

LONDON- WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

Resilience to impacts from climatic conditions (CL-003-000)

Climate

November 2013

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Department for Transport

High Speed Two (HS2) Limited has been tasked by the Department for Transport (DfT) with managing the delivery of a new national high speed rail network. It is a non-departmental public body wholly owned by the DfT.

A report prepared for High Speed Two (HS2) Limited.

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Executive summary

A high level climate change risk and resilience assessment has been undertaken to identify the potential risks of climate change on the Proposed Scheme, and to assess the Proposed Scheme's resilience and capacity to cope with these potential risks. The assessment has considered risks posed by climate related hazards such as extreme hot and cold weather, heavy rain, high winds and storms to the infrastructure and assets associated with the Proposed Scheme including tracks, tunnels, overhead line equipment, rolling stock, stations and earthworks.

The purpose of this report is to summarise these potential risks as understood at the interim preliminary design stage, to demonstrate how the Proposed Scheme will address potential risks through resilience measures.

UK climate change policy is set out in the Climate Change Act 2008, supported by a national Climate Change Risk Assessment (2012) and National Adaptation Programme (2013). Government has identified the resilience of UK infrastructure to climate change as a major 21st century challenge that needs to be addressed. This is supported by proposals for the revision of European Union Environmental Impact Assessment Directive 2012 and subsequent pilot guidance (not yet formally adopted) from the European Commission (2012) on integrating climate change into Environmental Impact Assessment which includes the consideration of measures to ensure the resilience of projects to climate change. This is reflected in the HS2 Sustainability Policy which states the aim to "build a network which is resilient for the long term and seek to minimise the combined effect of the project and climate change on the environment". This policy statement is reinforced within the National Adaptation Programme.

The likelihood and consequences of climate hazards have been considered, based upon the trends within the UK Climate Projections 2009 (UKCP09), to identify risks posed by climate change to infrastructure and assets associated with the Proposed Scheme. Assessment of the Proposed Scheme before resilience measures were considered identified two high risks posed by climate change: flooding of track work, cuttings and tunnels, and overheating in tunnels. However, route-wide and site specific flood risk assessments and resulting design measures incorporated into the current design (such as raising the threshold levels of potential water ingress points into ventilation shafts and portals, and the sizing of tunnels to allow for anticipated ventilation and cooling requirements) has reduced the likelihood of flooding and overheating. Accordingly, the risks posed by flooding and overheating have been reduced to low.

Risks relating to construction will be addressed by requirements in the Code of Construction Practice (CoCP) for the nominated undertaker to pay due consideration to the impacts of extreme weather events and related conditions. This assumes that all avoidance and mitigation measures are in place before construction.

Risks relating to operation and maintenance of the Proposed Scheme will be addressed by future operation and maintenance plans. Interdependencies are not considered in this report. Work during further design stages will clarify the interfaces and interdependencies between HS2 Ltd and other organisations with regards to climate change resilience across the life time of the Proposed Scheme.

It is currently anticipated that climate change risks will continue to be reviewed during future design, construction, operation and maintenance stages.

1 Introduction

1.1 Purpose and scope of report

- 1.1.1 The purpose of this report is to summarise the outcomes of a high level climate change risk and resilience assessment undertaken for the Proposed Scheme at the interim preliminary design stage. The assessment has been based on broad descriptions of changes to long-term, seasonal averages and extreme weather events from the UK Climate Projections 2009 (UKCP09)¹. It has taken account of current weather events and climatic conditions, and considered how these might worsen or improve during construction and the operational life of the infrastructure and assets associated with the Proposed Scheme due to projected climate change. In the case of flood risk, more detailed planning requirements and design guidance relating to climate change exists. Therefore an assessment of climate change impacts on flood risk has been carried out at the route-wide and site-specific levels and this is reported in Volume 5 of this Environmental Statement (Appendix: WR-001-000 and Appendices: WR-003-001 to WR-003-26 respectively). The flood risk assessments have used the recommended precautionary sensitivity ranges of key parameters as given in Table 5 in the Technical Guidance to the National Planning Policy Framework (NPPF). Sensitivity testing undertaken allows for variations in climate change factors included in other national guidance.
- 1.1.2 The assessment considers that the Proposed Scheme will be designed to be resilient to impacts arising from current weather events and climatic conditions, and designed in accordance with current planning, design and engineering practice and codes. The risk assessment then considered weather events and climatic conditions that could potentially worsen or improve due to current projected climate change beyond the parameters normally considered for major infrastructure projects. It also identifies the resilience measures for each risk either already in place or in development.
- 1.1.3 The high level risk and resilience assessment summarised in this report does not comprise a detailed quantitative study of individual climate change risks. However, this approach is considered appropriate for the interim preliminary design stage of the Proposed Scheme.
- 1.1.4 The temporal scope of the risk assessment includes consideration of risks relevant to the future design, construction, operation and maintenance stages of the Proposed Scheme. It is anticipated that the review of these potential climate change related risks will be an on-going process during these subsequent stages, and that the related resilience measures will also be reviewed accordingly.
- 1.1.5 This report forms part of Appendix: CL-003-000 within Volume 5 of this Environmental Statement.

