Present and future flood vulnerability, risk and disadvantage

A UK assessment

Neighbourhood Flood Vulnerability Index: Characteristics, indicators and support variables

A summary produced for the Climate Just Website

June 2017

SAYERS AND PARTNERS

Contents

Based upon Sayers, P.B., Horritt, M., Penning Rowsell, E., and Fieth, J. (2017). Present and future flood vulnerability, risk and disadvantage: A UK scale assessment. A report for the Joseph Rowntree Foundation published by Sayers and Partners LLP.

1.0 NTRODUCTION

FRM policy typically considers vulnerability through the lens of deprivation (as indicated by the Index of Multiple Deprivation) and this view provided the basis of the analysis presented in the CCRA (Sayers *et al.,* 2015). A focus on deprivation however does not necessarily reflect a community's vulnerability to a flood should it occur (although vulnerability is influenced by income deprivation, as clearly demonstrated by Tapsell *et al.,* 2002). To overcome this short-coming, a new measure is introduced here: the **Neighbourhood Flood Vulnerability Index** (NFVI).

The Neighbourhood Flood Vulnerability Index (NFVI) provides insight into the social vulnerability of a neighbourhood should a flood occur. The NFVI combines the five characteristics of vulnerability, based upon twelve 'vulnerability indicators' (Figure 1). Each indicator is, in turn, based upon a number of supporting variables.

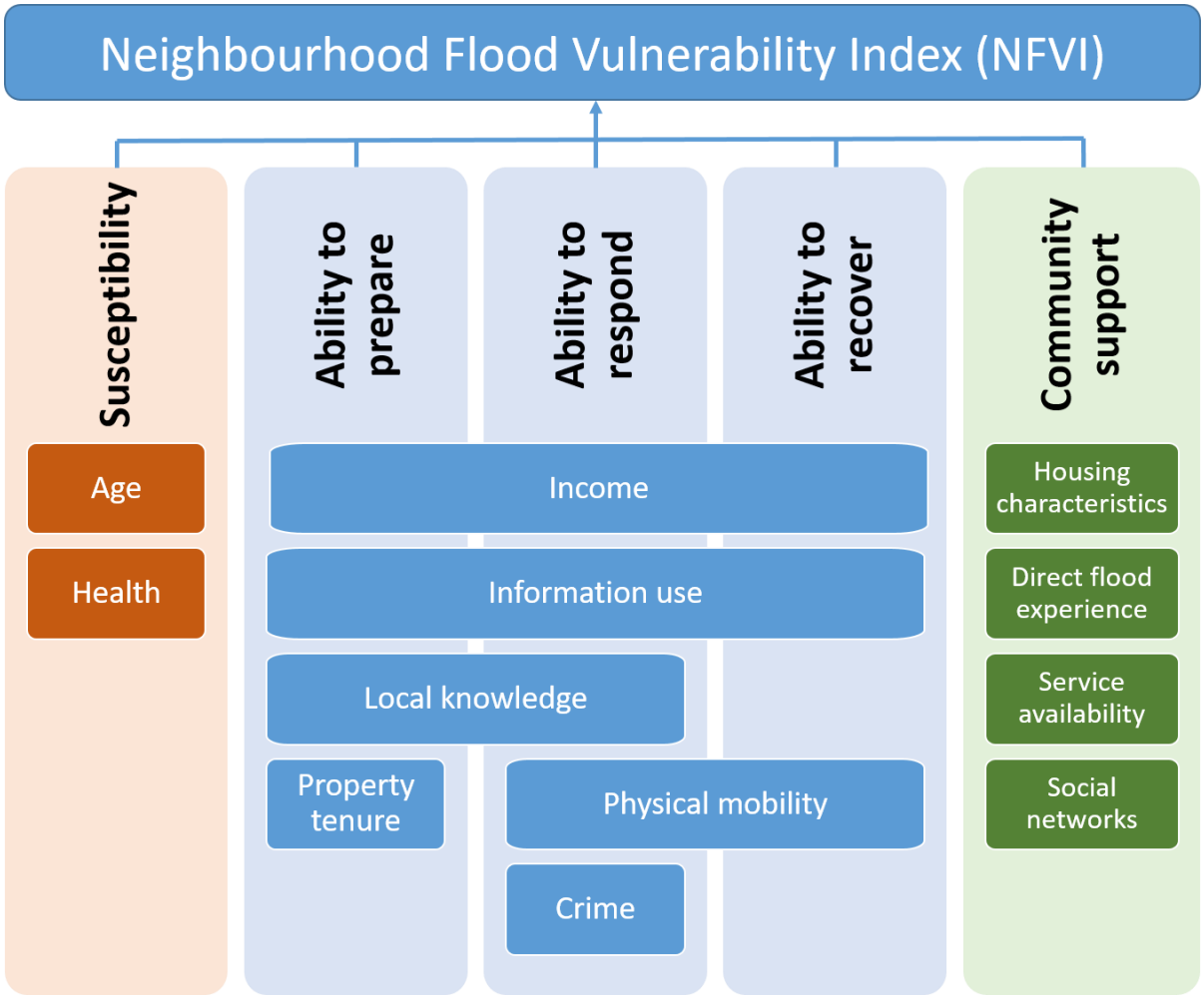

Figure 1 Neighbourhood Flood Vulnerability Index: Influential characteristics and indicators

In the context of the NFVI, a 'neighbourhood' is defined by census geographies (*i.e.* Lower Layer Super Output Areas (LSOA) in England and Wales, Data Zones (DZ) in Scotland and Super Output Areas (SOA) in Northern Ireland). This represents a natural evolution of the previous analysis for England and Wales (Lindley et al., 2011) based on Middle Level Super Output Areas (MSOAs); a scale that can cover very heterogeneous socio-economic conditions, and maintains the resolution of

previous studies in Scotland (Kazmierczak et al., 2015) whilst also taking advantage of an improved understanding of the flood hazard and exposure.

The supporting evidence for the selection of each characteristics, vulnerability indicator and supporting variables, and how they have been combined to derive the NFVI, is set out below.

