The HS2 approach to long-term resilience

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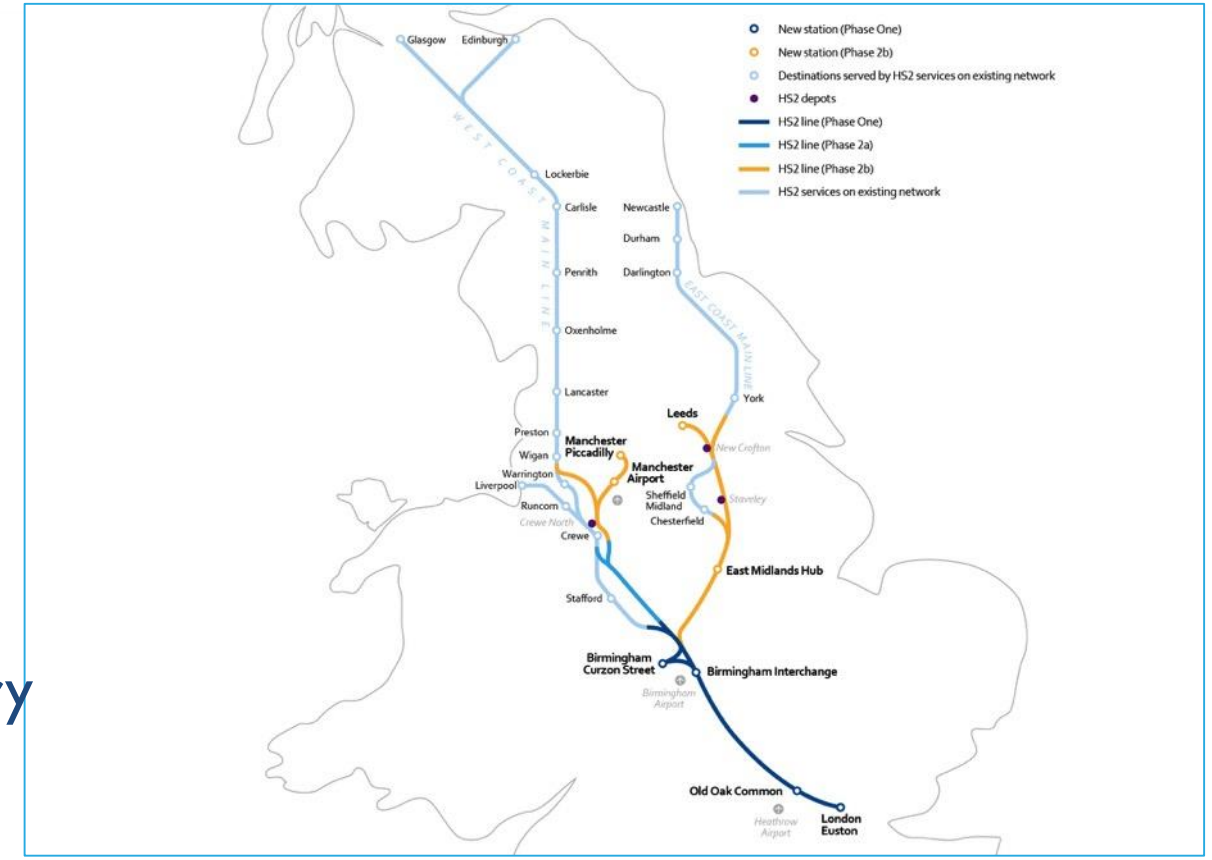
HS2: A new railway for Britain

- 345 miles of new high speed track
- Integrated into the East and West Coast Main Lines
- Phase 1 - London and Birmingham complete in 2026
- Crewe by 2027 – Phase 2a
- Phase 2b Y-shaped network to Manchester and Leeds - 2033
- Up to 48 HS2 trains/ 1,000 seats/ every hour
- Britain's first new intercity railway north of London in over 100 years



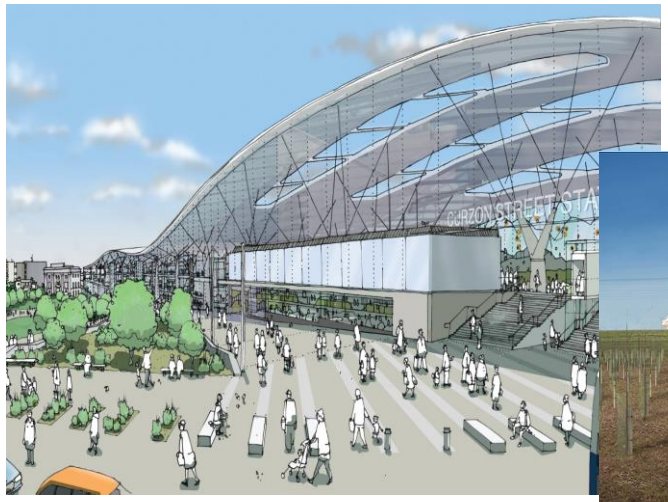
HS2 Timeline

2016

- Phase One construction starts

2022

- Full Phase 2 assent



2026

- Phase One starts to operate to Birmingham

2033

- Phase 2 starts to operate - Leeds and Manchester

Environmental statements

- European Directives from 2014 require climate change considerations including 'adaptation'
- HS2's Environmental Statement covers:
  - The impacts of climate change on HS2 infrastructure
  - 'In-combination' impacts of climate change and HS2 on receiving environments
- In addition, HS2 has looked at impacts on their proposed operations from climate change impacts on external infrastructure

HS2 Sustainability policy

"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."

