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The Scottish Government
Riaghaltas na h-Alba

Mapping Flood Disadvantage in Scotland 2015: Main Report

AGRICULTURE, ENVIRONMENT AND MARINE

social research

MAPPING FLOOD DISADVANTAGE IN SCOTLAND 2015

Final report to the Scottish Government

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2015

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Abbreviations

ABI	Association of British Insurers
AEP	Annual Exceedance Probability
CEH	Centre for Ecology and Hydrology
DCLG	Department for Communities and Local Government
FRM	Flood Risk Management
FRMS	Flood Risk Management Strategy
LFRMP	Local Flood Risk Management Plan
NFRA	National Flood Risk Assessment
OS	Ordnance Survey
PLP	Property Level Protection
PVA	Potentially Vulnerable Area
PWC	Population-weighted centroid
SEPA	Scottish Environment Protection Agency
SUDS	Sustainable Urban Drainage Systems

Glossary

Adaptive capacity	The ability of people to prepare for, respond to and recover after flooding, related mainly to their social and material situation.
Annual exceedance probability	Annual exceedance probability (AEP) describes the probability of a flood of a given magnitude occurring in any given year. AEP is the inverse of the flood return period. For example, 3.3% AEP refers to a return period of 1 in 30 years.
Data zones	Compact areas with around 500-1,000 residents that contain households with similar social characteristics used by the Scottish Government for reporting social statistics, for example the census. There are 6505 data zones in Scotland.
Defended flood extent	The area that has been identified as potentially exposed to flooding, where the underlying models have included consideration of formal flood prevention schemes (e.g. walls, embankments). Thus, defended flood extents cover smaller areas than undefended flood extents.
Direct indicator	An indicator that directly reflects the factor influencing social vulnerability to flooding, e.g. proportion of older people in the population
Exposure (enhanced)	One of the dimensions of vulnerability, which refers to the aspects of the physical environment (housing and presence of permeable surfaces), which accentuate or offset the severity of flood events.
Flood disadvantage	A situation when vulnerable neighbourhoods are exposed to flooding. In other words, disadvantage occurs where high social vulnerability to flooding spatially coincides with flood hazard-exposure represented by flood extents.
Flood extent	The predicted area of flooding from rivers, the sea or surface water based on the Scottish Environment Protection Agency Flood Maps.
Flood hazard-exposure	The degree to which people or other systems may come into contact with flooding. In this project flood hazard-exposure is estimated spatially as the proportion of residential addresses located within flood extents.
Flood return period	The average interval between floods of a given magnitude. It is a measure of the rarity of flood events – the longer the return period, the rarer the event.
Population-weighted centroid	A summary single reference point which represents how the population at census time was spatially distributed and grouped within the census unit.
Property level protection	Flood protection measures implemented for individual properties, which either keep the flood waters outside the property or minimize the damage if flood waters enter the building.
Proxy indicator	An indicator that provides an approximation of the factor influencing social vulnerability to flooding, e.g. the density of social networks is represented by a proxy indicator of older people living on their own as they are likely to be the most socially isolated.
Sensitivity	One of the dimensions of vulnerability, which reflects the personal characteristics, namely age and health status, that increase the likelihood that a flood event will have negative health and well-being impacts on people.
Social vulnerability to flooding	The varying degree to which people's health and well-being would be negatively affected by flooding (the higher the vulnerability, the greater the negative effect of flooding).
Standard deviation	A measure expressing how much the scores in a group differ from the mean score for the group. Standard deviation is found by taking the square root of the variance – which is the spread of the scores within the group.
Standardisation	A statistical process of re-calculating values for variables or indicators measured using different scales in order to present them on a uniform scale.

Surface water flooding	Flooding that results from rainfall runoff flowing or ponding over the ground before it enters a natural (e.g. watercourse) or artificial (e.g. sewer) drainage system or when it cannot enter a drainage system (e.g. because the system is already full to capacity or the drainage inlets have a limited capacity) (JBA, 2014).
Undefended flood extent	The areas that may be affected by flooding if no flood defences were present, in other words assuming that all areas are undefended. In practice some areas identified as flood prone do have defences in place and thus have a lower chance of flooding than the data would suggest.
Z-score	A statistical measurement of a score's relationship to the mean (average value) in a group of scores. A Z-score of 0 means the score is the same as the mean (average value). A Z-score can be positive or negative, indicating whether it is above or below the mean and by how many standard deviations. Z-score standardisation represents the deviation of a raw score from its mean in standard deviation units.

Executive summary

This report summarises the research into the assessment of social vulnerability to flooding and flood disadvantage, based on the assessment framework developed by Lindley et al. (2011). It is aimed at policy-makers and practitioners working in flood risk management, resilience, emergency services, public health, social care, housing, environment and other areas that would benefit from an improved understanding of vulnerable communities and flooding across Scotland.

Social vulnerability in this report is understood as the degree to which people's health and well-being would be negatively affected if they came into contact with flooding. Social vulnerability is a combination of:

- Sensitivity (personal characteristics that increase the likelihood that a flood event will have negative health and well-being impacts on people),
- Adaptive capacity (the ability of people to prepare for, respond to and recover after flooding, related mainly to their social and material situation), and,
- Enhanced exposure (the aspects of the physical environment, such as housing and presence of permeable surfaces, which accentuate or offset the severity of flood events).

Flood disadvantage occurs where socially vulnerable areas coincide with areas which may be exposed to flooding, or in other words have high flood hazard-exposure. In this report, flood hazard-exposure is estimated spatially as the percentage of residential properties within flood risk areas.

This research updates an assessment of flood disadvantage carried out by Lindley and O'Neill (2013). However, the two assessments are not comparable as the following modifications have been made:

- A revised set of indicators for socio-spatial vulnerability has been developed. The list takes account of the availability of new datasets, feedback from stakeholders and an additional evidence review.
- Updated versions of indicators that represent the most up-to date picture of socio-spatial vulnerability. Sources of information include the Scottish census 2011 and Scottish Neighbourhood Statistics.
- New flood maps produced by SEPA (version 1.1, March 2015) have been used to represent the likelihood of flooding across Scotland and the assessment has been carried out for different flood return periods than in the first assessment. The 'defended' flood outlines have been used in order to represent the risk of flooding taking into consideration the presence of flood defences.

- Surface water flooding, as a substantial flood problem in Scotland, is included in the analysis alongside flooding from the rivers and the sea.

The assessment was carried out for the whole of Scotland at data zone level[1]. In total, 34 indicators relating to 14 thematic domains (Age, Health, Income, Information use, Insurance, Local knowledge, Social networks, Tenure, Mobility, Physical access, Crime, Access to services, Housing and Green space) were combined into the index of social vulnerability to flooding.

The index of social vulnerability to flooding was combined with the flood hazard-exposure index which took into account different sources of flooding (coastal, river, surface water) and different return periods[2] (1:25/30; 1:200, 1:200 including the impacts of climate change). This was then developed into the index of flood disadvantage. Social vulnerability and flood disadvantage are categorised into six classes, based on the deviation from average Scottish values, and range from extremely low to acute.

The key findings (for 1 in 200 year flood return period that accounts for climate change - a low probability-high damage flood scenario not including the impact of flood defences) are as follows:

Flood exposure:

- Over 4% of residential properties in Scotland (just over 108,000) are estimated to be exposed to any type of flooding. At least some of these may be properties constructed since 1st January 2009.
- Nearly half of all data zones in Scotland contain residential properties which may be exposed to any source of flooding.
- Falkirk, the Orkney Islands and West Dunbartonshire have the highest proportion of residential properties exposed to coastal flooding.
- Stirling, the Scottish Borders, Perth and Kinross and Moray have the highest proportion of residential properties exposed to river flooding.
- Surface water flooding affects fewer properties. The highest proportion of residential properties exposed to surface water flooding is in Aberdeen City, Highland and Moray.

Just below 8% of the data zones are classified as having an extremely high or acute vulnerability to flooding. These are located mainly in the large Scottish cities, with Glasgow containing 191 such data zones, Edinburgh - 82; Dundee - 44 and Aberdeen – 27.

[1] Data zones 2001 were used rather than data zones 2011, as most of the data underpinning the assessment was originally collected for the data zones 2001.

[2] The return periods estimate the average length of time between flood events of similar magnitude (e.g. 1 in 200 years).