1.2 Policy and guidelines

- 1.2.1 Climate change policy in the United Kingdom (UK) is set out in the Climate Change Act 2008², supported by a national Climate Change Risk Assessment (January 2012)³

¹ UK Climate Impacts Programme, (2009), Climate Change Projections.

² *Climate Change Act 2008*, (c. 27). London, Her Majesty's Stationery Office.

³ Department for Environment, Food and Rural Affairs, (2012), *The UK Climate Change Risk Assessment 2012 Evidence Report*.

and National Adaptation Programme (published 1 July 2013)⁴, which will be reviewed every five years. European Union (EU) Environmental Impact Assessment (EIA) Directive 2011⁵ places a requirement upon projects anticipated to have significant effects on the surrounding environment and communities to make a formal assessment of these effects. In the 2012 European Commission (EC) proposal for the revised EIA Directive⁶, the impacts of climate change on the environment and communities affected by the project, and the resilience of the project to climate change, were also raised as issues to be addressed. Subsequent pilot guidance from the EC on integrating climate change and biodiversity into EIA⁷ (not yet adopted) recommends that alternatives and measures are considered at the planning stage to ensure, amongst other things, projects are resilient to the impacts of climate change. It states:

“A number of recent studies on the vulnerability of the EU and specific sectors and territories to the changing climate have shown that Europe’s infrastructure needs to be adapted to better cope with natural phenomena caused by climate change. This means considering that the design parameters identified at a project’s inception may no longer be valid at the end of its potentially long lifespan. It represents a shift in thinking, from the traditional assessment of environmental impact to taking possible long-term risks into account. EIA can help projects to adapt to this shift through the concept of resilience. A project needs to be assessed against an evolving environmental baseline. EIA should show an understanding of how the changing baseline can affect a project and how the project may respond over time. The EIA process is particularly important since it can help set the context for projects; taking potential climate change impacts (including disaster risks) into consideration in EIA can make projects more resilient”.

- 1.2.2 Nationally, government departments such as Defra⁸ and the Department for Transport (DfT)⁹, and bodies such as Transport for London (TfL)¹⁰ have identified resilience to climate change as a major 21st century transport challenge that needs to be addressed. In particular, Government has identified a need for “an infrastructure network that is resilient to today’s natural hazards and prepared for the future changing climate”¹¹.
- 1.2.3 This is reflected in the HS2 Sustainability Policy, which states the aim to “build a network which is resilient for the long term and seek to minimise the combined effect of the project and climate change on the environment” (see Volume 1, Section 1 of this Environmental Statement). This policy statement is reinforced within the National Adaptation Programme¹².

⁴ Department for Environment, Food and Rural Affairs, (2013), *The National Adaptation Programme – Making the Country Resilient to a Changing Climate*.

⁵ Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment. Strasbourg, European Parliament and European Council.

⁶ European Commission, (2012), *Proposal for a Directive of the European Parliament and of the Council amending Directive 2011/92/EU on the Assessment of the Effects of Certain Public and Private Projects on the Environment*.

⁷ European Commission, (2013), *Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment*.

⁸ Department for Environment, Food and Rural Affairs, (2011), *Climate Resilient Infrastructure: Preparing for a Changing Climate*.

