months on record: https://news.sky.com/story/england-soaked-by-record-rainfall-in-last-18-months-new-met-office-figures-show-13106645

18 IPCC AR5: https://www.ipcc.ch/assessment-report/ar5

19 Met Office UK Climate Projections Headline Findings: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18_headline_findings_v4_aug22.pdf

20 Environment Agency Flood risk assessments: climate change allowances guidance: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

21 British Standard for structures: https://landingpage.bsigroup.com/LandingPage/Series?UPI=BS%20EN%201991-1

22 BREEAM scheme: https://breeam.com

23 CIBSE Weather files: https://www.cibse.org/weatherdata

24 TfL Climate Change Adaptation Plan: https://tfl.gov.uk/corporate/about-tfl/adapting-to-climate-change

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