Flood disadvantage:

- Considering any source of flooding, 3-4% of all data zones or 7-8% of data zones exposed to flooding can be classified as extremely or acutely disadvantaged.
- Falkirk, West Dunbartonshire, Highland and Dumfries and Galloway have the highest number of extremely/acutely flood disadvantaged data zones in relation to coastal flooding.
- With regard to river flooding, the highest number of extremely/acutely flood disadvantaged data zones is in Edinburgh, Stirling and Highland, followed by Falkirk and Aberdeen.
- One-third of the acutely/extremely disadvantaged data zones in relation to surface water flooding are in Glasgow, followed by Edinburgh and Aberdeen.
- At the national level, considering the low-probability flood scenario, the extremely and acutely flood disadvantaged data zones contain around 100,000 people. Over 28,000 people may be flood-disadvantaged in relation to coastal flooding; 60,000 in relation to river flooding and 14,000 in relation to surface water flooding.

Geographical distribution of social vulnerability to flooding and flood disadvantage:

- Urban areas are more likely to contain the extremes of social vulnerability to flooding: 73% of the extremely or acutely vulnerable data zones were located in large urban areas and a further 23% in other urban areas. However, extremely low vulnerability also tends to focus in urban areas: 29% of data zones classed as having extremely low vulnerability were in large urban areas and nearly 50% in ‘other urban’ areas.
- Remote small towns and remote rural areas emerge as having potential issues with social and physical isolation and mobility of people, especially older populations, which may raise issues with regard to responding to flood events.
- Flood disadvantage in Scotland (any type of flooding) tends to concentrate in urban areas; in particular the smaller urban areas contain a high proportion of extremely and acutely disadvantaged neighbourhoods.
- Both social vulnerability and flood disadvantage are concentrated in coastal areas.
- The results of the flood disadvantage assessment are consistent with the SEPA’s 2011 National Flood Risk Assessment. Nearly all acutely/extremely vulnerable data zones were located within Potentially Vulnerable Areas (PVAs); 97.5% of the extremely vulnerable neighbourhoods were located within PVAs. Only one of 98 acutely flood disadvantaged neighbourhoods and five of 138 extremely flood

disadvantaged neighbourhoods fell outside PVAs. This compatibility allows for the use of this assessment alongside PVAs to differentiate between communities with different characteristics.

Case studies with local authorities (Dumfries and Galloway, Dundee City and Scottish Borders):

- The participants were supportive of the framework used and of the explicit links made between the vulnerability of communities and the hazard of flooding, as these issues tend to be considered in separation in local authorities' work.
- The data broadly reflected the participants' experience of where exposure and vulnerability are located and coincide. However, in one case-study rural local authority there were fine-grained differences that were not picked up by the level of assessment at the data zone level. This indicates the need for further investigations into vulnerability and communities at the level of smaller spatial units or individuals.
- The potential uses of the results included: supporting cross-departmental working; identifying priority areas for emergency services; and, communicating flood risk issues to local communities.
- A strong recommendation emerging from the meetings with local authorities is to develop a spatial portal which would allow selected layers of information to be displayed and would bring together the underlying spreadsheets, containing the data, with the maps.

Recommendations:

- For local authorities, mapped flood disadvantage provides a useful framework for planning actions in anticipation of the increased risk of flooding (e.g. redevelopment that alters the use of the ground floor to minimise damage if a flood happens) and developing recovery strategies in the aftermath of flooding (e.g. targeting financial assistance to groups least likely to have flood insurance).
- It is recommended that local authorities collaborate with third sector organisations in particular in remote rural areas but also in inner-city areas to increase the self-help potential of communities, facilitate development of social networks and provide support in the case of flooding.
- Raising awareness of flooding and actions to be taken among landlords and tenants is needed as the private rented sector continues to grow.
- The extensive set of indicators compiled in the vulnerability assessment may be used by various local authority departments to identify areas for actions unrelated to flooding (e.g. adult and social care).
- The information on the concentrations of residential properties and neighbourhoods characterised by acute and extreme flood disadvantage

can be used by SEPA to provide additional information to support the implementation of Flood Risk Management Strategies for Local Plan Districts.

- The dataset may be used by SEPA in future flood risk management cycles to inform the delivery of actions such as provision and method of delivery of flood warnings and flood prevention schemes. The highly vulnerable and disadvantaged data zones located outside PVAs identified in 2011 NFRA could be considered against candidate PVAs for the next cycle NFRA.
- The spatial distribution of flood disadvantage can be used to support or evaluate decisions made on flood risk investment. Requiring particular attention are areas with acute and extreme disadvantage in coastal and urban areas, and reducing the risks associated with physical and social isolation of communities in remote towns and rural areas.
- Future research could focus on: developing more direct indicators of social vulnerability to flooding; exploring the future dimension of vulnerability alongside climate projections; and, investigating localised, fine-grained variability in social vulnerability to flooding and flood disadvantage. Mapping the provision of emergency services, rest centres and other social infrastructure that could be used in response to flooding and in the recovery phase would offer additional layers of information.

1. Introduction

This report presents the outcomes of the Mapping Flood Disadvantage in Scotland 2015 project. The aim of this project was to provide an up-to-date spatial assessment of social vulnerability to flooding and flood disadvantage in Scotland, to enable local authorities, service providers and other agencies to better target work around flood resilience and response, and in particular to assist local authorities in meeting their duties under the Flood Risk Management (Scotland) Act 2009.

Social vulnerability to flooding **is understood as the varying degree to which people's health and well-being would be negatively affected by flooding if they come into contact with a flood.**

Flood disadvantage **relates to the situation where vulnerable neighbourhoods are located within areas which may be affected by flooding.**

The project builds on the first assessment of flood disadvantage in Scotland (Lindley and O'Neill, 2013) and the earlier assessment of social vulnerability to climate change impacts (Lindley et al., 2011). It applies the same assessment framework. However, certain modifications have been made to the methodology applied previously. This includes the use of alternative or more recent social datasets (e.g. Scottish census 2011); amendments to the set of indicators following feedback from stakeholders; inclusion of the latest flood risk data; and, a different selection of flood return periods in the analysis. Therefore, the results of the assessment of social vulnerability to flooding and flood disadvantage presented in this report should not be compared with the first disadvantage assessment.

The focus of the project is on communities and residential properties, and, in contrast to the National Flood Risk Assessment (NFRA; SEPA, 2011a), the scope of the vulnerability assessment does not cover commercial properties or economic activities.

The objectives of the project were to:

- Present the concepts of social vulnerability to flooding and flood disadvantage, and describe the personal, social and environmental factors that make individuals, households or communities vulnerable to flooding;
- Carry out an assessment of the social vulnerability to flooding and flood disadvantage for Scotland using the most up to date socio-economic data and flood risk data;

- Analyse the spatial distribution of social vulnerability to flooding and flood disadvantage in Scotland, with regard to urban, rural and coastal areas, as well as the coincidence with the Potentially Vulnerable Areas identified in NFRA (SEPA, 2011a); and,
- Investigate views from local authorities regarding the dataset produced and suggest potential uses of the data through case studies.

The report starts by positioning the project within the existing policy context and research (section 2). Section 3 provides a brief outline of the data and methods used in the assessment. Section 4 summarises the results of the project – the assessment of social vulnerability to flooding and flood disadvantage, followed by case studies for three local authorities discussing their views on the data produced and the possible applications envisaged. The conclusions (section 5) reflect on the key outcomes and outline recommendations for future work on social vulnerability to flooding and flood disadvantage assessment in Scotland.

This report is accompanied by the following outputs:

- A detailed methodology document, describing the data used and the stages of the analysis, which aims to enable the readers to understand, evaluate and replicate the method applied;
- Interactive maps of social vulnerability to flooding and flood disadvantage.
- The spatial dataset providing information on flood disadvantage with regard to different types of flooding and for various return periods, as well as the disaggregated underlying indicators used in the assessment;
- The dataset compiling the indicators and indices (in a spreadsheet format) accompanied by a short, user-friendly guide, directed at those who may not have a technical or statistical background;
- Recommendations report; and,
- Research findings report summarising the headline messages.

2. Background

Flooding is already a significant issue in Scotland as the winter 2013/14 floods in Dumfries and Galloway; surface water flooding in Glasgow in 2002, and, more recently, in July 2015 in Aberdeen; and floods in Moray in 1995, 2002 and 2009 have shown. In 2011 SEPA produced the first National Flood Risk Assessment (NFRA) for Scotland, which suggests that 1 in 22 of all residential properties in Scotland is at risk of flooding from any source (sea, river and surface water), considering the 1 in 200 years return period.

Climate change is likely to exacerbate the frequency and severity of flooding in Scotland.