⁹ Department for Transport, (2010), *Climate Change Adaptation Plan for Transport 2010-2012 – Enhancing Resilience to Climate Change*.

¹⁰ Transport for London, (2011), *Providing Transport Services Resilient to Extreme Weather and Climate Change*.

¹¹ Department for Environment, Food and Rural Affairs, (2011), *Climate Resilient Infrastructure: Preparing for a Changing Climate*.

¹² Department for Environment, Food and Rural Affairs, (2013), *The National Adaptation Programme – Making the Country Resilient to a Changing Climate*.

1.3 Climate change projections

- 1.3.1 The UKCP09 climate change projections¹³ have been used as a source of national and regional climate change trends for the high level climate change risk and resilience assessment of the Proposed Scheme, except for the flood risk assessments which have used the recommended precautionary sensitivity ranges of key parameters as given in Table 5 in the Technical Guidance to NPPF. Due to the high level of the risk assessment, a specific climate change scenario has not been applied and quantitative assessment of climate change projection data has not been undertaken. Instead, this assessment has used the broad descriptions of changes in long-term, seasonal averages and extreme weather events provided in UKCP09 to assess qualitatively the effects of climate change using professional expertise and judgement.
- 1.3.2 During the construction and operation phases of the Proposed Scheme in the period 2017-2099, the trends within UKCP09 suggest the following changes to long-term, seasonal averages:
- warmer, drier summers, particularly in parts of southern England¹⁴;
 - milder, wetter winters, particularly on the western side of the UK¹⁵;
 - an increase in annual average temperature¹⁶; and
 - fewer days with snow and frost¹⁷.
- 1.3.3 During the construction and operation phases the following changes are also anticipated:
- very likely to be more very hot days¹⁸;
 - likely to be more intense downpours of rain¹⁹ (particularly in summer); and
 - very likely to be an increase in dry spells²⁰.
- 1.3.4 In addition, it is likely, although with a higher level of uncertainty, that the probability of the following extreme weather events will increase as a consequence of climate change²¹:
- short periods of intense cold weather (still expected as a result of natural variability²²); and
 - an increase in the frequency of storms and high winds (widely accepted as difficult to predict with any certainty²³).
- 1.3.5 During the course of the operation phase (2026 onwards), changes in climatic averages and extreme weather events are projected to become more pronounced.

¹³ UK Climate Impacts Programme, (2009), Climate Change Projections.

¹⁴ UK Climate Impacts Programme, (2009), Climate Change Projections. Table 4.1, 4.2, 4.4 and 4.5.

¹⁵ UK Climate Impacts Programme, (2009), Climate Change Projections. Table 4.1, 4.2, 4.4 and 4.5.

¹⁶ UK Climate Impacts Programme, (2009), Climate Change Projections. Section 4.3.5.

¹⁷ UK Climate Impacts Programme, (2009), Climate Change Projections. Figure 4.31.

¹⁸ UK Climate Impacts Programme, (2009), Climate Change Briefing Report. Table 3

¹⁹ UK Climate Impacts Programme, (2009), Climate Change Projections. Table 4.2.

²⁰ UK Climate Impacts Programme, (2009), Climate Change Briefing Report. Table 4.

²¹ Scaife, A, Met Office; Climate Jigsaw Puzzle, Met Office; <http://www.metoffice.gov.uk/barometer/science/2012-04/climate-jigsaw-puzzle>; Accessed: 4th July 2013.

²² UK Climate Impacts Programme, (2009), Climate Change Briefing Report. Table 3.

²³ UK Climate Impacts Programme, (2009), Climate Change Projections. Section 1.4.

2 Methodology

2.1 Literature review

2.1.1 A wide range of climate change risk assessments (CCRA) undertaken by external parties have been assessed for relevance to the climate risk and resilience assessment of the Proposed Scheme. It appears that the level of industry precedent on CCRA for high-speed rail is limited in the UK. While High Speed 1 (HS1) may be a comparable scheme, it predates much of the climate change legislation and policy applicable to the Proposed Scheme (see Section 1.2). There is, however, a considerable amount of resilience-related literature for the existing conventional railway, which has significant overlap with and relevance to the risks associated with the Proposed Scheme. The CCRA and climate change adaptation reports which have contributed most to this climate change resilience report are listed in the reference section at the end of this report. In addition, the Tomorrow's Railway and Climate Change Adaptation (TRaCCA) project reports^{24, 25} produced by RSSB (Rail Safety Standards Board) have been reviewed.