2.0 FIVE CHARACTERISTICS OF SOCIAL VULNERABILITY

The NFVI is used to express the characteristics of an individual and the community in which they live that influence the potential to experience a loss of well-being when exposed to a flood and over which flood management policy has limited or no control. This understanding reflects previous studies (Tapsell *et al.,* 2002; Lindley *et al.,* 2011; Twigger-Ross *et al.,* 2014; Kazmierczak *et al.,* 2015) and requires consideration of five characteristics:

2.1 Susceptibility

Susceptibility describes the predisposition of an individual to experience a loss of well-being when exposed to a flood. It is widely evidenced that the dominant characteristics that influence susceptibility to harm relate to the age (the old and very young) and health of the individuals exposed.

2.2 Ability of an individual to prepare for a flood

Preparedness reflects the actions taken by an individual during normal conditions (*i.e.* in the absence of a forecast or actual flood) that are likely to reduce the harm they suffer when a future flood occurs. Although an area of continued research, an individual's ability to prepare is influenced by their income, capacity to act, local knowledge and property tenure.

2.3 Ability of an individual to respond to a flood

The underlying reasons why some individuals act more effectively in the run up to and during a flood is an area of continued research. There is however broad agreement that an individual's ability to respond is influenced by their income, capacity to access and use formal and informal information, local knowledge and physical mobility.

2.4 Ability of an individual to recover from a flood

Many flood events have highlighted the length of time it can take for individuals and communities to recover from a flood. The degree to which an individual can aid their own recovery is influenced by several factors, particularly their income, capacity to use information, and physical mobility.

2.5 The ability of the community to support individuals

The availability and quality of services provided by health and emergency services as well as broader care and social services are all important social facilities that have a real influence on the severity of harm caused by a flood. Despite a lack of quantified evidence, there is also strong anecdotal evidence that community support networks can help ameliorate vulnerability by providing support to affected groups and flood management policy is increasingly recognising the value of community

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networks (for example by supporting the national Flood Community Resilience Pathfinders schemes, Defra, 2012, 2015). As such, the presence or absence of community support is legitimately considered here as a component of vulnerability. A formal representation of community cohesion and its influence on flood vulnerability is not however available. In recognition of the importance of community support, but in the absence of more detailed insights, four indicators are considered to gauge the nature of this support: housing characteristics, the collective experience of past floods, the likely availability of community services in a flood (including emergency service provides, schools, GPs, care homes) and the social networks that exist. This is recognised as very much a first step and further research will be required to better quantify supportive community contexts.

3.0 TWELVE INDICATORS VULNERABILITY AND ASSOCIATED SUPPORTING VARIABLES

The twelve supporting variables used to support the assessment of the five characteristics of flood vulnerability together with the variables used in their assessment are summarised in Table 1. The rationale for each indicator is discussed below and builds upon previous research (Lindley *et al.*, 2011 and Kazmierczak *et al.*, 2015) as well as the useful review and summary provided by Gibson *et al.* (2016).

3.1 Age

- The number of deaths caused by the 1953 'Big Flood' was highest among older people (Baxter, 2005), with people over 60 year olds accounting for 42% of resulting deaths in Essex (Vardoulakis and Heaviside, 2012).

- Older people are less likely than other social groups to respond to flood warnings and may be more reluctant to leave their houses (Age UK, 2016), as well as having more limited physical mobility, making it difficult to use flood defence measures, such as putting up property level flood gates (Vardoulakis and Heaviside, 2012).

- Tapsell *et al.* (2002) looked in detail at six case studies from across the UK; these showed that those over the age of 75 were more vulnerable to flooding.

- Numerous studies have highlighted the association between flooding and increased mental health and behavioural problems in children (e.g. Mort *et al.*, 2016).

- Children's stories of the impacts of the floods in Hull reveal the range of impacts which can affect younger children, including physical and mental health and the disruption of schooling and home-life (Mort *et al.*, 2016).

The supporting variables selected to characterise 'age' are summarised in Table 2.

3.2 Health

- The six detailed case studies referred to above showed that the long-term sick were more vulnerable to flooding, the flood they experienced often making their pre-existing condition

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worse either as a one-off 'hit', or accelerating its adverse trajectory (Tapsell *et al.*, 2002; Ebi *et al.*, 2006).

- Flooding may restrict an individual's access to medicine, e.g. due to loss or damage or it being left behind in the context of an emergency (Age UK, 2016).

- Flooding may prevent the use of complex home-based health care systems, for example home dialysis, due to direct flood damage or to loss of power (Klinger *et al.*, 2014).

- Being flooded is stressful and mental health impacts can be serious. Recorded psychological stresses caused by flooding in the UK and OECD (e.g. Tapsell *et al.*, 2002) include: post-traumatic stress disorder, depression, anxiety and domestic violence (Pendlebury and Bates, 2015). A delayed increase in suicide rates has been observed following natural disasters, although the evidence of this after flood events is very limited (Kolves *et al.*, 2013). Many of these psychological effects last much longer (2+ years) than any adverse physical health effects (Tapsell *et al.*, 2002). While post-event stress is likely to affect everyone, those with existing mental health conditions are likely to suffer the most (Sims *et al.*, 2008; Waite *et al.*, 2017).

- Telephone connectivity and transport routes are often disrupted during flood events making it difficult for carers to contact and reach their patients that are receiving care at home (Age UK, 2016). This was a problem in Lancashire during the flooding in 2015 caused by Storm Desmond.

The **s**upporting variables selected to characterise 'health' are summarised in Table 3

3.3 Income

- The six detailed case studies referred to above showed that low income households were more vulnerable to flooding, especially those in Wales, Scotland and coastal England (Tapsell *et al.*, 2002). The main reason for this was the lack of savings that could be used immediately to spend on repairs and replacements that would kick-start a recovery process.

- Low income households are less likely to have the capacity to fully prepare for future floods (through insurance and property level measures). Housing tenure together with low income may restrict their ability to make modifications to the home they do not own (Fielding and Burningham, 2005).

Note: The impact of income on access to flood insurance and property level protection is considered through the differential take-up of these adaptation measures in more and less vulnerable neighborhoods (as discussed further in the main report).

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- Disruption of transport systems by flood events is likely to particularly affect people who depend upon (rather than choose to use) public transport to get to their place of work or to access other services (for example, public transport is typically more used by low income households)[1].

The supporting variables selected to characterise 'income' are summarised in Table 4.