Ref: HS2 Sustainability Policy

HS2's Design vision

We aim to enhance the lives of future generations of people in Britain by designing a transformational rail system that is admired around the world.

create an environmentally sustainable solution and be a good neighbour to local communities

Major infrastructure perspective

- Assurance
- Complexity (wide range of contracts)
- Decision-making under uncertainty
- Adaptive capacity
- System of systems, and interdependencies

HS2's sustainability themes

Spreading the benefits:
Economic growth and community regeneration

Opportunities for all:
Skills, employment and education

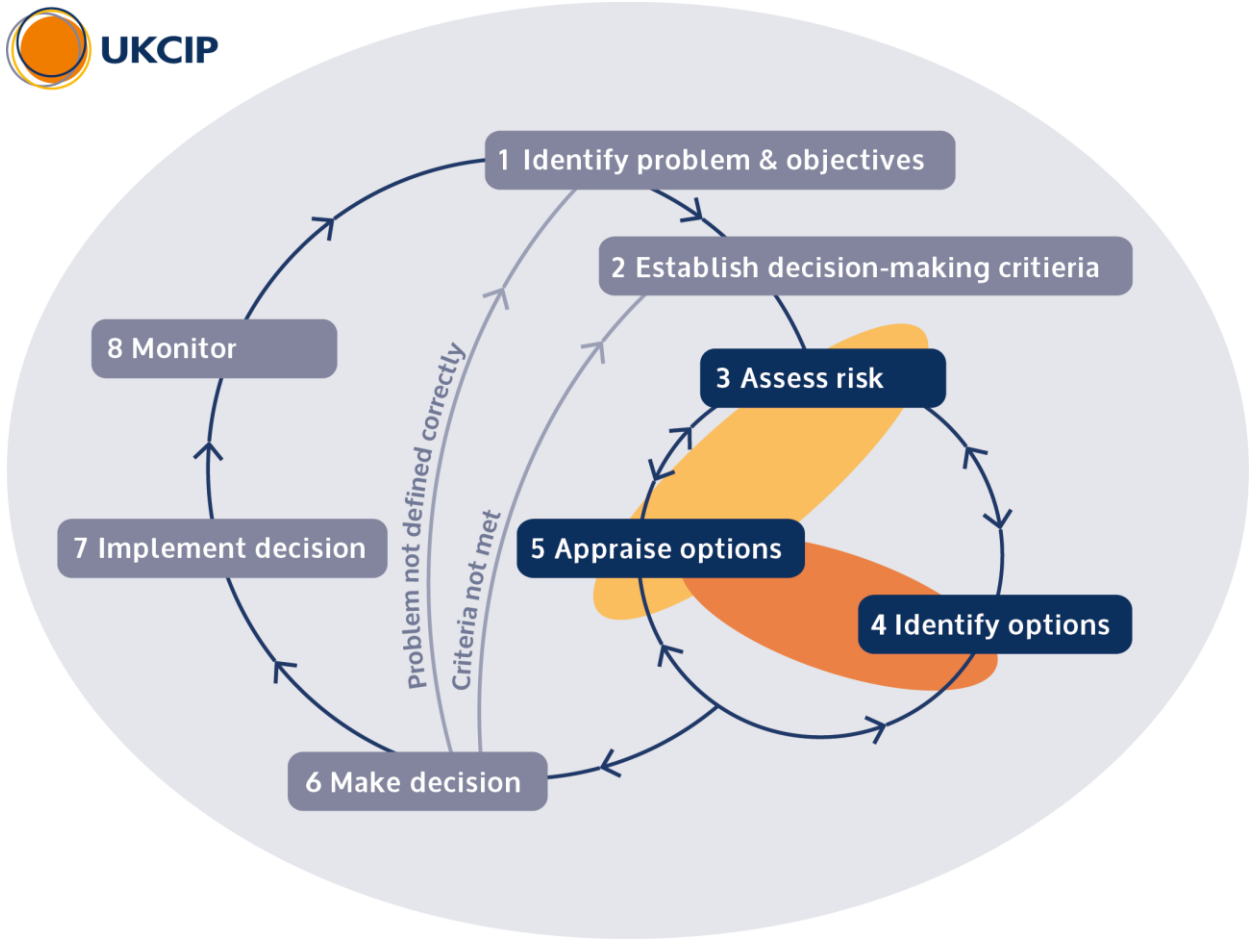
Safe at Heart:
Health, safety and wellbeing

Respecting our surroundings:
Environmental protection and management

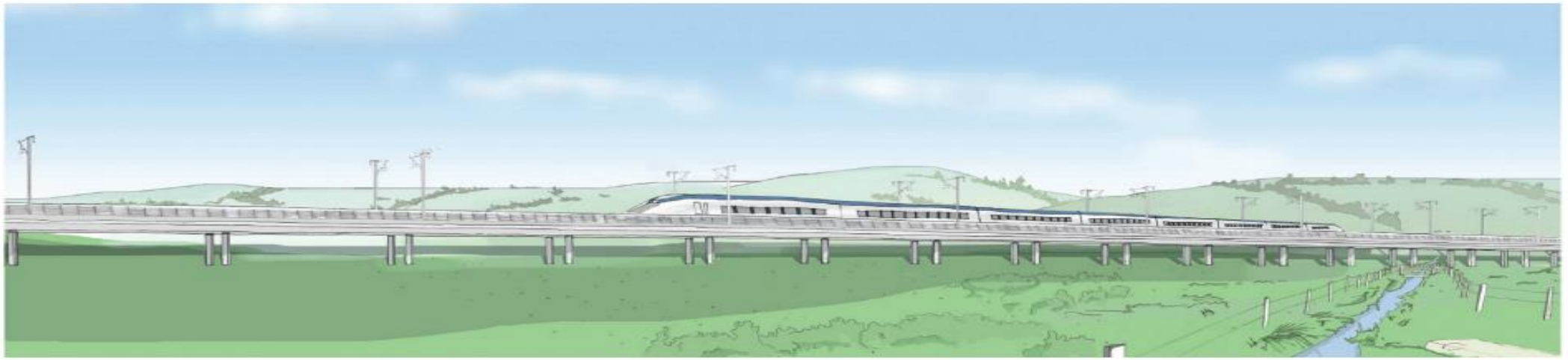
Standing the test of time:
Design that is future-proofed

Adaptation process

- UKCIP 'Adaptation Wizard'
- Iterative nature
- "Plan Do Check Act'
- Similar being proposed with 'continual learning' in the draft ISO 14090 *Framework standard for adaptation*



Case study: Flood risk management



"The design aim is for no increase in the risk of flooding for vulnerable receptors including residential property during the lifetime of the development, including an additional allowance for climate change".