The UK Climate Projections data indicates that rising sea levels, increases in winter rainfall, and more days of heavy rainfall will affect Scotland (Defra, 2012). The sea level in Edinburgh is projected to rise by between 10.5 and 18.0 cm by the 2050s (The Scottish Government, 2009). Depending on the region in Scotland, it is unlikely that the increase in winter precipitation by the 2050s, under the high emissions scenario would be less than 6% or greater than 55% (The Scottish Government, 2009). The consequential increased risk of river, coastal and surface water flooding is recognised in Scotland's Third National Planning Framework (The Scottish Government, 2014a). Also, the intensity of rainfall is likely to increase: the wettest days of the year are likely to be considerably wetter than at present (The Scottish Government, 2009). By the 2050s, rainfall on the wettest day in winter is projected to change in the range of -5% to 25% across regions in Scotland, under the high emissions scenario, with a central estimate (50% probability) of 10% increase (UK Climate Projections, 2009).

The UK Climate Change Risk Assessment emphasised that, under the changing climate, flooding would increase the risk of deaths, injuries, and health effects (Defra, 2012). However, not all individuals or communities will be affected equally, as their ability to cope with these events is different. For example, groups such as older people, those on low incomes or in poor health are more prone to harm (Defra, 2013).

The impacts from extreme weather events under the changing climate could disproportionately affect some sectors of society.

The uneven distribution of climate impacts has implications for social justice, which in relation to flooding is about ensuring that people, both individually and collectively, have the ability to prepare for, respond to and recover from flood events and that the policies for reducing the risks take account of existing and

projected vulnerabilities, resources and capabilities (Preston et al., 2014). Thus, there is an urgent need for the development of tailored policy responses for vulnerable groups who are the most likely to be affected by the impacts of climate change, including flooding (Lindley et al., 2011).

2.1 Policy context

In recent years there has been an increasing focus on the notion of vulnerability to climate change in UK and Scottish policy. The UK National Planning Policy Framework includes guidance for planning authorities on meeting the challenge of climate change, flooding and coastal change, and emphasises the need to protect vulnerable locations (DCLG, 2012). In addition, the UK Climate Change Risk Assessment (DEFRA, 2012) highlights the potential impacts on, and the need to protect, the most vulnerable individuals and communities. The Scottish Climate Change Adaptation Programme accordingly presents the vision of Scotland with "strong, healthy, resilient communities which are well informed and prepared for a changing climate" (The Scottish Government, 2014b: 84).

SEPA's (2014) report *'Our Climate Challenge: helping to deliver a resilient, low carbon Scotland'* aims to assist the delivery of Scotland's Climate Change Adaptation Programme and promote adaptation across all of SEPA's strategic themes by 2018. SEPA identifies their role in flooding as particularly key in terms of adapting Scotland to a changing climate. Further, Scotland's *Climate Change Adaptation Framework* advises that decisions on adaptation should be informed by robust scientific research into the impacts of climate change, vulnerabilities to those impacts, and effectiveness of adaptation options, and emphasises the importance of various agencies in supporting vulnerable groups (The Scottish Government, 2009).

The Flood Risk Management (Scotland) Act 2009 (FRM Act) sets a framework for Responsible Authorities to exercise their functions collaboratively towards the overall reduction of flood risk in Scotland. It enables a plan-led and risk-based approach to sustainable flood risk management that considers catchments holistically. The NFRA (SEPA, 2011) established for the first time a strategic consideration of flood risk across Scotland. Using available data, it defined flood risk in terms of the hazard likelihood and potential exposure, vulnerability and value of receptors to enable an assessment of the potential adverse consequences of flooding to people, businesses, the environment and cultural heritage. The NFRA considered a broad suite of metrics, one element of which was social vulnerability, to define those areas most affected by flooding (Potentially Vulnerable Areas (PVAs)) and which are the focus of Flood Risk Management Strategies (FRMSs) and Local Flood Risk Management Plans (LFRMPs). The PVAs therefore identify those communities which may be most adversely affected by flooding, considering the impacts on people and community services, but does not explicitly report on flood disadvantage.

The FRMSs will be published in 2015 and will update the NFRA using the most up-to-date information on flood hazard. These establish the Management Actions which, when implemented, will reduce overall flood risk considering a 30-50 year time horizon. The development of a wide range of socio-economic metrics that detail social vulnerability to flooding could greatly support local authorities in better understanding how to implement and target their Actions within LFRMPs and thus support current strategic flood risk management tools.

Beyond flood risk management and climate change policies, there are a number of cross-cutting policy issues that support efforts aiming at better understanding of flood disadvantage. The importance of reducing inequalities is emphasised in *'Achieving our Potential: A Framework to Tackle Poverty and Income Inequality in Scotland'* (Scottish Government, 2008a). This document mainly addresses material disadvantage but it also provides a strong focus for various public, private and third sector organisations in its emphasis on community planning and empowering locally based stakeholders.

Flooding has significant impacts on physical health and mental well-being and therefore health policies also bear strong relevance to flood disadvantage. Reducing health inequalities in materially disadvantaged areas is prioritised as documented in *'Equally Well'* (Scottish Government, 2008b:1) which stresses that "radical cross-cutting action is needed to address Scotland's health gap to benefit its citizens, communities and the country as a whole". This may be seen as supporting increased cross-departmental working between flood risk management teams, emergency planning and health and social care to reduce flood disadvantage.

Matters of civil contingencies are also the responsibility of the Scottish Government except in a few identified areas (such as terrorism). The Civil Contingencies Act 2004 (Contingency Planning) (Scotland) Regulations 2005 notes a wide range of Category 1 responders in the event of an emergency who could all be involved in helping to address flood disadvantage. Many Category 1 responders operate beyond local authority boundaries including the police, NHS Health Boards and SEPA. Effectively addressing flood disadvantage, with a particular focus on securing adequate response in the event of flooding, will mean identifying stakeholders both within and beyond the local authority.

Of future policy relevance is the current Community Empowerment (Scotland) Bill (Scottish Parliament, 2014) that was passed by the Scottish Parliament during June 2015. The Bill aims to strengthen community voices in decision making and to improve community planning. Flooding could be an issue through which conversations around empowerment might begin particularly since more responsibilities are being placed upon citizens to manage their own risks.

2.2 Building on previous research on flood disadvantage in Scotland

Several previous studies have assessed the impact of flooding on communities in Scotland in relation to their characteristics. For example, Werritty et al. (2007) found that the lowest income households reported the highest levels of stress and anxiety and suffered from more adverse health impacts; and that older people were more affected by 'intangible' impacts such as loss of cherished memorabilia. Houston et al. (2011) carried out an analysis of the pattern of pluvial (rain related) flood risk within Glasgow, which indicated that groups with a lower socio-economic status may be over-represented in the areas at risk. Houston et al. (2011) also emphasised the need for better identification of which social groups are most vulnerable to the impacts of a flood, i.e. the most negatively affected by flooding. It has been recognised that there remains considerable scope to introduce indicators and measures of vulnerability taking into account the uneven impacts of flooding on different communities (Lindley et al., 2011; Preston et al., 2011).

Understanding the geographical distribution of social, economic and environmental factors contributing to vulnerability may assist with flood risk management

Knowing the location of vulnerable groups can support actions aimed at reducing exposure of communities, prioritising particularly vulnerable populations for intervention and anticipating where the future risk 'hot spots' may be located (Preston et al., 2011). Accordingly, Lindley et al. (2011) carried out a spatial analysis of social vulnerability to flooding in Scotland, using an extensive set of indicators derived from the 2001 census data and other socio-economic datasets based on factors recognised as contributing to social vulnerability in the literature. Lindley et al. (2011) identified a strong concentration of the characteristics increasing community vulnerability to flooding in urban and coastal areas. This assessment was taken forward by Lindley and O'Neill (2013), who identified to what extent these social, economic and environmental characteristics of neighbourhoods that increase their vulnerability coincided with the probability of flooding, i.e. where there was flood disadvantage.

Whilst the assessment by Lindley and O'Neill (2013) provided a valuable picture of the spatial distribution of flood disadvantage, **the assessment of flood disadvantage needs to be updated given the economic, societal and demographic changes in Scotland that have occurred in the last decade**. For example, between 2001 and 2011, the number of people in Scotland aged 65 and over increased by 85,000 (11%) (National Records of Scotland, 2012). In addition, the number of private tenants – a group which is potentially disproportionately affected by flooding due to limited legal protection and poor housing standards in the private rented sector – nearly doubled and stood at

11% in 2011 (The Scottish Government, 2012a). However, these numbers do not tell us where change has occurred and how the spatial distribution of potentially vulnerable groups has changed since 2001. Thus, it is important to use the most up to date socio-economic information to determine the current spatial distribution of the most vulnerable neighbourhoods in Scotland.