3.4 Information use

Information is considered to influence vulnerability as follows ((Lindley *et al.*, 2011):

- Higher proportions of people recently arrived from outside the UK in an area indicate a higher vulnerability.
- People who cannot speak English are more likely to have difficulty obtaining and using information and guidance provided to the general public.

The supporting variables selected to characterise 'information use' are summarised in Table 5.

3.5 Local knowledge

- Communities where population turnover is high may be less aware of the likelihood of being affected by events like floods, how to respond and where to seek support (Penning-Rowsell *et al.*, 1986).

- Non-English speakers may also find it difficult to access flood warnings if they are not immediately available in languages other than English (Tapsell *et al.*, 2005). Currently Environment Agency flood warnings are only available in English, and so groups of residents with no or insufficient English language skills will find them more difficult to access (Shaw *et al.*, 2005). This is exacerbated as ethnic groups often live clustered together and so may all be at flood risk, and interaction with other residents outside of this group may be limited making it more difficult for flood warning messages to penetrate the group (Robertson, 2005, cited in Environment Agency, 2009).

- People who have recently moved into an area may lack awareness of local flood risk provided through family and community clues. Blaikie *et al.* (1994) states that lack of knowledge and information is one of the most important underlying reasons for vulnerability (Werritty *et al.*, 2007).

[1] As the example below from Australia illustrates: http://www.9news.com.au/wild-weather/2016/06/05/11/44/dangerous-weather-forces-closures-to-roads-and-public-transport-across-new-south-wales

- People living in rural areas tend to have more knowledge of local flood risk compared to urban areas, not least (but not exclusively) because they have longer residence times (Penning-Rowsell *et al.*, 1986).

The supporting variables selected to characterise 'local knowledge' are summarised in summarised in Table 6**.**

3.6 Property tenure

- Social housing tenants may encounter difficulties in preparing for and responding to flooding due to their living arrangements (Climate Just, 2014), and because they are likely to have a low income (see above). Additionally, their tenure status can affect the propensity to take damage-reducing measures (e.g. Porter *et al.*, 2014; Homes, 2013).

- Tenants are often not allowed to make physical alterations to their properties, and leaseholders may be disinclined to as they may not feel the additional expense of making those changes is worthwhile given that they do not own the freehold. Landlords of social housing may be more inclined to make these alterations, but little quantified evidence exists.

- Where tenants are permitted to make physical alterations to their dwellings, there is little incentive to do so. This may be because:

  I. Tenancies are often short, with limited security of tenure. The lack of ownership means tenants often have limited incentive to invest significantly in improving the property. Similarly, the average stay of tenants in a property is shorter than homeowners (The Poverty Site, 2014) so these residents are likely to be less aware of the flood risk in their neighbourhoods;

  II. Tenants are generally less well-off than homeowners (The Poverty Site, 2014), and therefore cannot afford to install meaningful physical risk reducing measures.

  III. Tenants are less likely than homeowners to speak English as their first language (for example, in Boston, Lincolnshire, there are more than 10,000 migrant workers the majority of whom live in rented accommodation), and so may not be easily able to access information on flood risk and preparedness.

The supporting variables selected to characterise 'property tenure'' are summarised in Table 7**.**

3.7 Physical mobility

- Limited physical mobility creates a number of practical challenges in preparing for, responding to and recovering from a flood. Someone with a disability will require a higher amount of resources and planning for them to reach the same level of wellbeing as someone without that disability and this should be reflected in disaster management and evacuation plans (Cabinet Office, 2013).

- People with reduced mobility may be more reliant on others to assist them for example during evacuation either from their own homes or from serviced accommodation such as care homes.

Disruption caused by a flood may prevent carers reaching those they care for and may leave assistance tools such as electronic lifts unusable.

- Where individuals are normally able to help themselves, any loss of power or internal flooding may severely reduce their capacity to do so.

The supporting variables selected to characterise 'physical mobility' are summarised in Table 8**.**

3.8 Crime

- People living in areas with higher crime rates may be more wary of taking preventative measures against flooding in case they are 'scams', and so may be more socially vulnerable than communities with lower crime rates.

- Where crime rates are high, residents may hesitate to evacuate properties during floods for fear of looting. For example, during the 2014 floods on the Somerset Levels, it was reported that empty houses were being targeted by thieves taking domestic heating oil (The Independent, 2014).

- Where dwelling-related crime levels are highest, residents are more likely to have extra security mechanisms on their houses such as multiple locks on doors and windows; this can cause delays in evacuation and rescue attempts.

The supporting variables selected to characterise 'crime' are summarised in Table 9**.**

3.9 Housing characteristics

- Poor quality housing and mobile homes provided more limited protection against flood waters than structurally competent buildings. Flood waters can devastate such homes, and even place life at risk. Response to flood warnings is also likely to be lower in these properties as residents are less likely to be able to move their possessions to a place of safety (Thrush *et al.*, 2005).

- Caravans are considered in project appraisals as moveable in times of flood and therefore do not benefit from having any damage avoided as counted against the costs of flood defences (Penning-Rowsell *et al.*, 2013). Hence within the standard assessment of damages caravans rarely feature. Residents of caravans are also more likely to have a limited knowledge of the local area (McEwen *et al.*, 2002) (see above, local knowledge).

The supporting variables selected to characterise 'housing characteristics' are s summarised in Table 10**.**

3.10 Direct flood experience

- A large body of research from Kates (1962) onwards, shows that those with experience of flooding are less vulnerable in subsequent events as they have more knowledge as to what to do and how to respond. For example, Fielding *et al.* (2007) found that there was a higher level of understanding of what the EA flood warning codes meant in households that had previously flooded.

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- Flood experience has often been shown to be a key factor in level of willingness to take preventative action against future floods, and also respond seriously to warnings (Tapsell *et al.*, 2005; McCarthy *et al.*, 2006; Tunstall *et al.*, 2006).

- This is characterised by the "prisoner of experience" phenomenon (e.g. Shaw *et al.*, 2005), whereby those without experience are less able to cope, and until people (unfortunately) have direct experience of flooding they are more vulnerable (although it may require homes to flooded several times before people are willing to act).

The supporting variables selected to characterise 'direct flood experience' are summarised in Table 11**.**

3.11 Social networks

- Connections have been made between a lack of social or community networks and levels of social deprivation in an area (Whittle *et al.*, 2010; Patrick *et al.*, 2013; Preston *et al.*, 2014). This is also linked to areas with highly transient populations, with residents less likely to have access to family or friends nearby (Zsamboky *et al.*, 2011). Individuals that are more likely to feel socially isolated include single parents, lone pensioners and new arrivals to an area.