Design and asset performance considerations

Indicative design standard	Target asset performance level			
(1 in x annual chance)	Unaffected	Restricted operation	Safe but not operational	Near failure
10 -75	CAT 1			
75 -100	CAT 2	CAT 1		
100 -200	CAT 3	CAT 2	CAT 1	
200 -1,000	CAT 4	CAT 3	CAT 2	CAT 1
> 1,000	CAT 5	CAT 4	CAT 3	CAT 2

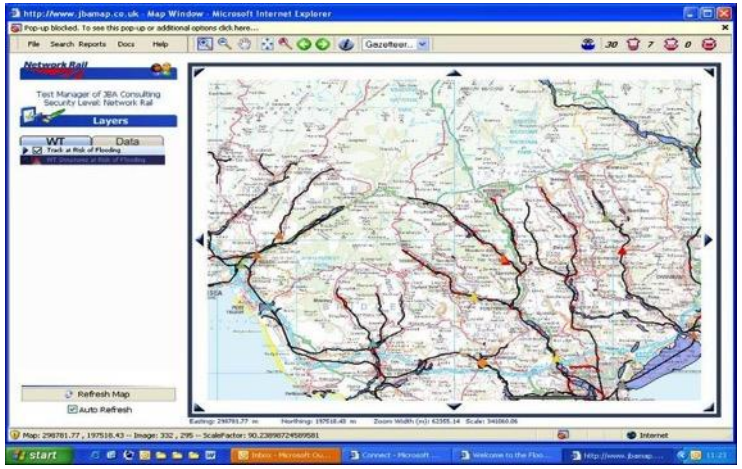
From "Flood resistance and resilience for critical infrastructure", CIRIA Publication C688, McBain et al, 2010

Flood risk and resilience design principles

- HS2 itself protected from a **1 in 1,000 (0.1%) annual probability flood** from any source;
- No increase in flood risk. Where impacts are anticipated these are assessed using hydraulic modelling and mitigation is developed to avoid significant effects, where reasonably practicable;
- Design makes an explicit allowance for climate change to beyond 2080, **using latest EA guidance.**

Not like this!

Key potential impacts considered

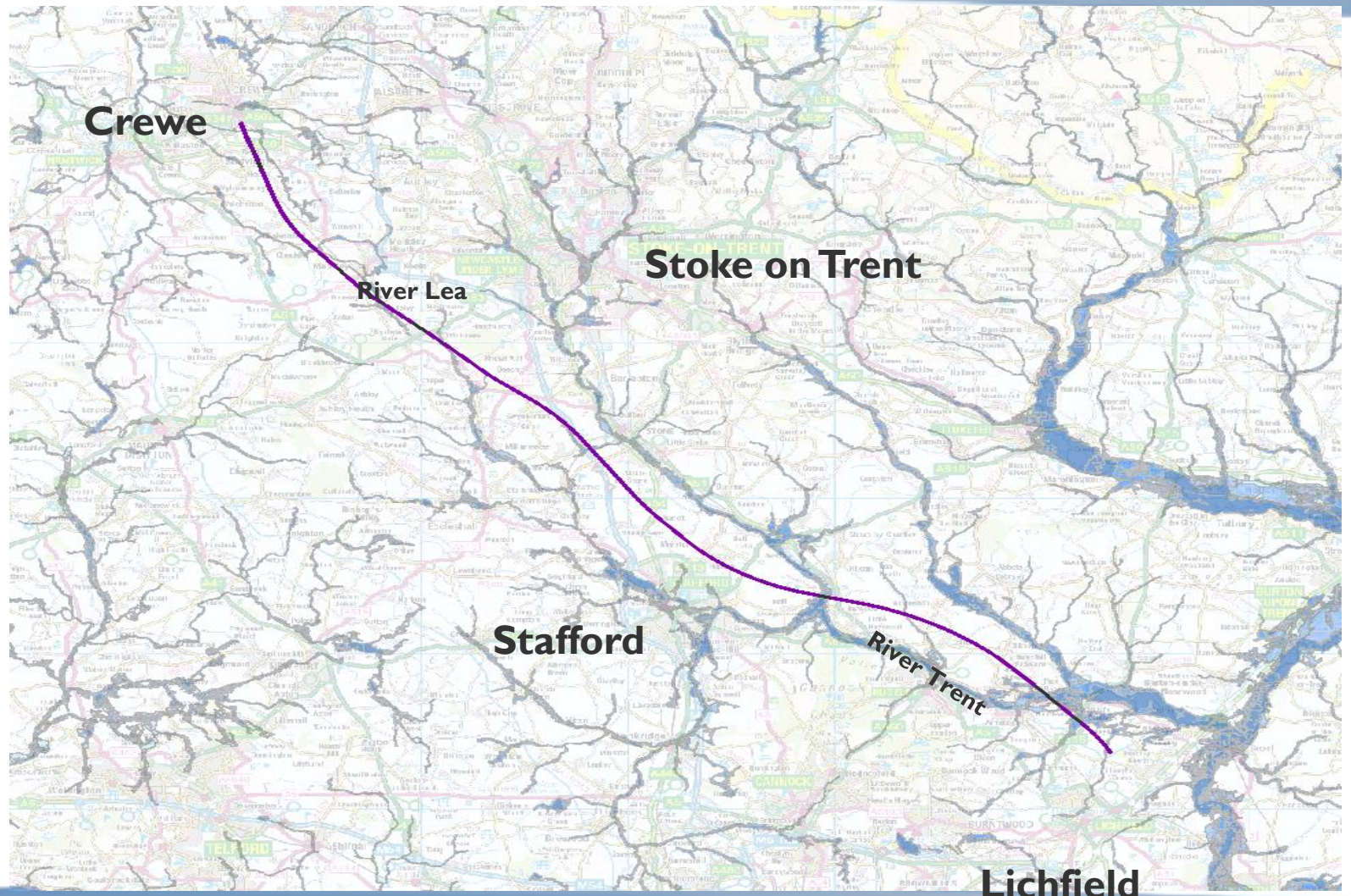


- Reductions or increases in flood conveyance.
- Losses of floodplain storage.
- Interference with existing flood defence and land drainage infrastructure
- Disruption to surface and groundwater flows
- Increases in surface water run-off