Further, this project has provided the opportunity for a detailed review of the social vulnerability indicators used in the original study on social vulnerability to climate change impacts (Lindley et al., 2011). The review allowed for the **consideration of new evidence from the literature** that was not possible in the earlier assessments. As a result there have been some modifications to the methodology (see section 3 and the methodology document). Importantly, the results from this study cannot be used to illustrate temporal changes with regard to the first disadvantage assessment (Lindley and O'Neill, 2013) or for comparisons with other parts of the UK.

Also, recent advances in flood mapping since the first assessment of vulnerability and disadvantage, together with them **taking account of the influence of flood defences** (represented by the defended flood extents), add an additional angle to the analysis of flood disadvantage. Moreover, the first assessment of vulnerability and disadvantage to flooding did not include the risk of surface water flooding, which has only recently been systematically mapped for Scotland. Surface water flooding poses a significant threat to the well-being of communities, accounting for approximately 38% of all flood impacts in Scotland (SEPA, 2011a). Whilst the intense rain events that cause surface water flooding are difficult to forecast and it is challenging to provide adequate warning times (Houston et al., 2011), it is possible to predict where pluvial flooding might occur and be a significant hazard for a range of return periods that enables mitigation measures to be put in place. Thus, **estimating the levels of surface water flooding disadvantage** by combining the spatial distribution of surface water flooding hazard with the updated vulnerability assessment in this project will provide additional information guiding the appropriate mitigating actions of the Scottish Government, local authorities and service providers.

3. Methods and data

This section begins by explaining the assessment framework for social vulnerability to flooding and flood disadvantage used in the project (section 3.1) before discussing the personal, social and environmental factors that affect vulnerability to flooding, introducing the corresponding indicators, and describing how the indicators were combined into the vulnerability index (section 3.2). The datasets pertaining to flood hazard in Scotland are described in section 3.3. The details of the datasets used, processing methods and map development are provided in the methodology document.

3.1. Assessment framework for social vulnerability to flooding and flood disadvantage

This project applies the approach to social vulnerability to flooding and flood disadvantage developed in the assessment for the UK (Lindley et al, 2011) and the first disadvantage assessment for Scotland (Lindley and O'Neill, 2013). The text in this section therefore refers to these reports and the subsequent Climate Just website (www.climatejust.org.uk).

The assessment framework developed by Lindley et al (2011) is based on the 'risk triangle' (Crichton, 1999), originally applied as a method for estimating risk (the probability of loss) in the insurance industry. In the risk triangle, the magnitude of risk depends on:

- The extent of vulnerability, or the extent to which the object or system in question would suffer damage or loss;
- The frequency and severity of hazard; and,
- The level of exposure, for example the location that results in contact with the hazard.

Lindley et al. (2011) used this framework to carry out the assessment of climate disadvantage of communities, focusing on neighbourhoods as the elements at risk, or at disadvantage from climate change impacts. As with the 2011 study, the assessment is carried out at the level of communities, or neighbourhoods (represented by data zones), therefore the geographical characteristics are also important in the assessment. Thus, social vulnerability to flooding considers how the characteristics of individuals, communities and places affect the chance of a neighbourhood being negatively affected by flooding, should it happen in that location.

Social vulnerability to flooding in this report is understood as the varying degree to which people's health and well-being would be negatively affected if they came into contact with flooding. **The higher the vulnerability, the greater the negative effect of flooding.**

Social vulnerability to flooding is the combination of sensitivity, enhanced exposure and the adaptive capacity, which comprises the ability to prepare for, respond to, and recover from, flooding (see Figure 1).

Sensitivity reflects the personal characteristics, namely age and health status, that increase the likelihood that a flood event will have negative health and well-being impacts on people. In the neighbourhood-level assessment, a higher proportion of older people, young children and those in poor health would increase the sensitivity.

Enhanced exposure refers to the aspects of the physical environment, which accentuate or offset the severity of flood events. For example, neighbourhoods with little green space (and thus low flood water infiltration rates) and a high proportion of houses with basements would have higher enhanced exposure.

Adaptive capacity is the ability of people to prepare for, respond to and recover after flooding, related mainly to their social and material situation. For example, areas of high material deprivation, poor access or where social networks are weak, are likely to have lower adaptive capacity.

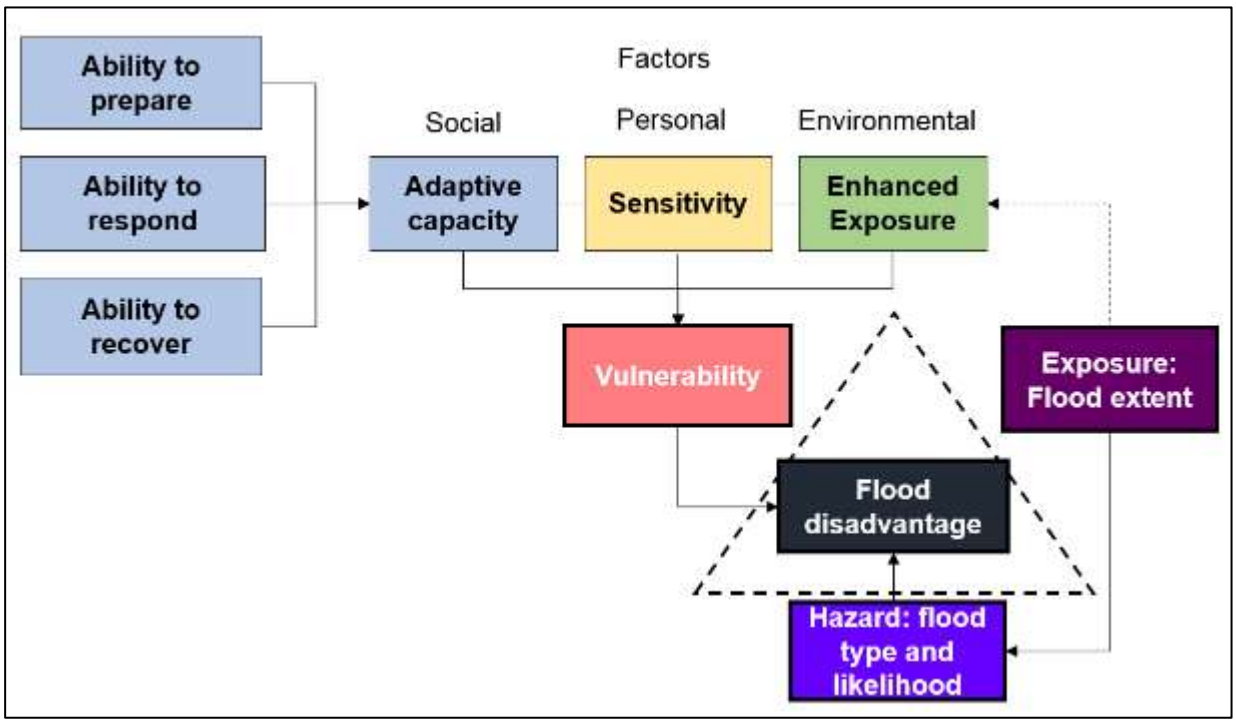

Figure 1. The framework of socio-spatial vulnerability and flood disadvantage (after Lindley et al., 2011; adapted to flood hazard).

Thus, this assessment framework recognises that vulnerability is influenced by a mix of personal (e.g. disability or age), environmental (e.g. elevation of housing, presence of green space) and social factors (e.g. levels of income, tenure or extent of social networks) which, when combined, affect the degree to which flood events may affect the well-being of individuals. These factors are discussed in section 3.2.

In the risk triangle, **hazard** is the type (or source) of flooding – coastal, river or surface water flooding and the likelihood of such flooding happening. The likelihood is expressed in return periods (for example 1 in 200 years), which estimate the average length of time between flood events of similar magnitude. The likelihood may also be expressed as the Annual Exceedance Probability of a flood event of a given magnitude taking place – for example, a 1 in 200 years event has a 0.5% chance of happening in any given year; whilst a 1 in 10 years flooding has a 10% chance of occurring in any given year.

Exposure in the risk triangle refers to the geographical location of flooding. It is represented by flood extents, i.e. areas on flood maps where flooding is predicted to occur for a given likelihood. SEPA produces flood extents for different types and likelihoods of flooding (see section 3.3), which therefore represent the combination of hazard and exposure of the risk triangle and are referred to as **hazard-exposure**.

Flood hazard-exposure is the spatial extent of flooding of a given type and likelihood.