- People with weaker social networks;

    - Struggle to maintain continuity of treatment in relation to physical or mental health treatments (WHO, 2013). Where social networks are relatively good there is evidence of a better response to emergency situations and quicker recovery (Preston *et al.*, 2014).

    - Face practical difficulties in responding to a flood where children are dependent on them as there is less direct within-the-family support (Tapsell *et al.*, 2002).

    - Adults who live alone (including those with dependent children) are more likely to struggle to take action when receiving a flood warning, for example it may be physically impossible to move furniture or other items, and they will also feel more uncertain and anxious with no-one to confide in (Thrush *et al.*, 2005).

    - Face difficulties in accessing short-term alternative accommodation from family and friends, and so are more likely to need to use public shelters in the event of an evacuation (Scawthorn *et al.*, 2006), but also may be less likely to know about the existence and location of such services.

    - Informal networks are much reduced or even absent during a flood (Tapsell *et al.*, 2002; Penning-Rowsell and Tapsell, 2002)

As noted by Kazmierczak et al, 2015, people with children at school age however have, in general, better local social networks (Corcoran et al., 2010) and in many cases locally-focused charities reduce the social isolation of individuals (Leisure Futures, 2011).

The supporting variables selected to characterise 'social networks' are summarised in Table 12**.**

3.12 Service availability

- Various studies highlight the link between the degree of support provided by institutional (such as the police, the fire brigade, ambulances and local authority social care) and community support networks and the vulnerability of the individuals in those communities (Penning-Rowsell *et al.*, 2013). Research by the National Flood Forum confirms this to be the case and shows that higher levels of post-flood institutional support (in this case from a charity) accelerates the pace of recovery[2].

- Emergency services will aim to target the most vulnerable households in assistance efforts but the ability to do this effectively relies on the flood resilience of these services themselves. During the 2010 flood in Cockermouth, Cumbria, the police station itself was flooded which hampered the coordination of the relief effort and therefore increasingly the vulnerability of the population to the flood (BBC, 2010).

- If a school floods, children are often temporarily transferred to other schools which may be some distance away while the original school is restored. This adds to family disruption and dislocation, increasing their vulnerability[3].

- The location of services that should remain accessible throughout a flood event, such as GP surgeries, is very important, especially as they can be essential in relief plans (Kazmierczak and Kenny, 2011).

- If care or nursing homes are flooded, highly vulnerable residents must be evacuated and suitable placements for them have to be found. If a care home or hospital is in a flood prone area, it is also likely that many of its employees will also live in the flood risk area, or will have to travel through a flooded area. Additionally, care homes will also often take in vulnerable residents who have been evacuated from their own homes. This system is severely hampered if the care home itself is flooded (Donovan, 2014).

The supporting variables selected to characterise 'service availability' are summarised in Table 13.

[2] http://www.nationalfloodforum.org.uk/flood-recovery-and-empowering-grassroots-communities/ Accessed Oct 2016

[3] http://www.nationalfloodforum.org.uk/flood-recovery-and-empowering-grassroots-communities/ Accessed Oct 2016

Table 2 Age: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source and provider	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
a1	Young children (% people under 5 years)	Census, ONS	2011	Census table 102. Number of people aged 0-4 years was divided by the population and multiplied by 100.	LSOA	LSOA	DZ	SOA
a2	Older people (% people over 75 years)	Census, ONS	2011	Census table 102. Number of people aged 75 years or more was divided by the population and multiplied by 100.	LSOA	LSOA	DZ	SOA

Table 3 Health: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source and provider	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
h1	Disability / people in ill- health (% people whose day- to-day activities are limited)	Census, ONS	2011	Census table KS301. Number of people whose day to day activities are limited a lot + number of people whose day to day activities limited a little, divided by the total population and multiplied by 100.	LSOA	LSOA	DZ	SOA
h2	% households with at least one person with long term limiting illness	Census, ONS	2011	Census table KS106. Number of households with one or more persons with a long-term health problem or disability divided by the total number of households and multiplied by 100.	LSOA	LSOA	DZ	SOA

Table 4 Income: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source and provider	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
i1	Unemployed (% unemployed)	Census, ONS	2011	KS501, % Unemployed in population aged 16 -74	LSOA	LSOA	DZ	SOA
i2	Long-term unemployed (% who are LTU or who have never worked)	Census, ONS	2011	Census table KS611. Number of people aged 16- 74 'never worked and long-term unemployed' divided by the total number of people aged 16-74 and multiplied by 100.	LSOA	LSOA	DZ	SOA
i3	Low income occupations (% in routine or semi- routine occupations)	Census, ONS	2011	Census table KS611. Number of people aged 16- 74 in routine occupations + number of people in semi- routine occupations divided by all people aged 16 to 74 and multiplied by 100	LSOA	LSOA	DZ	SOA
i4	Households with dependent children and no adults in employment (%)	Census, ONS	2011	Census table KS106. Number of households 'No adults in employment in household: With dependent children' divided by the total number of households and multiplied by 100.	LSOA	LSOA	DZ	SOA
i5	People income deprived (%)	ONS, National Records of Scotland, Northern Ireland Department for Communities	2010	**England**: IMD; Average Weekly Household Net Income Estimate (equivalised after housing costs); **Scotland:** SIMD Income index, i.e. "percentage of people income deprived"; **Wales**: As England; **Northern Ireland**: NIIMD 2010	LSOA	LSOA	DZ	SOA

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Table A.15 Information use: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source and provider	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
f1	Recent arrivals to UK (% people with <1 yr residency coming from outside UK)	Census, ONS	2011	Census table QS801. Number of people within year of arrival 'Arrived 2010- 2011' divided by the total number of people and multiplied by 100.	LSOA	LSOA	DZ	SOA
f2	Level of proficiency in English	Census, ONS	2011	Census table QS205. Number of people 'Does not speak English at all' + 'Does not speak English well', divided by the total number of people and multiplied by 100.	LSOA	LSOA	DZ	SOA

Table 6 Local knowledge: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
k1	New migrants from outside the local area	Census, ONS	2011	Census table UKMIG001. Number of people who 'Lived elsewhere one year ago outside the area but within 'associated area'' + 'Lived elsewhere one year ago outside the 'associated area' but within the UK' (where associated area is the next level up in the census geography hierarchy, i.e. local authority in this case),	MSOA[4]	MSOA	DZ	SOA

[4] MSOA level results are sampled to neighbourhood by picking the value from the MSOA that the neighbourhood lies in. A neighbourhood lies entirely within 1 MSOA and do not t cross MSOA boundaries.

				divided by the total number of residents and multiplied by 100.				