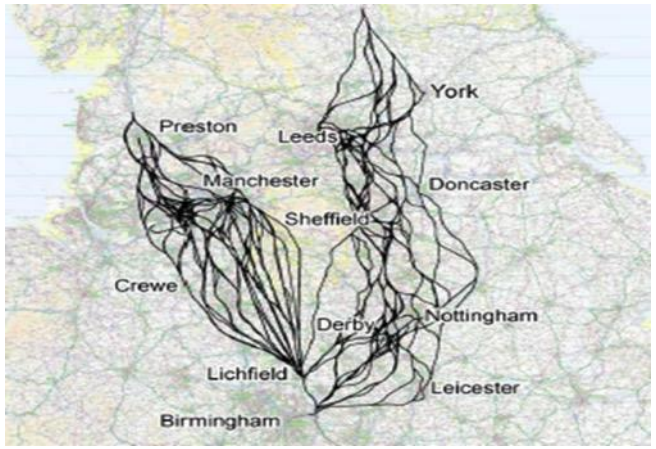
Approach to flood resilience

- Assess
- Avoid
- Substitute
- Control
- Mitigate

Route selection and the "sift" process



- 60 km route



Sequential approach adopted to route selection

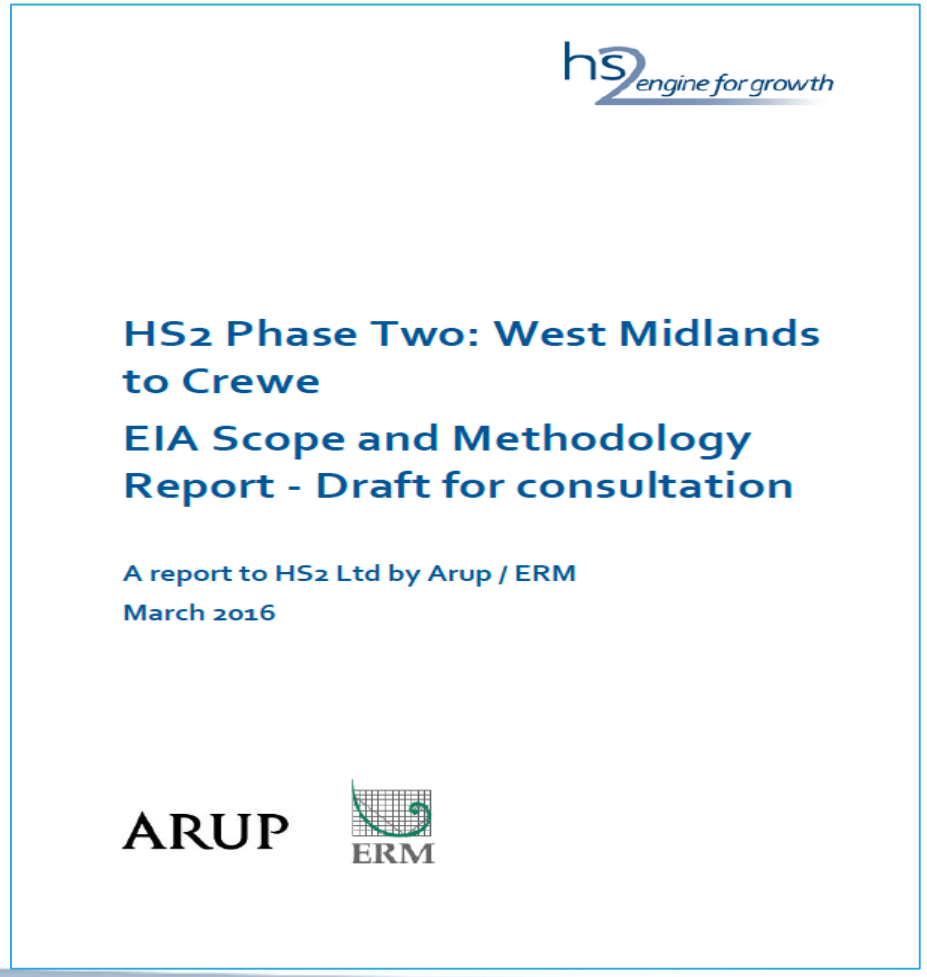
Ongoing sift process through preliminary design development

Impact magnitude definitions

Table 49 – Magnitude of possible impacts

Magnitude	Criteria	Examples
Major	Adverse: Loss of an attribute and / or quality and integrity of an attribute	Adverse: Increase in peak flood level* (> 100mm); loss of a fishery; decrease in surface water ecological or chemical WFD status or groundwater qualitative or quantitative WFD status.
	Beneficial: Creation of new attribute or major improvement in quality of an attribute	Beneficial: Creation of additional flood storage and decrease in peak flood level* (> 100mm); increase in productivity or size of fishery; increase in surface water ecological or chemical WFD status; increase in groundwater qualitative or quantitative WFD status.
Moderate	Adverse: Loss of part of an attribute or decrease in integrity of an attribute	Adverse: Increase in peak flood level* (> 50mm); Partial loss of fishery; measurable decrease in surface water ecological or chemical quality, or flow; reversible change in the yield or quality of an aquifer; such that existing users are affected, but not changing any WFD status.
	Beneficial: Moderate improvement in quality of an attribute	Beneficial: Creation of flood storage and decrease in peak flood level* (> 50mm); Measurable increase in surface water quality or in the yield or quality of an aquifer benefiting existing users but not changing any WFD status.
Minor	Adverse: Some measurable change to the integrity of an attribute	Adverse: Increase in peak flood level*(> 10mm); measurable decrease in surface water ecological or chemical quality, or flow; decrease in yield or quality of aquifer; not affecting existing users or changing any WFD status.
	Beneficial: Measurable increase, or reduced risk of negative effect to an attribute,	Beneficial: Creation of flood storage and decrease in peak flood level* (> 10mm); Measurable increase in surface water ecological or chemical quality; increase in yield or quality of aquifer not affecting existing users or changing any WFD status.
Negligible	No change to integrity of attribute	Negligible change to peak flood level* (< +/- 10mm); Discharges to watercourse or changes to an aquifer which lead to no change in the attribute's integrity.

* Peak flood level for floods up to and including a 1% annual probability event, including climate change. Where access or egress routes are affected, the magnitude of the impact will be defined by the change in the Flood Hazard Rating as defined in Defra/EA report FD2320



Receptor flood vulnerability analysis

Table 50 – Examples of the value of possible waterbodies or receptors

Value	Criteria	Examples[1]
Very high	Nationally significant attribute of high value	Watercourse with a Q_{95} flow ≥ 1.0 m³/s , SPZ 1 within a Principal Aquifer, essential infrastructure or highly vulnerable development*
High	Locally significant attribute of high value	Watercourse with a Q_{95} flow < 1.0m³/s, Principal Aquifer, more vulnerable development*
Moderate	Of moderate quality and rarity	Watercourses with no permanent baseflow, Secondary Aquifer, less vulnerable development*
Low	Lower quality	Surface water sewer, non-aquifer, water compatible development *

* as defined in Table 2 of the Flood Risk section of the Technical Guidance to the NPPF.