2.2 Definitions of hazards, infrastructure and assets, and risk

2.2.1 For the purposes of this assessment a hazard is defined as one of the effects of a changed climate which has the potential to do harm to the infrastructure and assets associated with the Proposed Scheme. The following climate hazards are considered in this risk assessment:

- heat;
- drought;
- humidity;
- ice and snow/cold;
- insolation (solar irradiation);
- river, surface water and groundwater flooding;
- storms/lightning strikes; and
- wind.

Source: Adapted from UKCP09 and TRaCCA, 2011.

2.2.2 The degree to which the frequency and intensity of these potential hazards may change as a result of climate change is explained in the UKCP09²⁶ climate change projections. It should be noted that the route-wide and site-specific flood risk assessments cover all sources of potential flooding hazards.

2.2.3 A climate hazard may result in an impact on the Proposed Scheme. The impact may be direct, for example flooding of the infrastructure itself, or indirect, for example heat exhaustion of workers which could disrupt operation. The consequence in either

²⁴ RSSB (2010) Tomorrow's railway and climate change adaptation (TRaCCA), Phase 1 report.

²⁵ RSSB (2011) Tomorrow's railway and climate change adaptation (TRaCCA), Phase 3 report.

²⁶ UK Climate Impacts Programme, (2009), Climate Change Projections.

of these cases would be disruption of the service. The infrastructure and assets associated with the Proposed Scheme and which may be impacted by the climate hazards defined in Section 2.2.1 are defined (in alphabetical order) as:

- abstraction, drainage and flood conveyance systems;
- auto-transformer feeder stations;
- earthworks and landscaping (including retaining walls);
- emergency response services (for staff and passengers);
- feeder stations (National Grid responsibility)
- fencing and noise barriers;
- grid supply points (National Grid responsibility)
- HS2 and accommodation accesses (i.e. routes facilitating the movement of HS2 staff and neighbouring landowners);
- human factors (i.e. the staff and passenger experience of the Proposed Scheme);
- lineside equipment;
- mechanical and electrical equipment (including tunnel ventilation);
- overbridges and underbridges;
- overhead line equipment (OLE);
- rolling stock;
- signalling and communications;
- stations / interchanges;
- track work;
- tunnels (including portals and vent shafts);
- utilities;
- viaducts; and
- water supply.

2.2.4 An understanding of the likelihood of an impact occurring is needed to identify the risk to the Proposed Scheme from climate change. The risk assessment therefore considers the likelihood of a hazard occurring that could result in an impact on the infrastructure and assets associated with the Proposed Scheme. In addition, the risk to the Proposed Scheme will depend on the severity of the consequence of the impact, and the vulnerability of the infrastructure or asset itself. The definitions of these terms can therefore be summarised as follows:

- hazard is the potential to cause an impact
- risk is the likelihood of impact occurring multiplied by consequence of impact of hazard
- vulnerability is the degree to which infrastructure or assets are susceptible to adverse impacts and is influenced by sensitivity, adaptive capacity and magnitude of impact.

2.3 The risk assessment process

2.3.1 The potential likelihood and consequence of impacts to the infrastructure and assets associated with the Proposed Scheme were considered for a number of climate hazards and were scored using a five point scale:

- likelihood – very likely, likely, possible, unlikely, very unlikely; and
- consequence of impact – very high, high, medium, low, very low.

2.3.2 The assessments of impact likelihood and consequence were initially based on a scheme with no resilience measures to protect against the additional effects of climate change, and were then re-evaluated with resilience measures included to determine the need for and benefit of these measures. This level of risk assessment is considered appropriate for the interim preliminary design stage, and will be developed further during future design, construction, operation and maintenance stages.