Table 7 Tenure: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source and provider	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
f1	Private renters (% Households)	Census, ONS	2011	Census table KS402. Number of households 'Rented: Private Landlord or Letting Agency' + 'Rented: Other', divided by the total number of households and multiplied by 100.	LSOA	LSOA	DZ	SOA
f2	Social renters (% Households renting from Social or Council landlords)	Census, ONS	2011	Census table KS402. Number of households 'Rented: Council (Local authority)' + 'Rented: Other social rented', divided by the total number of households and multiplied by 100.	LSOA	LSOA	DZ	SOA

Table 8 Physical mobility: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source and provider	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
m1	High levels of disability (% of population who are disabled)	Census, ONS	2011	% with 'activities limited a lot'	LSOA	LSOA	DZ	SOA
m2	% people living in medical and care establishments	Census, ONS	2011	Census table QS421SC. Number of people in 'Medical and care establishments' divided by the total population and multiplied by 100.	LSOA	LSOA	DZ	SOA
m3	Lack of private transport (% households with no car or van)	Census, ONS	2011	Census table KS404SC. Number of households where 'Number of cars or vans in household: No cars or vans' divided by the total number of households and multiplied by 100.	LSOA	LSOA	DZ	SOA

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Table 9 Crime: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source and provider	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
c1	High levels of crime	Department of Communities and Local Government, Statistics for Wales, Scottish Government, NI Statistics and Research Agency	See next column	**England**: Indices of Deprivation 2015: Crime Domain: Crime Score (all crime); **Scotland:** SIMD Crime Score, 2012 **Wales**: SIMD Crime score, 2014; **Northern Ireland**: NIIMD Crime Score, 2010	LSOA	LSOA	DZ	SOA

Table 10 Housing characteristics: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source and provider	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
l1	% caravan or other mobile or temporary structures in all households	Census, ONS	2011	Census table KS401. 'All household spaces: Caravan or other mobile or temporary structure' divided by the total number of households and multiplied by 100.	LSOA	LSOA	DZ	SOA

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Table 11 Direct flood experience: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
e1	number of properties within historical flood boundary	EA, NRW, SEPA, NI Rivers Agency	Various	Based on query of property dataset and flood outline; limited to past 50 years when date information available	LSOA	LSOA	DZ	SOA

Table 12 Social networks: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source and provider	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
n1	% single-pensioner households	Census, ONS	2011	Census table QS113. Number of households 'One-person household: Aged 65 and over' divided by the total number of households and multiplied by 100.	LSOA	LSOA	DZ	SOA
n2	% lone-parent households with dependent children	Census, ONS	2011	Census table QS113. Number of households of lone parent with one or more dependent children divided by the total number of households and multiplied by 100.	LSOA	LSOA	DZ	SOA
n3	% children of primary school age (4-11) in the population	Census, ONS	2011	Census table QS103. Number of people aged '4-11 years' divided by the total population and multiplied by 100.	LSOA	LSOA	DZ	SOA

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Table 13 Service availability: Supporting variables, data sources and spatial resolution

ID	Indicator description	Source and provider	Date	Indicator processing details	Spatial Unit			
					Eng	Wales	Scot	NI
s1	% of emergency services exposed to flooding	CCRA, Sayers et al, 2015	2011	Based on query of sites against hazard data to identify proportion of sites at risk of flooding 1:75 or greater	LA	LA	LA	LA
s2	% no. of care homes exposed to flooding	CCRA, Sayers et al, 2015	2011	Based on query of sites against hazard data to identify proportion of sites at risk of flooding 1:75 or greater	LA	LA	LA	LA
s3	% no. of GP surgeries exposed to flooding	CCRA, Sayers et al, 2015	2011	Based on query of sites against hazard data to identify proportion of sites at risk of flooding 1:75 or greater	LA	LA	LA	LA
s4	% no. of schools exposed to flooding	CCRA, Sayers et al, 2015	2011	Based on query of sites against hazard data to identify proportion of sites at risk of flooding 1:75 or greater	LA	LA	LA	LA

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4.0 APPROACH TO CALCULATING THE NEIGHBOURHOOD FLOOD VULNERABILITY INDEX (NFVI)

A.1 Approach to calculating the Neighbourhood Flood Vulnerability Index (NFVI)

The Neighbourhood Flood Vulnerability Index (NFVI) is determined through a three-stage process as outlined in Figure 2 and described below.