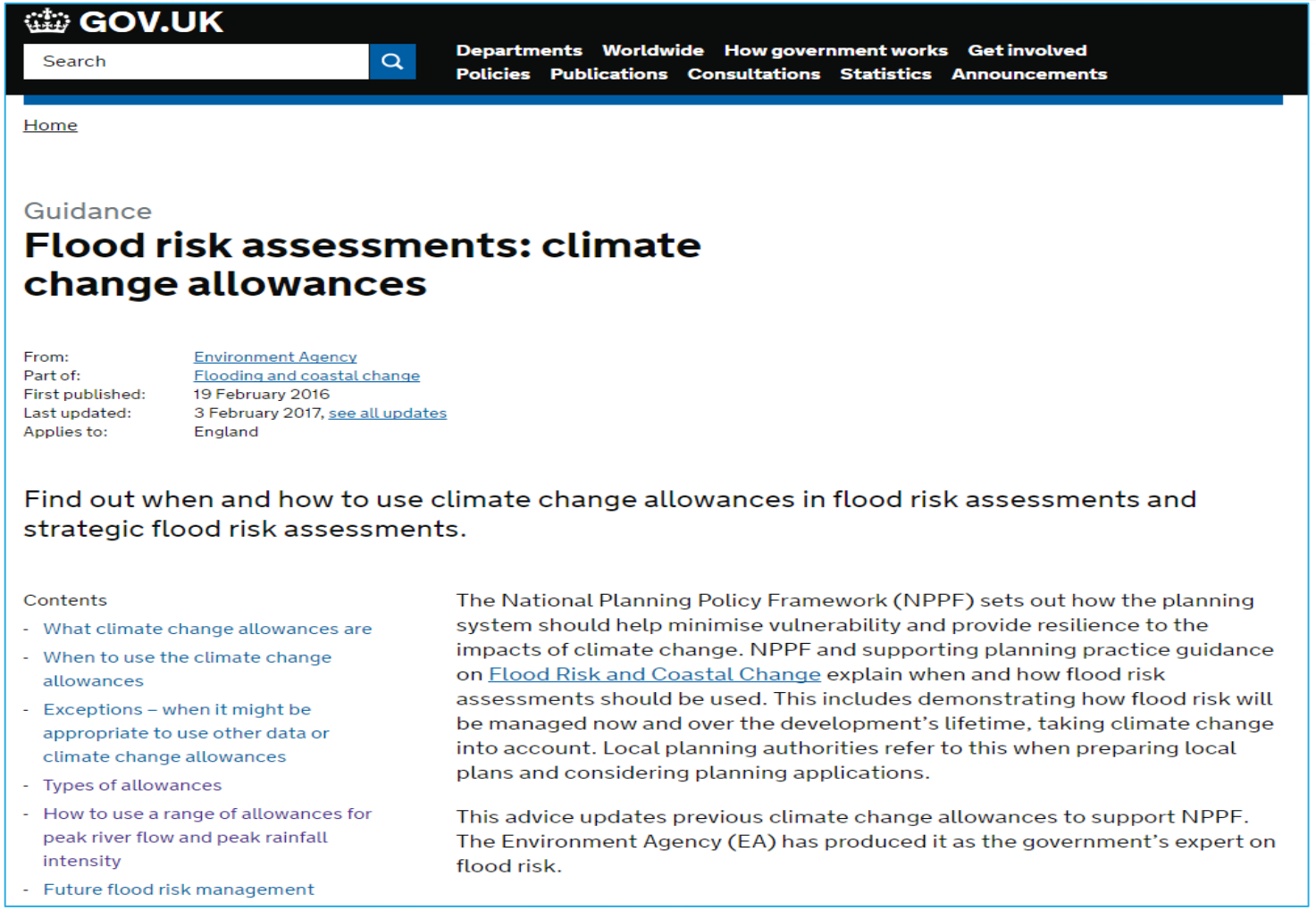
Taken from draft Phase 2a SMR

Reporting significance of flood risk effects

Flood vulnerability of receptor	Magnitude of impact on peak flood levels			
	Negligible (< +/- 10mm)	Minor > 50mm < 100mm	Moderate > 10mm < 50mm	Major > 100mm
Very high	Negligible - not significant	Moderate adverse – significant	Major adverse - significant	Major adverse – significant
High	Negligible - not significant	Moderate adverse – significant	Moderate adverse - significant	Major adverse – significant
Moderate	Negligible - not significant	Minor adverse - not significant	Moderate adverse - significant	Moderate adverse - significant
Low	Negligible - not significant	Negligible - not significant	Minor adverse - not significant	Minor adverse - not significant

- cumulative effects and mitigation...

Climate change guidance – Feb 2016



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Guidance

Flood risk assessments: climate change allowances

From: Environment Agency
Part of: Flooding and coastal change
First published: 19 February 2016
Last updated: 3 February 2017, see all updates
Applies to: England

Find out when and how to use climate change allowances in flood risk assessments and strategic flood risk assessments.

Contents

- What climate change allowances are
- When to use the climate change allowances
- Exceptions – when it might be appropriate to use other data or climate change allowances
- Types of allowances
- How to use a range of allowances for peak river flow and peak rainfall intensity
- Future flood risk management

The National Planning Policy Framework (NPPF) sets out how the planning system should help minimise vulnerability and provide resilience to the impacts of climate change. NPPF and supporting planning practice guidance on Flood Risk and Coastal Change explain when and how flood risk assessments should be used. This includes demonstrating how flood risk will be managed now and over the development's lifetime, taking climate change into account. Local planning authorities refer to this when preparing local plans and considering planning applications.

This advice updates previous climate change allowances to support NPPF. The Environment Agency (EA) has produced it as the government's expert on flood risk.

Application

- Selection of appropriate allowances depending on location and vulnerability of receptors (including HS2 itself) potentially affected;
- Use of zones in EA Flood Maps for Planning (Rivers and Sea) to identify receptor location, where this determines the appropriate allowance;
- Receptor vulnerability as defined in SMR and aligned with NPPF;
- The H++ scenario used to assess performance of the scheme beyond the furthest time horizon of the UKCP09.