According to the risk triangle framework, if any one component or 'side' of the triangle is zero, then there is no risk (Crichton, 1999). Therefore, in locations where social vulnerability is high but the likelihood of flooding is close to zero[3], the negative impacts of flood events on health and well-being will not be realised. **Flood disadvantage**, therefore, only occurs where social vulnerability coincides with hazard-exposure, i.e. where vulnerable communities live in areas that may be exposed to flooding. Therefore, the level of flood disadvantage reflects the magnitude of social vulnerability to flooding and the magnitude of hazard-exposure.

Flood disadvantage relates to the situation where neighbourhoods assessed as vulnerable coincide spatially with areas which may be affected by flooding.

[3] Whilst the flood maps used as a basis of flood disadvantage assessment in this research allow for identification of areas not exposed to flood hazard, in practice, there is no situation where there is "no" likelihood of flooding, only very to extremely low likelihoods. There may always be a chance of flooding although it might be extremely remote. This is particularly true in the case of surface water flooding caused by intense rainfall events, which are hard to predict but could occur anywhere.

3.2. Factors influencing social vulnerability to flooding

This section describes the personal, social and environmental factors that make individuals or households vulnerable to flooding and provides evidence that supports the use of direct or proxy indicators. These factors can be grouped into domains corresponding to different dimensions of vulnerability (Table 1).

Table 1. Thematic domains against the dimensions of social vulnerability to flooding.

Factors	Domains	Dimensions of vulnerability				
		Sensitivity	Enhanced exposure	Adaptive capacity		
				Ability to prepare	Ability to respond	Ability to recover
Personal	Age	✓				
	Health	✓				
Environmental	Housing		✓			
	Green space		✓			
Social	Income			✓	✓	✓
	Information use			✓	✓	✓
	Insurance			✓	✓	✓
	Local knowledge			✓	✓	
	Social networks			✓	✓	
	Tenure			✓		
	Mobility				✓	✓
	Physical access				✓	
	Crime				✓	
	Access to services					✓

The association of different domains with the dimensions of vulnerability is based on existing evidence and represents the strongest links found between the thematic domains and the dimensions of vulnerability. For example, tenure is considered to affect the ability to prepare due to the limited power of tenants to make changes to the property they live in. Yet, the literature also suggests that tenants' ability to recover may be hindered by the additional stress of dealing with landlords in the aftermath of flooding (Whittle et al., 2010). However, whilst the ability to prepare is similar for the majority of tenants, their recovery-phase situation can vary depending on the landlord's actions, and thus is more difficult to generalise.

3.2.1. Personal factors

Personal factors affecting the sensitivity of individuals to flooding include **age and health**. The impacts of floods on health are more likely to be felt by the old, the young, and those with pre-existing health problems. Older people tend to experience greater impacts from flood events. This includes higher rates of mortality due to drowning, hypothermia and heart problems (Green et al., 1994; Vardoulakis and Heaviside, 2012), and a potentially greater incidence of flood-related disease (for example, the gastro-intestinal infections associated with coming into contact with contaminated water (HPS, 2011), posing a risk in areas where sewage is mixed with flood water). Conditions such as dementia and Alzheimer's disease can affect how a person views the dangers associated with a flood and their behavioural responses (DEFRA, 2012).

Flooding has been associated with increased mental health and behavioural problems in children, as well as increases in the incidence of a range of diseases (Ahern et al., 2005; Norris et al., 2002). Cold or damp housing is known to increase the incidence of some minor illnesses and exacerbate the severity of others in children (Marmot Review, 2011). Both older people and children have been found to suffer considerable psychological trauma following flood events (Fernandez et al., 2002; Rygel et al., 2006; Tapsell et al., 2002).

For people in poor health, flooding may restrict an individual's access to medicine, e.g. due to loss or damage, and make it difficult to obtain appropriate medical attention in an emergency. Flood events can directly impact local medical services and also affect the wider community given that it may be necessary for hospitals to postpone routine or other non-urgent medical treatments. Vulnerability can be particularly high during flood events. For example, power-cuts can impact on life support equipment, such as oxygen generators or ventilators, or affect people's mobility given that they may be reliant on electric wheelchairs requiring recharging and/or access to lifts (Fernandez et al., 2002).

3.2.2. Social factors

One of the main social factors affecting vulnerability to flooding is related to **people's financial situation**. People on low incomes living in areas exposed to flooding may not be able to afford property level protection (PLP) measures (Bichard and Kazmierczak, 2012). They are also less likely to have home contents insurance (Tapsell et al., 2002). Also, lower skilled workers and those not in work were found to have lower awareness of being exposed to flooding than those in higher socio-economic groups (Fielding, 2012).

The rate of poverty tends to be higher among **renters** than homeowners, with social tenants having the lowest incomes (McInness, 2013). Thus, tenants tend to have fewer resources to invest in PLP measures, and either require the permission of property owners and managers to implement them or may be reluctant to fully or partly contribute to costs or to suffer the associated disruption of implementing flood resistance or resilience measures when they are living in a property that does not belong to them (ClimateJust, 2015).

Also, tenants are less likely to have home contents **insurance** compared to owner occupiers. The 2007 Scottish Household Survey found that 56% of local authority tenants and 50% of housing association, cooperative or private tenants had contents insurance, compared to 98% of owner-occupiers with a mortgage (Hayton et al., 2007). Buildings insurance is usually the responsibility of the owner, thus tenants are reliant on their landlord to ensure they live in a building which is appropriately insured (ClimateJust, 2015). As it is the occupiers who may bear most of the cost of flood damage, landlords are less motivated to invest in property-level resilience measures (ASC, 2011). Finally, private tenants may have less local knowledge as they tend to have shorter length of residence in an area compared to owner occupiers (DCLG, 2013).

People living in areas with a **high turnover of population** may be less aware of the likelihood of being affected by floods, how to respond and where to seek support. They may also lack social connections to friends and neighbours in the local community (Zsamboky et al., 2011) who can improve knowledge bases, and provide social support and a response network (Lindley et al., 2011). As a result, those without family and friends within their local area, especially the lower income groups, are the most likely to need to use public shelters in the event of evacuations (Scawthorn et al., 2006). Conversely, where social networks are relatively well-established there is evidence of a better response to emergency situations and quicker recovery (Preston et al., 2014). The World Health Organisation (WHO, 2013) identifies **poor social networks** as a vulnerability factor which is particularly associated with: older people, people in poor health or with disabilities, people reliant on social services for home care, people living alone, ethnic minorities, people who are homeless, people who are substance abusers and people living in rural areas. Isolated and housebound people (especially older people) may wait longer for help when service providers cannot reach them due to impassable roads affected by

floods (Fernandez et al., 2002). On the other hand, people with children at school age 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).

Other issues affecting the ability to prepare for, respond to, and recover after flooding include **the ability to understand information**, i.e. being literate (Cutter et al., 2003) and having knowledge of the official language (McGeehin and Mirabelli, 2001). Ability to respond is also influenced by **mobility**; for example, difficulties with balance or strength may mean that taking recommended flood measures is more challenging (Vardoulakis and Heaviside, 2012). Having access to a car, rather than relying on public transport and the general good connectivity of the area by roads, influences people's ability to respond to flood events quickly. Physical isolation presents a particular challenge for responding to floods, especially if critical transport infrastructure is also affected by the event. People working far away from home may also have limited capacity to assist others, move their belongings or deploy any property-level protection (PLP) measures at home, such as door guards, in the case of rapid onset events like surface water flooding (ClimateJust, 2015). Also, the deployment of door guards as a precautionary measure when a person leaves home, may be affected by the **fear of crime** and the anxiety that they could indicate that the residents are away (Douglas et al., 2010).

3.2.3. Environmental factors

The physical characteristics of the neighbourhood can affect the extent to which people are impacted by a flood event. Increased "**surface sealing"** by roofs, roads, car parks, walkways and paved-over gardens reduces the ability of drainage systems to remove runoff created during intense rainfall events or as a result of flooding. Where water cannot be absorbed into the ground because of built surfaces, it forms surface runoff, which is then channelled into any drainage system. If the rates of rainfall and subsequent runoff are higher than the capacity of the drainage system it can cause surface water flooding (ClimateJust, 2015). Conversely, the presence of vegetation reduces surface runoff and thus can support the reduction of the risk of flooding (Armson et al., 2013).