2.4 Timeframes for risk assessment process

2.4.1 Table 1 shows the time periods for the UKCP09 climate change projections that have been used to assess potential risks during the interim preliminary design stage, future design, construction, and operation and maintenance stages over the 120 year design life of the Proposed Scheme. It should be noted that some of the infrastructure and assets associated with the Proposed Scheme may have shorter or longer design lives than others.

Table 1: Temporal scope for consideration of potential climate change risks

	Interim preliminary design and future design	Construction	Operation (start) and maintenance	Operation (peak) and maintenance	Operation (continued) and maintenance	Design life of Proposed Scheme
Proposed Scheme activities / stages	2012-2017	2017-2026	2026 onwards	2041	2041 onwards	2026-2146
UKCP09 time period ²⁷	2020s (2010-2039)	2020s (2010-2039)	2020s (2010-2039)	2050s (2040-2069)	2080s (2070-2099)	2100+ (Outside standard UKCP09 time periods)

²⁷ UKCP09 uses 30-year time periods for both the baseline climate and for all future climate projections. The projections are reported for seven overlapping 30-year time periods from 2010 - 2099. Each future time period is named based on the decade upon which it is centred. The 2020s, 2050s and the 2080s are most commonly used time periods.

3 Results of climate change risk assessment

3.1 Overview

- 3.1.1 This section sets out the results of the high level climate change risk assessment and provides details of risks from a number of climate hazards for each stage of the Proposed Scheme across a range of infrastructure and assets. It also identifies the associated resilience measures either in place at the interim preliminary design stage or to be reviewed during future design, construction, operation and maintenance stages (Sections 3.3-3.5 respectively).
- 3.1.2 The EC Guidance on integrating climate change and biodiversity into EIA lists the benefits of integrating climate change considerations into the EIA process when alternatives are still possible and opportunities exist. The risk assessment has helped with this process of integration by promoting consideration of options, which may provide multiple benefits, during the interim preliminary design stage of the Proposed Scheme.

3.2 Summary of risks addressed by HS2 Ltd during interim preliminary design

- 3.2.1 Assessment of the Proposed Scheme before resilience measures were considered, identified two high risks posed by climate change; potential flooding of track, cuttings and tunnels, and overheating of tunnels. These risks are highlighted below with the related climate hazards in brackets. These risks have been reduced from high to low risk due to the resilience measures adopted to address them during interim preliminary design stage.

Flooding of track, cutting and tunnels (river, surface and groundwater flooding)

- 3.2.2 Flooding of the track, cuttings and within tunnels is a potentially significant risk that could affect safety, cost, journey times and public perception of the Proposed Scheme. During the interim preliminary design stage, a comprehensive flood risk assessment (FRA) has been carried out in consultation with the Environment Agency for each community forum area to assess the vulnerability of infrastructure and assets associated with the Proposed Scheme to all possible types of flooding. A route-wide FRA has also been carried out. The assessments followed technical guidance within the NPPF²⁸ and examined flood risks at the existing baseline level and at the future baseline for the lifetime of the development, taking into account projected climate change impacts for all sources of flooding.
- 3.2.3 To address the potential increase in flood risk, all operational infrastructure and assets associated with the Proposed Scheme will be protected by a 1m freeboard above the 1 in 1,000 year (0.1%) annual probability of flooding. Replacement flood storage areas are to be implemented to mitigate the potential for a significant increase in flood risk

²⁸ Department for Communities and Local Government, (2012), *Technical Guidance to the National Planning Policy Framework*.

to and from sites along the Proposed Scheme. Management measures, such as flood risk management plans will also be required in addition to avoidance measures included in the design. Cuttings will be designed based on the assumption that groundwater levels are 1 metre below ground surface. Railway drainage will accommodate for storms up to the 1 in 100 year (1%) annual probability of flooding (including +30% for climate change allowance). This will allow for an expected increase in the intensity of rainfall events and will require regular maintenance to ensure drainage systems are not blocked by debris during heavy storms.

- 3.2.4 With the above resilience measures in place the risks to track, cuttings and tunnels from flooding are considered to be low.