Application of the new allowances - rivers

River basin district	Allowance category	Allowance
Humber	H++	65%
	Upper end	50%
	Higher central	30%
	Central	20%
North West	H++	95%
	Upper end	70%
	Higher central	35%
	Central	30%

Flood Zone	Vulnerability (NPPF)	Uplift
Flood Zone 2	Essential infrastructure	Upper end
	Highly vulnerable	
	More vulnerable	Higher central
	Less vulnerable	Central
	Water compatible	Central
Flood Zone 3a	Essential infrastructure	Upper end
	Highly vulnerable	
	More vulnerable	
	Less vulnerable	Higher central
	Water compatible	Central
Flood Zone 3b	Essential infrastructure	Upper end
	Highly vulnerable	
	More vulnerable	
	Less vulnerable	
	Water compatible	Central

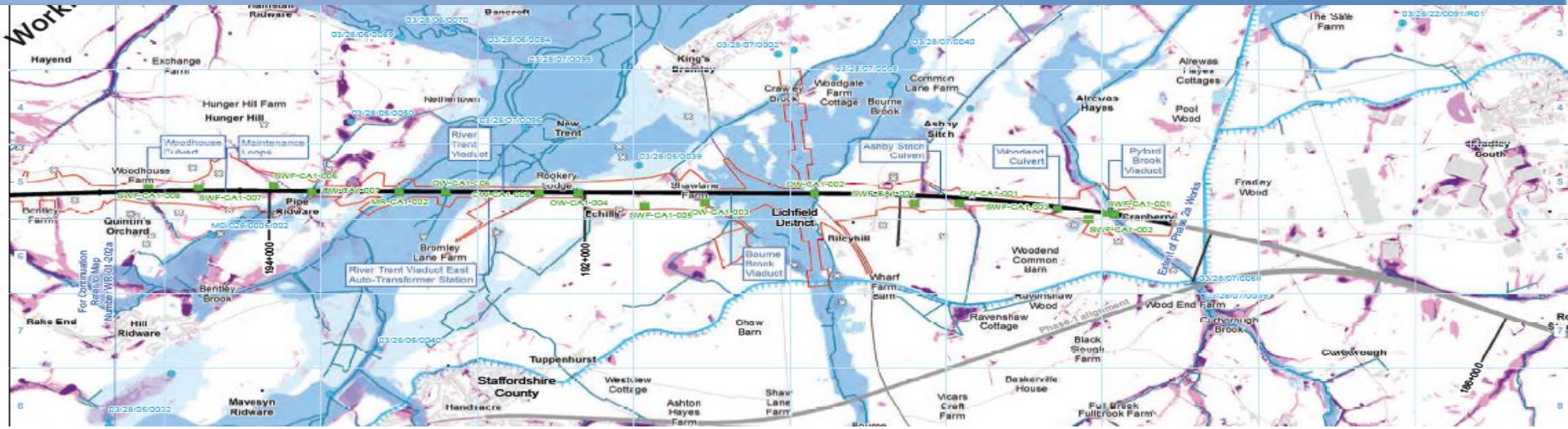
Climate change allowances

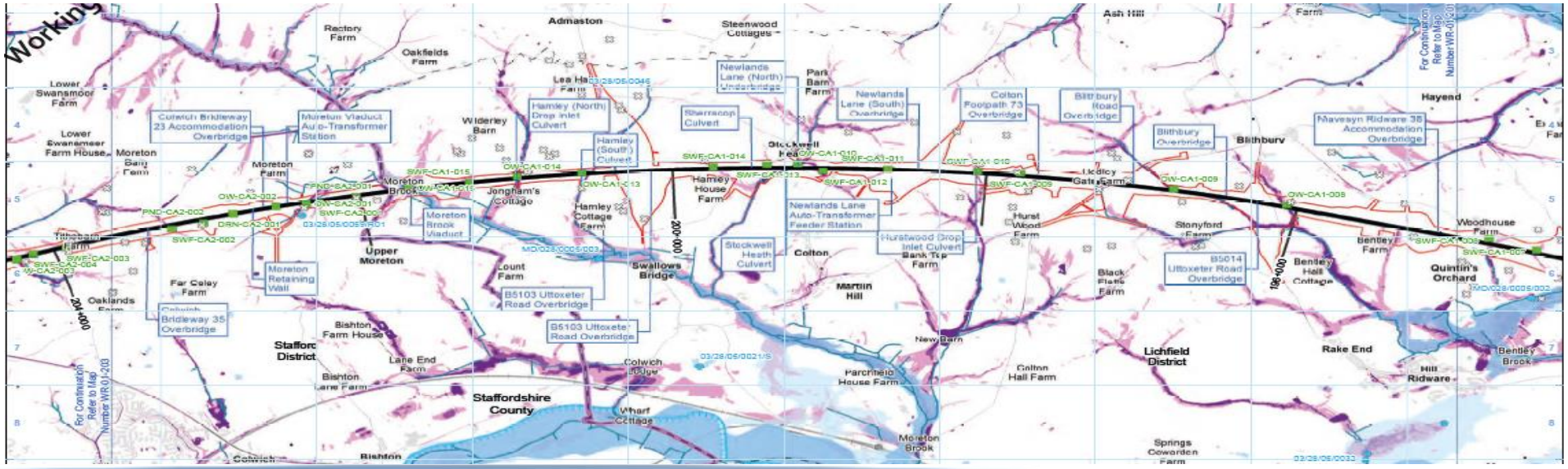
- Standard uplifts used for cross drainage on catchments less than 5km^2 regardless of receptors present;

- 40% (Upper End) uplift in peak rainfall intensities adopted for all SuDS facilities.