The type of housing also plays a role in mitigating the effect of flooding on people. Houses with the **lowest floor at or below ground level** are more exposed than dwellings located on higher floors, and occupants and their belongings may be more significantly affected by a flood event (Thieken et al., 2005). Single level properties favoured by older people and constructed as retirement developments (Pannell and Blood, 2012), may mean that older people living in such houses are disproportionately affected by flooding (nowhere to move their belongings to protect them from flood water; remaining on the floor affected by the flood water in the aftermath of flooding). Also, solid masonry buildings can withstand flooding without suffering major structural

damage, whilst lightweight constructions – in particular **mobile or temporary structures** - may be more easily damaged (Sanders and Phillipson, 2003). In addition, these lightweight and temporary structures also tend to be occupied by people on lower incomes (Benzie et al., 2011).

3.2.4. Indicators of social vulnerability to flooding

As the evidence above indicates, the personal, social and environmental factors affecting vulnerability to flooding are strongly interconnected. It is extremely challenging to identify with full certainty the indicators or proxies that would reflect the complexity of the problems of social vulnerability to flooding emerging from the literature. Therefore, in order to ensure that vulnerability to flooding is represented adequately, stakeholder input was sought in defining the list of indicators in an iterative process. The organisations involved included the Scottish Government, SEPA, JRF, local authorities in Scotland and the National Flood Forum. Table 2 presents the list of indicators used in the assessment of social vulnerability to flooding.

The assessment of social vulnerability to flooding and flood disadvantage presented in this report is based on a quantitative geospatial assessment. Therefore, the values of the indicators were obtained for census units – data zones. Scottish census 2001 data zones were used, since the majority of the data underpinning the assessment has been reported for these census units. Data zones are compact areas with around 500-1,000 residents that contain households with similar social characteristics (SG ATOM Feed, 2014).

Social vulnerability to flooding and flood disadvantage are assessed at the data zone level. In this report data zones are also referred to as neighbourhoods.

3.2.5. Developing the index of social vulnerability to flooding

In order to add all of the indicators together, the indicators were standardised, which means presenting all the indicators on a uniform scale. Z-score standardisation was used. Then, the indicators were equally weighted within each of the thematic domains (Table 2) they were assigned to. This was done to avoid over-representing the domains with a larger number of indicators. The weighted indicators were added together to develop the dimensions of sensitivity, exposure, and ability to prepare, respond and recover. The dimensions of sensitivity, exposure, and ability to prepare, respond and recover were standardised and summed to form the vulnerability index. The vulnerability index was then standardised. The methodology document provides more details on the procedure.

Table 2. Indicators used in the assessment of social vulnerability to flooding.

Domain	Indicator
Age	% people under 5 years old [1]
	% people over 75 years old [1]
Health	% people whose day-to-day activities are limited [1]
	% households with at least one person with long term limiting illness [1]
Income	% people in routine or semi-routine occupations [1]
	% of people who are long term unemployed or who have never worked [1]
	% households with dependent children and no adults in employment [1]
	Number of Income Support claimants [2]
	Number of Job seeker allowance claimants [2]
	Total pension credit claimants [2]
	Total number of families receiving tax credits (WTC and CTC) [2]
Information use	% people with <1 year residency in the UK [1]
	% people who do not speak English/no not speak English well [1]
Insurance	% new addresses (01.01.2009) in flood risk areas (insurance availability) [3]
	Number of historic flood events (insurance cost) [4]
Local knowledge	% addresses in Flood Warning Target Areas [5]
	% new residents (< 1 year) arriving from outside the local area [1]
Tenure	% social rented households [1]
	% private rented households [1]
Mobility	% of Incapacity Benefit/Severe Disablement allowance claimants [2]
	% people living in medical and care establishments [1]
	% households with no car or van [1]
Social networks	% children of primary school age [1]
	Number of voluntary organisations focused on local community [6]
	% single pensioner households [1]
Physical access	% people working further than 30km from home [1]
	Low road density [7]
Crime	Number of domestic break-ins [2]
Access to services	Travel time to GP surgery (private transport) [2]
	Travel time to GP surgery (public transport) [2]
Housing Characteristics	% households with the lowest floor level: ground floor [8]
	% households with the lowest floor level: basement or semi-basement [8]
	% caravan or other mobile or temporary structures in all households [1]
Physical environment	% urban land cover [9]

Sources of data: 1 - Scottish census 2011; 2 - Scottish Neighbourhood Statistics; 3 -OS AddressBase and SEPA flood extents; 4 - SEPA Historic Flood Data; 5 - SEPA Flood Warning Target Areas and OS AddressBase; 6 - Scottish Charity Register; 7 - OS MasterMap Integrated Transport Network Layer; 8 - Scottish census 2001; 9 - Land Cover Map 2007

The index of social vulnerability to flooding has been categorised into six classes (Table 3). The negative values of the index indicate lower than the average social vulnerability to flooding. The higher the positive values, the higher the social vulnerability to flooding; the highest values of the index are in the 'acute' category. The values oscillating around zero are near the national average. The same categories have been used for flood disadvantage.

Table 3. Classes of social vulnerability to flooding and flood disadvantage

Value of the standardised index	Level of vulnerability / disadvantage
≥ 2.5	Acute
1.5 – 2.5	Extremely high
0.5 – 1.5	Relatively high
-0.5 – 0.5	Average
-1.5 – -0.5	Relatively low
-2.5 – -1.5	Extremely low

3.3. Flood hazard-exposure

Three types of flooding were considered in this assessment: coastal, river, and surface water flooding. SEPA provided flood maps for each source of flooding for different return periods (Table 4) in consultation with the project's steering group. These flood hazard maps were developed with nationally applied methodologies. Further information about the datasets is provided in the methodology document.

The flood return periods were chosen to reflect a range of flood event probabilities. They included:

- 1 in 25 years (coastal) and 1 in 30 years (river and surface water). In this report they are referred to as 'high probability';
- 1 in 200 years (all types of flooding), referred to as 'medium probability';
- 1 in 200 years (all types of flooding) which incorporates climate change projections, referred to as 'low probability' events. Considering this return period allows incorporating a future perspective.

The highest likelihood scenario considered by SEPA, 1 in 10 years return period, was not used due to considerable levels of uncertainty associated with its spatial extent in some locations. The 1 in 1000 years return periods were not considered as these events are extremely rare.

The defended extents were used where available in order to take the presence of flood defences into consideration[4]. For surface water flooding, a relatively low

[4] Defended extents were not available for surface water flooding and the low probability scenarios for river and coastal flooding.

depth of 0.1 metres was considered, since even shallow water can cause significant damages and repair costs, thus making it difficult for people to recover after flooding (Kazmierczak and Cavan, 2011).

Table 4. Flood maps used (SEPA, version 1.1, March 2015).

Type of flooding	Return period	Description	Code used in tables and figures
Coastal	1 in 25 year defended	A flood event is likely to occur in the defined area on average once in every 25 years (1:25). Or a 4% chance of happening in any one year.	C25
	1 in 200 year defended	A flood event is likely to occur in the defined area on average once in every two hundred years (1:200). Or a 0.5% chance of happening in any one year.	C200
	1 in 200 year: climate change 2080H	A flood event is likely to occur in the defined area in the 2080s (2070-2099) on average once in every two hundred years (1:200). Or a 0.5% chance of happening in any one year.	C200+cc
River	1 in 30 year defended	A flood event is likely to occur in the defined area on average once in every 30 years (1:30). Or a 3.3% chance of happening in any one year.	R30
	1 in 200 year defended	A flood event is likely to occur in the defined area on average once in every two hundred years (1:200). Or a 0.5% chance of happening in any one year	R200
	1 in 200 year defended: climate change 2080H	A flood event is likely to occur in the defined area in the 2080s (2070-2099) on average once in every two hundred years (1:200). Or a 0.5% chance of happening in any one year.	R200+cc
Surface water	1 in 30 year	A flood event is likely to occur in the defined area on average once in every 30 years (1:30). Or a 3.3% chance of happening in any one year.	S30
	1 in 200 year	A flood event is likely to occur in the defined area on average once in every two hundred years (1:200). Or a 0.5% chance of happening in any one year.	S200
	1 in 200 year: climate change 2080H	A flood event is likely to occur in the defined area in the 2080s (2070-2099) on average once in every two hundred years (1:200). Or a 0.5% chance of happening in any one year.	S200+cc

The index of flood hazard-exposure represents the percentage of residential addresses exposed to flooding in each data zone. Residential addresses were obtained from Ordnance Survey AddressBase, supplied by the Scottish Government (version: 11 April 2015); therefore, as previously noted, this assessment is different to the NFRA, which also considered flood risk to commercial properties. The residential addresses were spatially overlaid with the flood extents listed in Table 4 and the proportion located in flood risk area was calculated for each data zone.