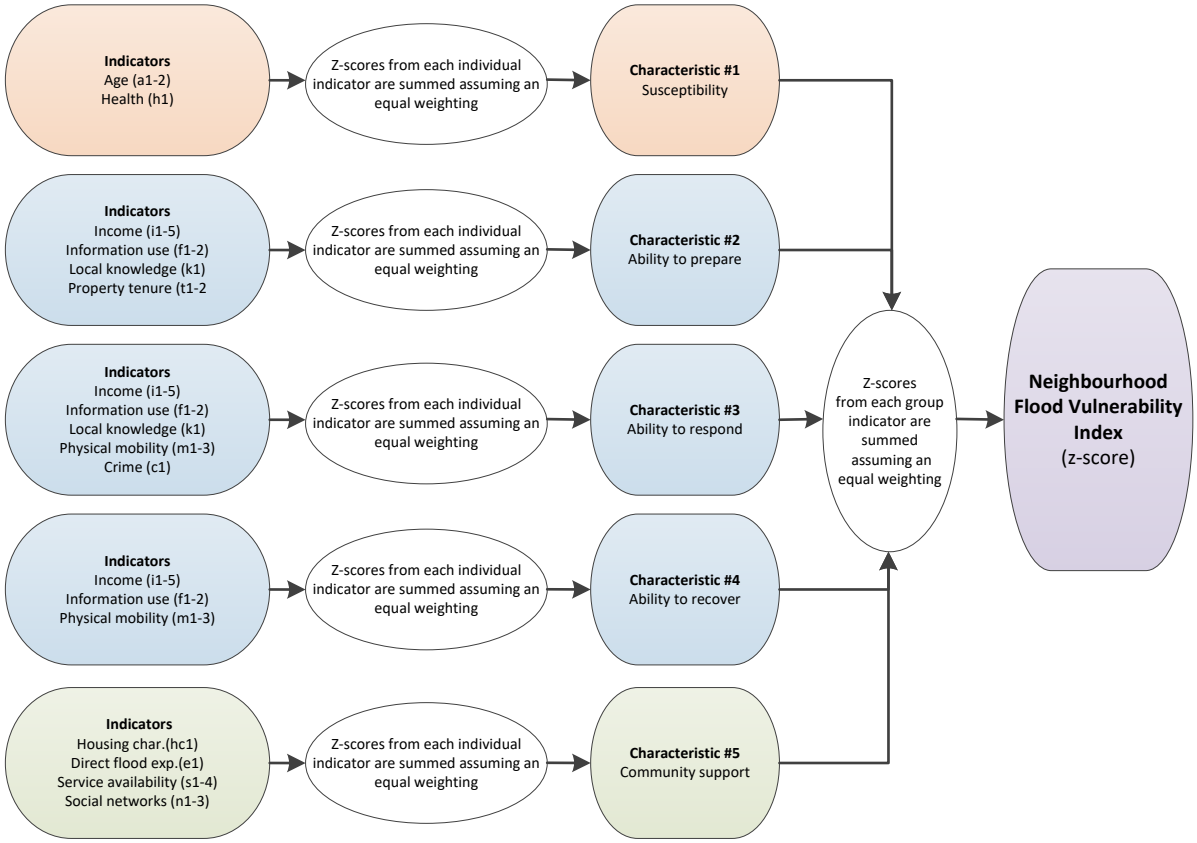


Figure 2 The process used to calculate the NFVI

A.1.1 Stage 1: Determine the z-score for Supporting variables

Each indicator ('age' etc as described in the previous section) is normalised to a z score. The z score is derived by subtracting the mean value and dividing by the standard deviation. If an indicator is already in the form of a rank (e.g. as is the Index of Multiple Deprivation, IMD), the equivalent z score is determined by assuming the rank is drawn from a normal distribution and calculating the number of standard deviations from the mean associated with that rank. This is done so that each indicator has the same numerical parameters, rather than its original numbers (which might be a %, a number, a rank, a fraction, etc.), and to enable them to be compared and combined on the "same playing field".

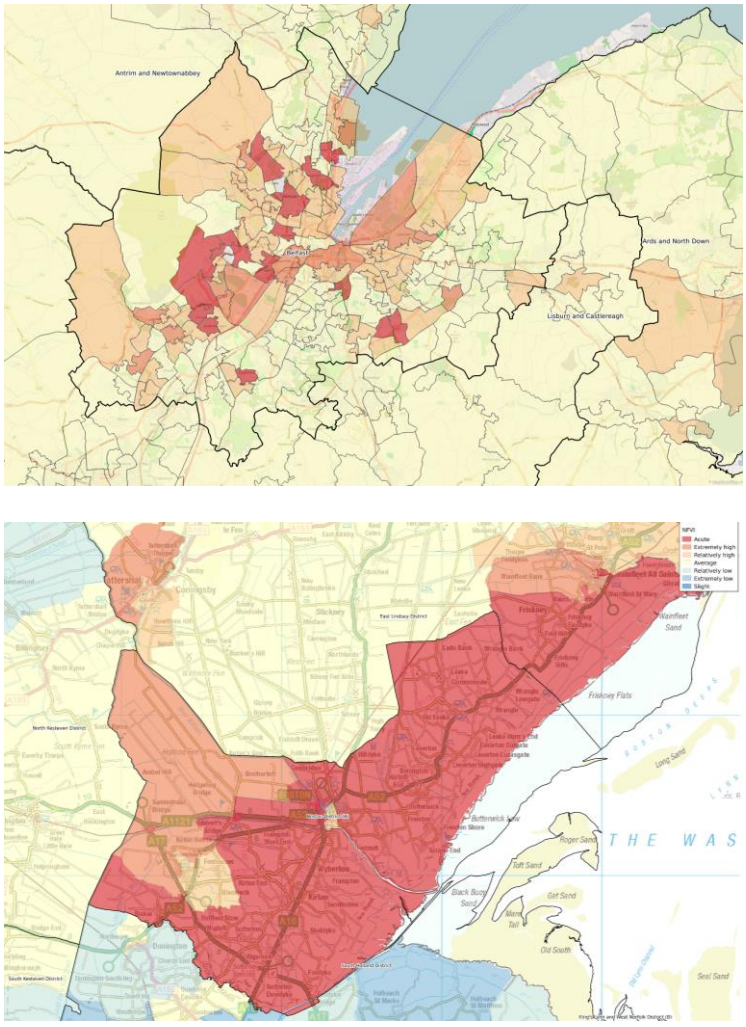
A.1.2 Stage 2: Determine the z-score for each characteristic

Z scores for the supporting variables that contribute to each characteristic (Susceptibility, Ability to Prepare, Respond and Recover, and Community Support) are combined based upon the assumption of equal weighting (Table 14). The only exception is the individual indicator associated with 'direct flood experience' (e1). In this case the weighting is negative as it acts to reduce the relative vulnerability of one neighbourhood compared to another.

The resulting values for each characteristic are then themselves transformed into a z score.

A.1.3 Stage 3: Determine the NFVI

For each neighbourhood, the z scores derived for each Indicator are summed with equal weighting. The final z score is calculated based on these results and used as the NFVI (Figure 3).