Examples map books from EIA

212 crossings comprising main rivers, ordinary watercourses and surface water flow paths





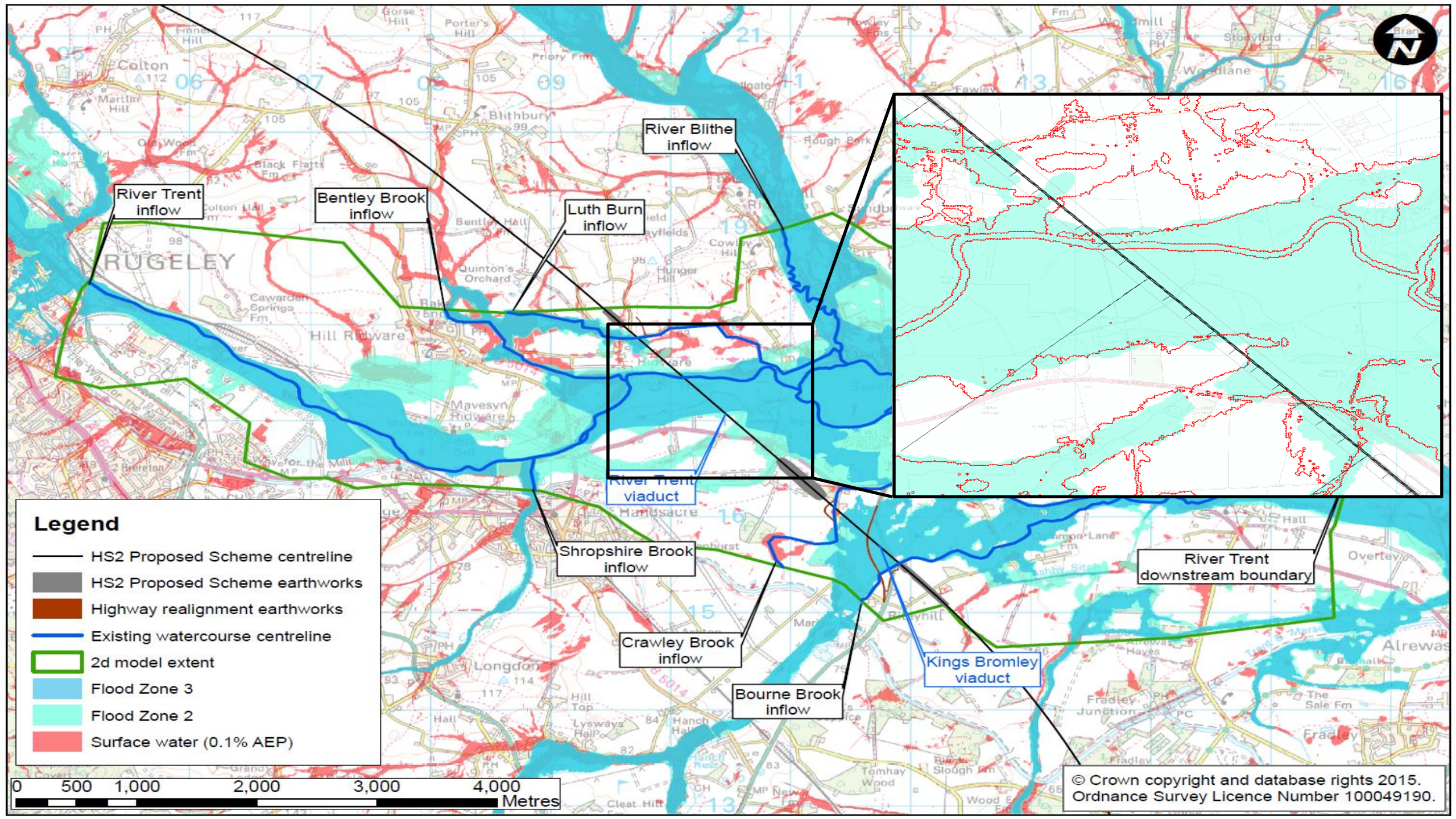
NB from working draft EIA, for illustrative purposes only

Example schedule with receptors and uplifts

Table 3. Summary of sites analysed.

CLIMATE CHANGE ASSESSMENT											
CROSSING LOCATION AND DETAILS		Waterbody Name	Receptor Upstream	Receptor Downstream	Flood Zone	National Policy Planning Framework Classification (1)			River Basin District	Allowance Category	Percentage Increase
CA	Element Type					Upstream	Downstream	Highest Rating			
1	Viaduct	Pyford Brook	Trent and Mersey Canal - water compatible (WC) Wood End Lane and Wood End Farm - More vulnerable (MV) Sewage treatment works (WC) Agricultural Land - LV	Trent and Mersey Canal - water compatible (WC) Residences at Alrewas Hayes (MV) Agricultural Land - LV	3	MV	MV	MV	Humber	Upper End	50
1	Viaduct	Ordinary Watercourse	Agricultural land (LV)	Agricultural land (LV)	1	LV	LV	LV	Humber	Central	20
1	Viaduct	Ordinary Watercourse	Agricultural land (LV)	Agricultural land (LV)	1	LV	LV	LV	Humber	Central	20
1	Culvert	Ordinary Watercourse	Agricultural land (LV)	Agricultural land (LV)	1	LV	LV	LV	Humber	Central	20
1	Culvert	Ashby Stitch	Agricultural land (LV) Trent and Mersey Canal (WC) Woodland (LV)	Agricultural land (LV) Unclassified road (LV)	1	LV	LV	LV	Humber	Central	20
1	Viaduct	Bourne Brook	A515 and access to Kings Bromley Wharf (main roan) (MV) Shaw Lane and access to properties such as Riley Lane Farm (MV) Trent and Mersey Canal (WC)	A515/A513 (main roads) and access to residential areas of Kings Bromley (MV) Shaw Lane and access to properties such as Crawley Lodge, Woodgate Farm Cottages and Common Lane Farm (MV) Nurseries and Cockshoot	3	MV	MV	MV	Humber	Upper End	50
1	Viaduct	Crawley Brook	A515 and access to Kings Bromley Wharf (main roan) (MV) Shaw Lane and access to properties such as Riley Lane Farm (MV) Trent and Mersey Canal (WC)	A515/A513 (main roads) and access to residential areas of Kings Bromley (MV) Shaw Lane and access to properties such as Crawley Lodge, Woodgate Farm Cottages and Common Lane Farm (MV) Nurseries and Cockshoot	1	MV	MV	MV	Humber	Upper End	40
1	Viaduct	Ordinary Watercourse	Agricultural land (LV)	Rugeley Road and Rookery Lodge (MV) Gravel pit workings (WC)	2	LV	MV	MV	Humber	Upper End	50
1	Viaduct	Ordinary Watercourse	Glebe Farm (MV) Kings Bromley Road Nature Reserve (WC)	Rugeley Road and Rookery Lodge (MV) Gravel pit workings (WC)	2	MV	MV	MV	Humber	Upper End	50

