APPENDIX B: **RISK METRICS**

Contents

B.1 People exposure metrics

Three people focussed metrics are used. Each metric is presented for *'all neighbourhoods'* and the 10% most socially vulnerable neighbourhoods (as defined by the top 20% Neighbourhood Flood Vulnerability Index, NFVI).

Exposed population (EP): This is an estimate of the number of people living (not working) within areas that may be exposed to flooding. The estimate is made by combining the average occupancy rate of a household within a given neighbourhood and the number of residential properties that would be exposed to flooding. The metric is reported as (i) the 'total' exposed population (i.e. those exposed to flooding with a return period of 1:1000 years or more frequent in the absence of defences, where they exist), and (ii) the number of people exposed to flooding at different return periods taking account of the defences and other adaptation measures where they exist.

Note: The floodplain extent, defined by the present day 1:1000-year return period flood, is assumed to remain unchanged in the future (although flood probability within the floodplain does change). This means that the total exposed population does not change with climate change (although does change with population growth). This is a reasonable assumption for fluvial and surface water flood risk, but at the coast this assumption is more challengeable under extreme sea level rise (beyond those considered here). The influence of extreme rSLR was however explored in the CCRA (Sayers et al., 2015).

Number of People Exposed to Frequent Flooding (PEFf): This metric (PEFf) focuses on the number of people exposed to flooding more frequently than 1:75 years (on average). To enable a valid comparison between areas where the PEFf is expressed as an average value per head of those living within areas exposed to a probability of flooding of 1:1000 or greater (and within the aggregation area of interest). The PEFf provides useful additional insights to a focus on expected values alone (*e.g.* EAI below) and highlights potentially important differences in the profile of the risk faced between neighbourhoods. For example, an area with many people exposed to very infrequent flooding would yield the same estimate of EAI as an area where only a few people are exposed to frequent flooding.

Note: To quantify exposure to flooding, only those living in properties with a ground floor or basement are considered in England, Wales and Scotland (i.e. those on that are likely to be on ground floor or basement); for Northern Ireland ground floor properties only are included, and additional multiple properties within the same building footprint are not counted. These differences in the treatment of properties stem from the different data sets used in each country. No distinction is made between those living in a basement flat and those living on the ground in terms of exposure. It is however assumed that basement properties suffer more economic damage (by a factor of 1.5 owing to likely greater impact of a flood on household inventory items stored there: personal communication with Edmund Penning-Rowsell) compared to an equivalent ground floor property experiencing the same return period flood (see risk metrics).

Expected annual probability of flooding: Individual (EAI): This metric represents the expected annual probability of an individual experiencing a flood and is calculated by combining the spatial variation in the annual probability of flooding (to any depth) with the location of individual residential properties and neighbourhood average occupancy rate. In doing so, the EAI is used to provide a people-focused annual 'average' exposure to flooding.

Note: EAI is calculated at a neighbourhood level and is an average value for those living within the 1:1000-year floodplain (or surface water equivalent) within that neighbourhood and is not associated with a specific individual. In some texts, the term 'exposure' incorporates the chance that a person will be present when a flood occurs (e.g. Hartford and Baecher, 2004). Under this more nuanced interpretation fewer people may be exposed in a predominantly residential floodplain during the day because they are away at work, or because they have successfully evacuated the area in response to a warning. This is not done here.

B.2 Property exposure metrics

Expected Annual number of Properties flooded (EAPf): This metric represents the number of properties that, on average, are expected to experience flooding in a given year. It is calculated by combining the spatial variation in the annual probability of flooding (to any depth) with the location of individual residential and non-residential properties. In doing so, the EAPf provides a property-focused annual 'average' exposure to flooding.

Number of Properties exposed to flooding (by probability band): This metric provides insight into the relationship between the chance of flooding and the number of properties exposed at different return periods. This is useful in helping understand the nature of the risks faced and the adaptation responses that may be most useful.

B.3 Agriculture exposure metrics

The area (in hectares) of Best and Most Versatile Land (BMV) exposed to flooding more frequently than 1:30 years, on average, is used as indicator of the impact on agriculture.