Top: Belfast, Bottom: Boston

Figure 3 Example Neighbourhood Flood Vulnerability Index Maps

Based upon Sayers, P.B., Horritt, M., Penning Rowsell, E., and Fieth, J. (2017). Present and future flood vulnerability, risk and disadvantage: A UK scale assessment. A report for the Joseph Rowntree Foundation published by Sayers and Partners LLP

Table 14 Indicator weighting

Neighbourhood Flood Vulnerability: Weighting of individual indicators							
		Weighted contribution to each characteristic					
	Individual indicator	Suscept.	Ability to prepare	Ability to respond	Ability to recover	Community support	Relative weighting in NFVI
Age							**0.11**
a1	Young children (% people under 5 years)	0.25					0.05
a2	Older people (% people over 75 years)	0.25					0.05
Health							**0.11**
h1	Disability / people in ill- health (% people whose day- to-day activities are limited)	0.25					0.05
h2	% households with at least one person with long term limiting illness	0.25					0.05
Income							**0.31**
i1	Unemployed (% unemployed)		0.10	0.08	0.10		0.06
i2	Long-term unemployed (% who are LTU or who have never worked)		0.10	0.08	0.10		0.06
i3	Low income occupations (% in routine or semi- routine occupations)		0.10	0.08	0.10		0.06
i4	Households with dependent children and no adults in employment (%)		0.10	0.08	0.10		0.06
i5	People income deprived (%)		0.10	0.08	0.10		0.06
Information use							**0.12**
f1	Recent arrivals to UK (% people with <1 year residency coming from outside UK)		0.10	0.08	0.10		0.06
f2	Level of proficiency in English		0.10	0.08	0.10		0.06
Local knowledge							**0.04**
k1	New migrants from outside the local area		0.10	0.08			0.04
Tenure							**0.04**
t1	Private renters (% Households)		0.10				0.02
t2	Social renters (% Households renting from Social or Council landlords)		0.10				0.02
Physical mobility							**0.12**
m1	High levels of disability (% of population who are disabled)			0.08	0.10		0.04
m2	% people living in medical and care establishments			0.08	0.10		0.04
m3	Lack of private transport (% households with no car or van)			0.08	0.10		0.04
Crime							**0.02**
c1	High levels of crime			0.08			0.02
Housing characteristics							**0.02**
hc1	Caravan or other mobile or temporary structures in all households (%)					0.11	0.02
Direct flood experience							**-0.02**
e1	Properties exposed to significantly flood risk (% of homes in floodplain)					-0.11	-0.02
Service availability							**0.10**
s1	Emergency services exposed to flooding (%)					0.11	0.02
s2	Care homes exposed to flooding (%)					0.11	0.02
s3	GP surgeries exposed to flooding (%)					0.11	0.02
s4	Schools exposed to flooding (%)					0.11	0.02
Social networks (non-flood)							**0.02**
n1	Single-pensioner households (%)					0.11	0.02
n2	Lone-parent households with dependent children (%)					0.11	0.02
n3	Children of primary school age (4-11) in the population (%)					-0.11	-0.02

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A.2 References

Age UK (2016) Older people and power loss, floods and storms. Age UK.

Baxter, P. J. (2005) The east cost Big Flood, 31 January – 1 February: a summary of the human disaster. Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences, 363, no. 1831 (2005): pp. 1293-1312.

BBC (2010) Flooded Cockermouth police station reopens doors. Available at: http://www.bbc.co.uk/news/10440691. [Accessed: 25/10/2106]

Blaikie, P., Cannon, T. Davis, I. and Wisner, B. (1994) At Risk: Natural Hazards, People's Vulnerability, and Disasters. Routledge: London.

Cabinet Office (2013) Evacuation and shelter guidance. HM Government

Climate Just (2014) Website available at: http://www.climatejust.org.uk [Accessed: 25/10/2016]

Corcoran, M.P., Gray, J. and Peillon, M. (2010) Suburban affiliations. Social relations in the Greater Dublin Area. Syracuse University Press, New York.

Donovan, T. (2014) Social care and the floods: finding a safe haven for the vulnerable. Available at: http://www.communitycare.co.uk/2014/02/17/social-care-floods/. [Accessed: 25/10/2016]

Ebi, K.L., Hajat, S., Penning-Rowsell, E.C., Kovats, S., and Wilson, T. (2006) Floods and human health. In: Climate Change and Adaption Strategies for Human Health. Darmstadt: Steinkopff Verlag.

Environment Agency (2009) More targeted flood warnings: A review: Improving Institutional and Social Responses to Flooding. Joint Defra / Environment Agency Flood and Coastal Erosion Risk Management R&D Programme.

Fielding, J., Burningham, K., Thrush, D. and Catt, R. (2007) Public responses to flood warnings. Environment Agency Science Report SC020116.

Fielding, J., & Burningham, K. (2005). Environmental Inequality and Flood Hazard, *Local Environment* 10(4), 1–17.

Gibson, J. P. (2016) Flood risk posed to the Joseph Rowntree Housing Trust's housing stock. Joseph Rowntree Housing Trust.

Homes, S. (2013). *Your social housing in a changing climate.* London: London Climate Change Partnership.

The Independent (2014) Somerset floods: Thieves target victims. Accessed: 24/10/2016. [Available at: http://www.independent.co.uk/news/uk/crime/somerset-levels-thieves-cash-in-on-floods-misery-9103851.html]

Kates, R.W. (1962) Hazard and choice perception in flood plain management. *Chicago, Illinois, University of Chicago, 1962. 157 p.*

Kazmierczak, A., Cavan, G., Connelly, A. and Lindley, S. (2015) Mapping Flood Disadvantage in Scotland 2015. *The Scottish Government.*

Kazmierczak, A. and Kenny, C. (2011) Risk of flooding to infrastructure in Greater Manchester. Manchester: The University of Manchester.

Klinger, C., Landeg, O. and Murray, V. (2014) Power Outages, Extreme Events and Health: a Systematic Review of the Literature from 2011-2012. PLOS Currents Disasters.

Kolves, K., Kolves, K. E. and De Leo, D. (2013) Natural disasters and suicide behaviours: A systemic literature review. Journal of Affective Disorders, 146. 1-14.

Leisure Futures (2011) Impact on reducing rural isolation. Final research report.Prepared for the Big Lottery Fund. Available at: https://www.biglotteryfund.org.uk/global-content/research/uk-wide/impact-onreducing-rural-isolation

Lindley, S., O'Neill, J., Kandeh, J., Lawson, N., Christian, R. and O'Neill, M. (2011) Climate change, justice and vulnerability. *Joseph Rowntree Foundation, York.*

McCarthy, S., Parker, D. and Penning-Rowsell, E. (2006). Preconsultation social survey: Community based flood risk reduction options. Reach 4: Walton Bridge to Teddington. Enfield: Flood Hazard Research Centre, Middlesex University. Science Report: Improving Institutional and Social Responses to Flooding – Work Package 1 54

McEwen, L. Hall, T., Hunt, J., Dempsey, M. and Harrison, M. (2002) Flood warning, warning response and planning control issues associated with caravan parks: the April 1998 floods on the lower Avon floodplain, Midlands region, UK. Applied Geography, 22, 271-305.