NB for illustrative purposes only


River Trent inflow
Bentley Brook inflow
Luth Burn inflow
River Blithe inflow
River Trent viaduct
Shropshire Brook inflow
Crawley Brook inflow
Bourne Brook inflow
Kings Bromley viaduct
River Trent downstream boundary
Legend
HS2 Proposed Scheme centreline
HS2 Proposed Scheme earthworks
Highway realignment earthworks
Existing watercourse centreline
2d model extent
Flood Zone 3
Flood Zone 2
Surface water (0.1% AEP)
0 500 1,000 2,000 3,000 4,000
Metres
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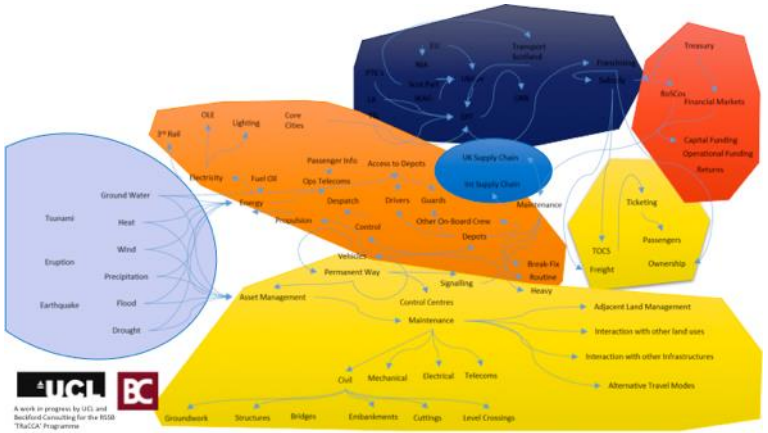
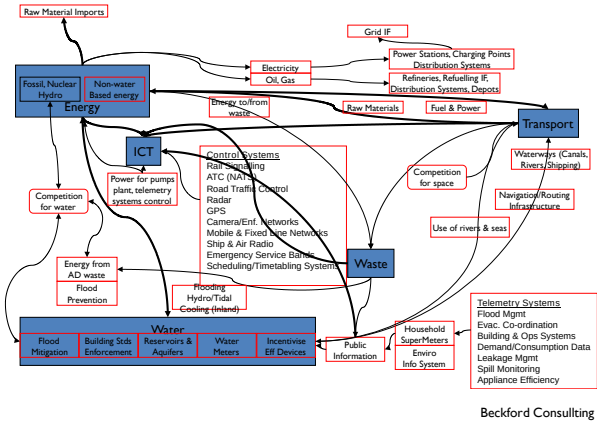
External risk to resilience

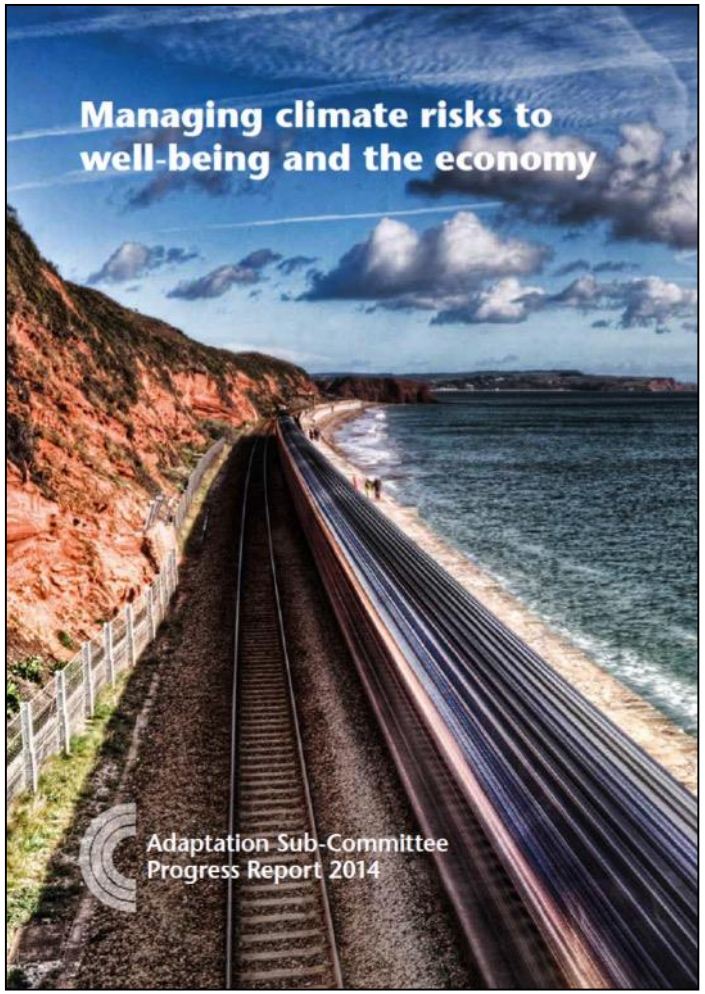
- HS2 recognises how it is part of the UK's wider infrastructure System – part of a 'system of systems'
  - It depends upon others to operate, as others will depend upon it
  - HS2 is directly dependent upon Energy, other Transport, Information Communications
- HS2 has studied external risks and aims to work with infrastructure service providers to:
  - Understand these risks and
  - Provide resilience through supply chain – drafting the right contracts is vital
- Embedding this knowledge in HS2 will help long term resilience





Beckford Consultting

Positive reception..



"The comprehensive approach taken by the HS2 Environmental Statement [for Phase One] to the full range of climate risks serves as an example of good practice."

UK Adaptation Sub-committee

Concluding remarks

- Climate change adaptation and resilience is prominent in HS2's high level policy, and forms part of the strategic goals
- Climate change risks have been identified and assessed to determine how climate change may affect the resilience of HS2 over its construction and operational lifetime
- The approach to flood risk assessment and design should ensure a level of resilience suitable for this important piece of proposed critical national infrastructure
- New climate change guidance promotes a risk based approach, with H++ sensitivity analysis providing a useful means of assessing the consequence of design exceedance scenarios
- Climate change adaptation is embedded within key decision-making processes and standards
- Building climate change resilience at HS2 is an iterative and ongoing process, with a range of assessments and decision-making process for different contracts and phases
- Knowing and providing for *external* risks to operations is a **supply chain** issue

Conclusions

- Impact magnitude and receptor vulnerability analysis aids the development of appropriate mitigation
- Now a tried and test methodology that can be adopted on the whole of HS2 Phase 2