In principle, SEPA's flood extents should not be used to determine the risk associated with individual properties as they have been developed for strategic national mapping and broad scale analysis. However, this study aggregated the number of individual properties within the flood extents first to the data zone level and then to the local authority level. The metric representing the proportion of address points that may be at risk of flooding in a data zone was considered as more representative of the actual levels of exposure than the proportion of the land surface of the neighbourhood potentially affected by flooding. This is because a data zone may have a large land area potentially affected by flooding but this land area may not be associated with housing. The same approach is taken by SEPA for the strategic appraisal process and it has also recently been used by JBA Consulting (2014) in a study of the PLPs.

The percentage of residential address points within each flood extent, and in all the extents combined (any flooding) was calculated for each data zone. For each of the flood extents separately, and for all data zones, the percentage of address points exposed to flooding was standardised to develop the hazard-exposure indicator.

3.4. Developing the flood disadvantage index

The flood hazard-exposure indicator for each of the flood types and return periods (as well as for the flood map combining any type of flooding of low probability) was added to the standardised index of social vulnerability to flooding in order to calculate the flood disadvantage indices. These were then standardised and categorised using the classes presented in Table 3.

Consequently, for each of the 10 flood extents considered, the disadvantage index compares the values in data zones to the average Scottish disadvantage for each particular flood extent. Therefore, each of the disadvantage indices are presented on a slightly different scale. As a result, whilst some areas may for example have relatively high disadvantage with regards to 'any type of flooding', for some of the flood types and return periods the disadvantage may be extremely high or average. The users are advised to investigate the values of flood-hazard indicators and vulnerability in the data spreadsheet in more detail (also, see the case study section).

This methodology addresses some of the shortcomings highlighted by the previous report (Lindley and O'Neill, 2013). Firstly, the defended flood outlines are used in order to represent the risk of flooding taking into consideration the presence of flood defences. Secondly, surface water flooding as a substantial flood risk is included in the analysis alongside flooding from the rivers and the sea. Further, the list of vulnerability indicators has been modified to take into account new data that more accurately reflects the diverse aspects of social vulnerability to flooding and the most up-to date sources of information have been used including census 2011 data (see Appendix 1). The details of the modifications to the methodology can be found in the methodology document. The assessment methodology still has some limitations, which relate to the aggregation of households at data zone level, data paucity e.g. for certain vulnerable groups and enhanced exposure, and no consideration of potential PLP. These are discussed in more detail in section 5.3.

4. Results

This section reports the results of the assessment of flood disadvantage in Scotland. Section 4.1 presents the results of investigating the exposure of residential properties to different types of flooding in Scotland, aggregated to data zones and local authorities. Section 4.2 provides the outcomes of the assessment of social vulnerability to flooding. In section 4.3, the flood disadvantage in relation to different types and return periods of flooding is analysed. In section 4.4, the geography of social vulnerability to flooding and flood disadvantage is explored with regard to urban-rural classification of the data zones and their proximity to the coast. Section 4.5 discusses the results against the PVAs identified in NFRA. Finally, section 4.6 presents the three local authority case studies.

4.1. Exposure of residential properties to flooding in Scotland

In total, over 4% of residential properties in Scotland (just over 108,000) are estimated to be exposed to one or more sources of flooding of low probability (Table 5). River flooding affects the greatest number of residential properties, followed by coastal and surface water flooding.

Table 5. Exposure of data zones and residential addresses to flooding

Flood type and return period	Number of data zones exposed [1]	% data zones exposed	% residential addresses exposed
C25	286	4.4	0.4
C200	375	5.8	0.5
C200+cc	552	8.6	1.2
R30	1327	21.2	1.0
R200	1619	25.0	1.9
R200+cc	1821	27.8	2.9
S30	1431	22.1	0.3
S200	1924	29.7	0.6
S200+cc	2043	31.5	0.7
Any 200+cc[2]	**3166**	**48.7**	**4.4**

[1] Considering the 6500 data zones identified to contain population on the day of the 2011 census
[2] These figures refer to the percentage of neighbourhoods which are exposed to *any* flood type, whether it is coastal, river or surface water (or any combination) at 1:200 years including climate change return period.

Nearly half of all data zones in Scotland contain residential properties which may be exposed to any type of flooding of 1 in 200 years return period, considering the impacts of climate change (Table 5). Surface water flooding at low probability affects the greatest number of data zones, indicating the widespread character of surface water flooding, compared to the lower number of data zones exposed to river and coastal flooding.

Figure 2 presents the spatial distribution of flood hazard-exposure (all types of flooding combined; the largest extents considered). The highest concentration of residential properties at risk of any type of flooding is present in Falkirk[5] and Stirling, followed by Scottish Borders, Orkney Islands and West Dunbartonshire (Figure 3).

Figure 4, Figure 5 and Figure 6 present the percentage of residential properties exposed to river, coastal and surface water flooding at different probability levels. Falkirk, Orkney Islands and West Dunbartonshire have the highest proportion of residential properties exposed to coastal flooding. Stirling, Scottish Borders, and Perth and Kinross and Moray have the highest proportion of residential properties exposed to river flooding, whilst surface water flooding may affect the highest proportion of residential properties in Aberdeen City, Highland and Moray, followed by Renfrewshire and Falkirk.

[5] All references to local authorities in this report pertain to the entire area of a local authority.

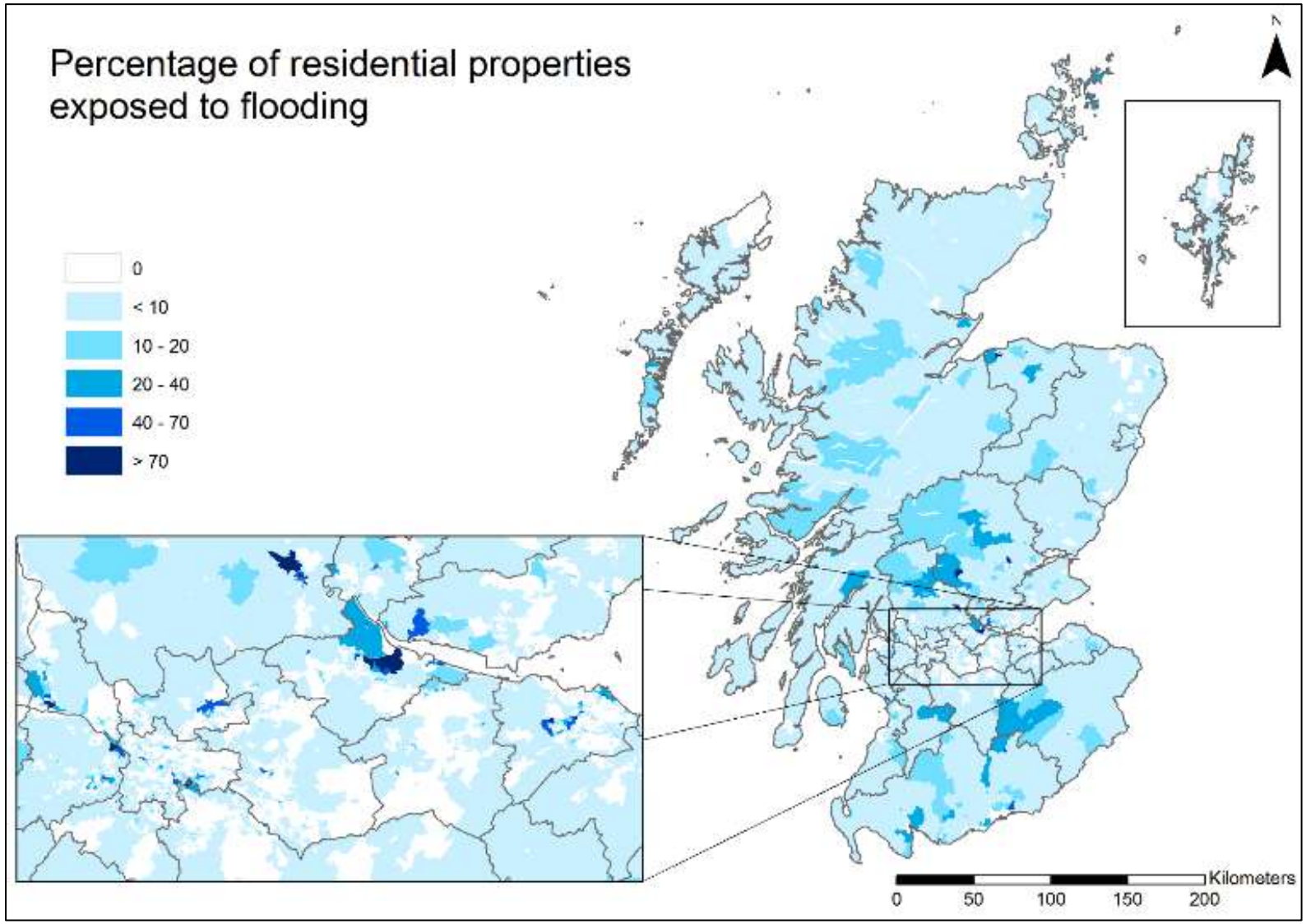

Figure 2. Percentage of residential properties exposed to any type of flooding (1:200+cc). Base map is Ordnance Survey data © Crown Copyright and database right 2015. Derived from OS AddressBase and SEPA data.