Mort, M., Walker, M., Lloyd Williams, A., Bingley, A. and Howells, V. (2016) Final project report for 'Children, Young People and Flooding: Recovery and Resilience'. Lancaster University, Lancaster, UK.

Patrick, P., Paavola, J., Dale, N., Sibille, R., Kent, N. and LeCornu, E. (2013) PREPARE – Understanding

the equity and distributional impacts of climate risks and adaptation options. Ricardo

AEA/R/ED58163/PREPARE R5/Issue 1.1. Leeds: Ricardo-AEA for Defra

Pendlebury, M. and Bates, G. (2015) Reducing adverse health impacts from flooding and flood risk: A review of the literature and development of questions for further research. National Flood Forum.

Penning-Rowsell, E.C., Parker, D.J. and Harding, D.M. (1986) Floods and Drainage. London: Allen and Unwin.

Penning-Rowsell, E. and Tapsell, S. (2002) Coping with extreme floods: warnings, impacts and response, The extremes of the extremes: extraordinary floods, International Association of Hydrological Sciences , Vol. 271 pp 379-383

Penning-Rowsell, E. C., Priest, S., Parker, D.J., Morris, J., Tunstall, S., Viavattene, C and Owen, D. (2013) Flood and coastal erosion risk management: A manual for economic appraisal. Routledge, London.

Porter, J., Dessai, S. and Tompkins, E. (2014). What do we know about UK household adaptation to climate change? A systematic review. *Climatic Change,* **127**, 371-379.

The Poverty Site. (2014). The Poverty Site: Key Facts. Available at: http://www.poverty.org.uk/summary/key facts.shtml. [Accessed: 12/01/15]

Preston, I., Banks, N., Hargreaves, K. Kazmierczak, A., Lucas, K., Mayne, R., Downing, C. and Street, R. (2014) Climate Change and Social Justice: an evidence review

Robertson, C. (2005) Unpublished MSc dissertation on flood warning and ethnic communities. Environment Agency. Cited in Environment Agency (2009) More targeted flood warnings: A review: Improving Institutional and Social Responses to Flooding. Joint Defra / Environment Agency Flood and Coastal Erosion Risk Management R&D Programme.

Sayers, P.B., Horritt, M. S., Penning-Rowsell, E., and Mckenzie, A. (2015). Climate Change Risk Assessment 2017: Projections of future flood risk in the UK. Pages 125. Sayers and Partners LLP report for the Committee on Climate Change.

Scawthorn, C. F., Flores, P., Blais, N., Seligson, H., Tate, E., Chang, S., Mifflin, E., Thomas, W., Murphy, J., Jones, C. and Lawrence M. (2006) HAZUS-MH Flood Loss Estimation Methodology. II. Damage and Loss Assessment. Natural Hazards 7(2) 72-81.

Shaw, J., Cudmore, S., Turner, D. and Collier, D. (2005) Improving flood warning awareness in low probability and medium-high consequence flood zones. Defra/Environment Agency Flood and coastal erosion risk management R&D Programme

Sims, R., Medd, W., Mort, M., Watson, N., Walker, G. and Twigger-Ross, C., (2008) Perspectives on resilience from households in Hull–response to Defra consultation on policy options for promoting property-level flood protection and resilience. Lancaster University.

Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M. and Wilson, T. L. (2002) Vulnerability to flooding: health and social dimensions, Flood risk in a changing climate. Papers of a Discussion Meeting organized and edited by D. Cox, J. Hunt, P. Mason, H. Wheater and P. Wolf. 15 July 2002, Vol 360, No. 1796, Philosophical Transactions of The Royal Society, Mathematical, Physical and Engineering Sciences pp. 1511-1525 - ISSN: 1364503X

Tapsell, S., Burton, R., Oakes, S. and Parker, D. (2005) The social performance of flood warning communications technologies. Technical Report Environment Agency.

Thrush, D., Burningham, K. and Fielding, J. (2005) Flood warning for vulnerable groups: A qualitative study. Environment Agency Science Report SC990007/SR3. Science Report: Improving Institutional and Social Responses to Flooding – Work Package 1 56 Trends Office for National Statistics Labour Market Trends Special Feature

Tunstall, S., Tapsell, S., and Fernández-Bilbao, A. (2006) The Roadtesting Project. Objective 13. The damage-reducing effects of flood warnings: Results from new data collection. Defra/Environment Agency Project 2014: Development of economic appraisal methods for flood management and coastal erosion protection. Enfield: Flood Hazard Research Centre, Middlesex University.

Vardoulakis, S. and Heaviside, C. (2012) Health effects of climate change in the UK 2012. Health Protection Agency

Waite, T. D., Chaintarli, K., Beck, C., Bone, A., Amlôt, R., Kovats, S., Reacher, M., Armstrong, B., Leonardi, G., Rubin, J., and Oliver, I. (2017). The English national cohort study of flooding and health: cross-sectional analysis of mental health outcomes at year one. DOI: 10.1186/s12889-016-4000-2

Werritty, A, Houston, D., Ball, T., Tavendale. T., and Black. A.2007). Exploring the social impacts of flood risk and flooding in Scotland. Report for the Scottish Executive, 2007. See http://www.gov.scot/resource/doc/174676/0048938.pdf accessed 25 Oct 2016

Whittle, R., Medd, W., Deeming, H., Kashefi, E., Mort, M., Twigger Ross, C., Walker, G. and Watson, N. (2010) After the Rain – learning the lessons from flood recovery in Hull, final project report for 'Flood, Vulnerability and Urban Resilience: a real-time study of local recovery following the floods of June 2007 in Hull'. *Lancaster University, Lancaster UK*

WHO (2013) Floods in the WHO European Region: Health effects and their prevention. World Health Organization.

Zsamboky, M., Fernandez-Bilbao, A., Smith, D., Knight, J. and Allan, J. (2011) Impacts of climate change on disadvantaged UK coastal communities. York: Joseph Rowntree Foundation