Overheating of tunnels (heat)

- 3.2.5 Warmer, drier summers and more intense hot weather events, indicated by the UKCP09 projections, could lead to increased temperatures within tunnels and which could potentially cause the overheating of trains.
- 3.2.6 Resilience measures considered at interim preliminary design stage include the provision of adequate space within tunnels and ventilation shafts for anticipated future cooling and ventilation requirements. Tunnel cooling and ventilation measures will be reviewed further during future design. Similarly, further work will be undertaken during future design to better understand the impacts of climate change on train cooling and ventilation requirements to ensure passenger comfort (see Section 3.2). The Technical Specification for Interoperability (TSI) requirement to permit the use of regenerative braking on rolling stock provides an opportunity to not only decrease waste heat emissions in tunnels, but also to reduce the carbon impact of the railway.

3.3 Risks to be addressed during future design

- 3.3.1 A number of potentially significant climate risks are to be considered further during the design. Risks from a number of climate hazards across a range of infrastructure and assets and the proposed resilience measures are presented in Table 2.

Table 2: Risks from a number of climate hazards across a range of infrastructure and assets to be addressed through future design

Climate hazard	Infrastructure and assets associated with the Proposed Scheme	Potential climate change impact	Unmitigated risk	Proposed resilience measure
Heat	Human factors	It may be too hot to work or travel.	Unmitigated, this is likely to occur with a high consequence of impact.	Practical management of heat risk for employees will take place during operation and maintenance. The passenger experience will be addressed during the future design of trains and stations.

Ice and snow/cold	Overhead line equipment (OLE) including overhead lines (OHL)	OLE may fail due to snow overloading.	Unmitigated, this is likely to occur with a high consequence of impact.	OLE and OHL will be designed to take into account a range of minimum and maximum temperatures and loads under current and future climate conditions.
Heat	Earthworks and landscaping	Increased shrinkage of soil due to decrease in groundwater level is possible. Planting failures may occur due to drought, and grassland fires are also possible.	Unmitigated, this is likely to occur with a medium consequence of impact.	Geotechnical issues will be covered in the future design and track side planting has already been considered in preliminary interim design. Further resilience measures will be considered as necessary within operation and maintenance procedures.
Heat	Tunnels	Higher temperatures may require increased climate control within trains.	Unmitigated, this is possible and could have a medium consequence of impact.	Sensitivity analyses will be undertaken for a range of possible ambient temperatures during future design to inform the specification of rolling stock.
Wind / Flooding	Abstraction, drainage and flood conveyance systems	Windborne debris may cause blockage of railway drainage systems.	Unmitigated, this is likely to occur and would have a high consequence of impact.	All abstraction, drainage and flood conveyance systems have been specified to allow for climate change and to reduce blockage.

3.4 Risks to be addressed during construction

- 3.4.1 Construction related climate risks identified relate to the potential for extreme weather events such as heavy rain, hot weather events and high winds to affect or disrupt construction activities. These risks will be addressed by requirements in the CoCP for the implementation of appropriate flood risk measures and due consideration of the impacts of extreme weather events and related conditions. This assumes that all proposed avoidance and mitigation measures are in place before construction commences. If appropriate, additional measures to ensure the resilience of the proposed mitigation of impacts during extreme weather events will be implemented. Changes to long-term, seasonal averages are not considered to be as significant by the 2020s and therefore specific resilience measures to address these changes are not required during the construction phase.

3.5 Risks to be addressed through operation and maintenance plans

- 3.5.1 Risks relating to operation and maintenance of the Proposed Scheme will be addressed by future operation and management plans. Interdependencies are not considered in this report.
- 3.5.2 Further review and evaluation of the climate change related risks and resilience measures identified in this assessment will continue to take place throughout the lifetime of the Proposed Scheme.

4 Summary and conclusions

- 4.1.1 In summary, the results of the high level climate risk and resilience assessment for the Proposed Scheme demonstrate that with the existing and proposed resilience measures developed by HS2 Ltd, climate risks can be minimised to ensure that the Proposed Scheme is resilient to the impacts of climate change for the long-term.

5 Next steps

- 5.1.1 As stated previously, the review and evaluation of climate hazards and risks will be an on-going process throughout the lifetime of the Proposed Scheme. Further work during future design stages will clarify the interfaces and interdependencies between HS2 Ltd and other organisations with regards to climate change resilience.

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