Note: No effort is made to assess the production losses, economic impact or a broader assessment of the impact of flooding on national food security. These are recognised as important but outside the scope of the current study.

B.4 Habitats and species exposure metrics

The area of land exposed to flooding within Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and Ramsar sites is used as a proxy for the impact on important habitats and species. This use of a simplified metric reflects the difficulty in linking flooding to impact and although considered appropriate for inclusion, the results must be viewed in the context of the significant caveats noted below.

Note: There is considerable uncertainty as to how flooding impacts the natural capital stocks and flows within the UK's network of important habitats. Expressing this complexity in terms of the area exposed is recognized as a significant simplification as it fails to differentiate the likely impact of a flood on sites of contrasting size and habitat type – the loss of natural capital in a small species-rich wetland (such as the River Spey, Insh Marshes SPA) is likely to be proportionately higher than that arising from remobilising a large area of sandbanks that provides habitat for the harbour seal (for example the Firth of Tay and Eden Estuary SAC). The omission of Sites of Special Scientific Interest (SSSIs) outside of the internationally designated areas also means that some protected sites (often with high natural capital) are excluded in the analysis. This means that the areas reported here will be an under-estimate of the natural capital in protected sites. The importance of this simplification is difficult to quantify and more detailed analysis, beyond the scope of this project, would be needed to identify those SPAs/SACs and Ramsar sites that are vulnerable to coastal and fluvial flooding. Future analysis should include a more comprehensive assessment of Natural Capital and the wide range of services provided.

B.5 Infrastructure exposure metrics

Infrastructure metrics cover a range of activities and report the number of infrastructure sites exposed to flooding across a range of probability bands. The infrastructure receptors considered are:

- **Category A infrastructure** (i) Water: Number of water distribution and wastewater treatment sites exposed to flooding (by probability band); (ii) Energy: Number of power stations (generation) and sub-stations (transmission/distribution) exposed to flooding (by flood probability band)
- **Category B infrastructure** (i) Transport: Number of railway stations and length (km) of major roads and railway track exposed to flooding (by flood probability band); (ii) Waste: Number of operational (and licenced) landfill sites exposed to flooding (by flood probability band); (iii) Emergency Services: Number of Hospitals and blue light service stations (police, ambulance, fire stations) exposed to flooding (by flood probability band), and (iv) Social support networks: Number of care homes, GP surgeries, and schools exposed to flooding (by flood probability band)

Note: Exclusions: (i) **Landfill sites:** Only operational landfill sites are considered. Historical landfill sites (no longer in operation) are excluded due to data incompleteness across the UK; (ii) **Information and Communication Technology** (ICT): Data sets on ICT infrastructure sites at a UK national scale are improving but remain difficult to access. Develop a coherent national dataset is unfortunately beyond the scope of this project and hence ICT infrastructure is excluded here; (iii) **Airports and ports**: Both are excluded here (including associated buildings that where classified as such in the underlying NRD). Ports tend to respond to issues of sea level rise rather than flooding per se. Therefore, ports are not a central consideration here. Airports are potentially impacted by flooding but approaches to assessing the associated impact remain immature and hence are excluded here.

B.6 Economic risk metrics

Expected Annual Damages (EAD): This provides the conventional view of risk that estimates the Expected Annual Damages in national economic terms. The assessment of EAD used here combines the annual probability of a property (residential and non-residential) being flooded and the associated direct and indirect economic damages as follows:

- **Direct damage:** The Weighted Annual Average Damage (WAAD) method (Penning-Rowsell *et al.,* 2013 as used in CCRA2, Sayers *et al.,* 2015) is applied to estimate the direct economic damage. The basic WAAD value is uplifted to a base date of 2018. A second uplift of 1.5 is applied to basement properties to account for the greater impact of a flood on household inventory items (personal communication with Edmund Penning-Rowsell) when compared to an equivalent ground floor property experiencing the same return period flood (where the number of basements flooded is determined as a portion of the total number properties within a neighbourhood).
- **Indirect damage:** Consideration is given to the disruption of economic networks and related activities associated with a flood. Although these can be highly site specific, they are assumed here to be a function of direct damages. The enhancement to the expected annual direct damages continues to be debated and typically considered to be an additional 70% (as used in CCRA2, Sayers et al., 2015 – for breakdown see Appendix A).
- **Intangible damage:** Indirect losses excludes broader 'intangible' losses (i.e. trauma; ill-health (mental); loss of treasured possessions; loss of pets as friends; etc.). These intangible issues can be significant (see for example, PHE, 2019) and are important considerations in flood risk management policy choices. Despite little quantified evidence on the scale of these impacts in monetary terms they are included as a 20% uplift to the direct damages. As suggested by the PHE, 2019 analysis this is **not** differentiated by social vulnerability.

Expected Annual Damage: Individual (EADi): This provides an estimate of the average (economic) loss faced by an individual living within the floodplain with a given neighbourhood. Although not representative of the risk faced by any specific individual, this provides a valid means of comparing risks between areas.

Note:

Non-residential damages: The assessment of non-residential damages includes consideration of businesses, police stations, schools, hospitals and all other building assets defined as non-residential within the supporting datasets. Damage is estimated using the non-residential sector average WAAD that includes direct damages only.

Expected values and risk profiles: Although the headline risk metrics reflect the ‘expected values’, where useful (and identifiable) further insights provided by the supporting risk profile are presented.: No consideration is given here to the consequences associated with particularly storm events (i.e. a spatial coherent storm) but rather the analysis is based annual expectations of damage. Ongoing studies enabling FFE to explore the changing risks associated with individual flood events (events sets) are underdeveloped and should be considered in future climate assessments.

B.7 Infrastructure risk metrics

The economic impact of infrastructure disruption is considered through a simple uplift to direct property damages (see above).

Note: **Disruption and associated economic impacts:** The disruption caused by flooding of infrastructure and the interconnections within the infrastructure networks and spatial coherent flood events is not considered here. Opportunities to incorporate disruption and associated cascading and escalating damage through infrastructure networks, although out of scope here, should be considered in further developments of the supporting analysis tools.

B.8 Social risk metrics

Relative Economic Pain (REP): Defined in Sayers et al., 2016, the REP recognizes the varying coping capacity between more affluent and lower income households and captures the relationship between uninsured economic damages and household income; and is defined as:

REP = (1- insurance penetration) x Expected Annual Damages (direct residential) per household within the floodplain / Average income per household within the neighbourhood.

Note: The damages calculated here are economic losses, whereas the impact of flooding on uninsured households is related to the financial losses. The *REP* metric should therefore not be viewed as directly representing the impact on household finances, but is nevertheless a useful metric relating losses to income and insurance take-up. No consideration is given to issues of excess, deductibles or exclusions (including uninsured impacts, such as long-term physical or mental health that may be associated with a flood). More detail on the background to the REP is provided in Sayers et al., 2016.

Social Flood Risk Index (SFRI): A third new risk metric, the SFRI, is used to identify those areas where the largest number of the most vulnerable people are exposed to frequent flooding. The SFRI therefore directly supports an understanding of Geographic Flood Disadvantage and is estimated at both a neighbourhood scale and as an individual 'average' as follows:

- SFRI helps identify those areas where many vulnerable people, as defined by the NFVI, are exposed to flooding and is calculated as follows:

  SFRI = Expected Annual Probability of Flooding: Individual (EAI) x Number of people within the floodplain (FP) x Neighbourhood Flood Vulnerability Index (NFVI).

- *Social flood risk index: Individual* (iSFRI) helps identify those neighbourhoods where the vulnerability of those exposed is high (even when only a few people may be exposed) and is calculated simply by dividing the SFRI by the floodplain population, to give:

  SFRI Individual = Expected Annual Probability of Flooding: Individual (EAI) x Neighbourhood Flood Vulnerability Index (NFVI).

Note: The SFRI is a relative index (i.e. it compares the risk in one neighbourhood with another) and has no units; the greater the value, the higher the level of social flood risk. More detail on the SFRI is provided in Sayers et al., 2016.

B.9 References

See Main Report