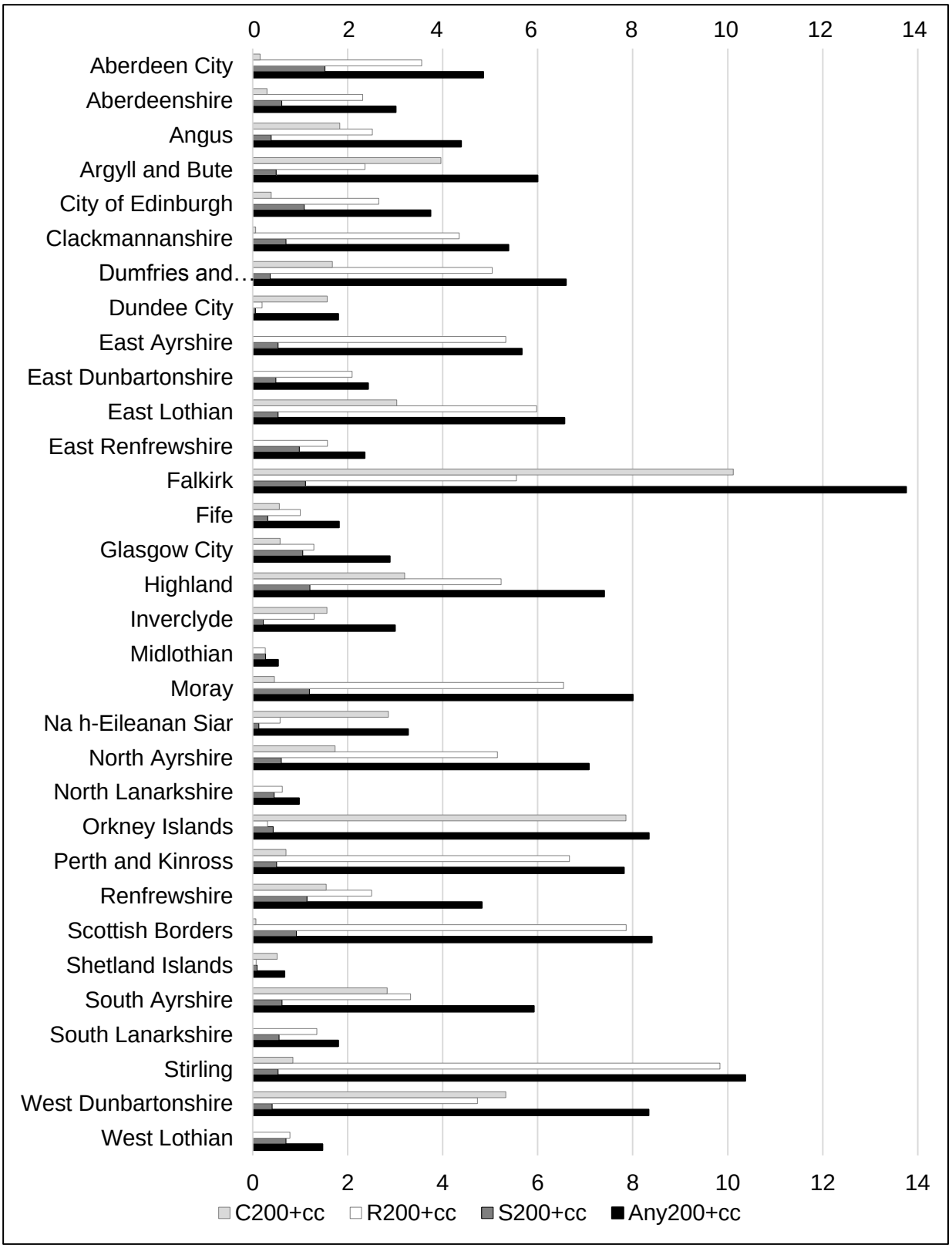

Figure 3. Percentage of residential properties in local authorities exposed to flooding[6].

[6] Where no bars are present, no residential properties are at risk from a given type of flooding.

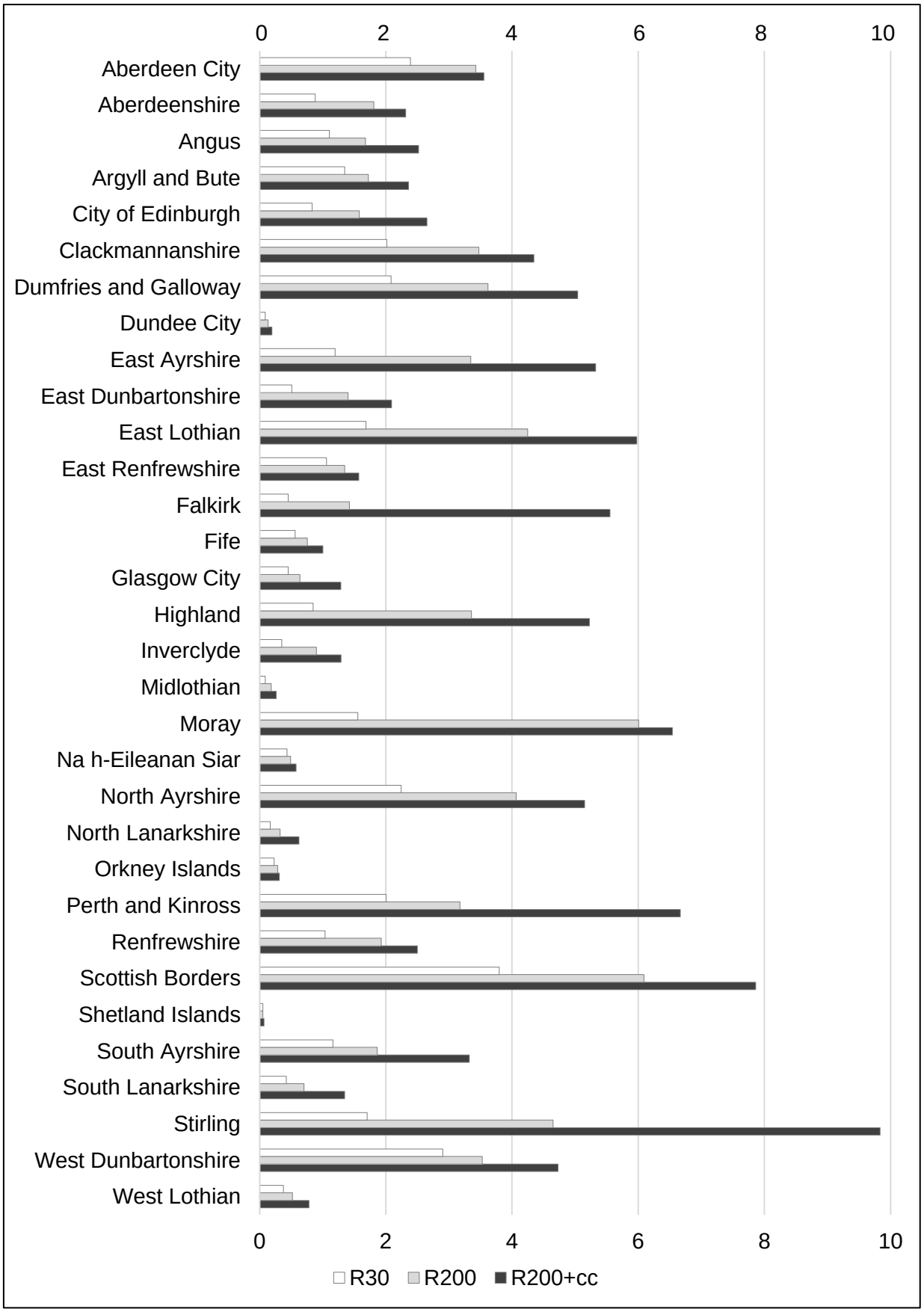

Figure 4. Percentage of residential properties in local authorities exposed to **river flooding**.

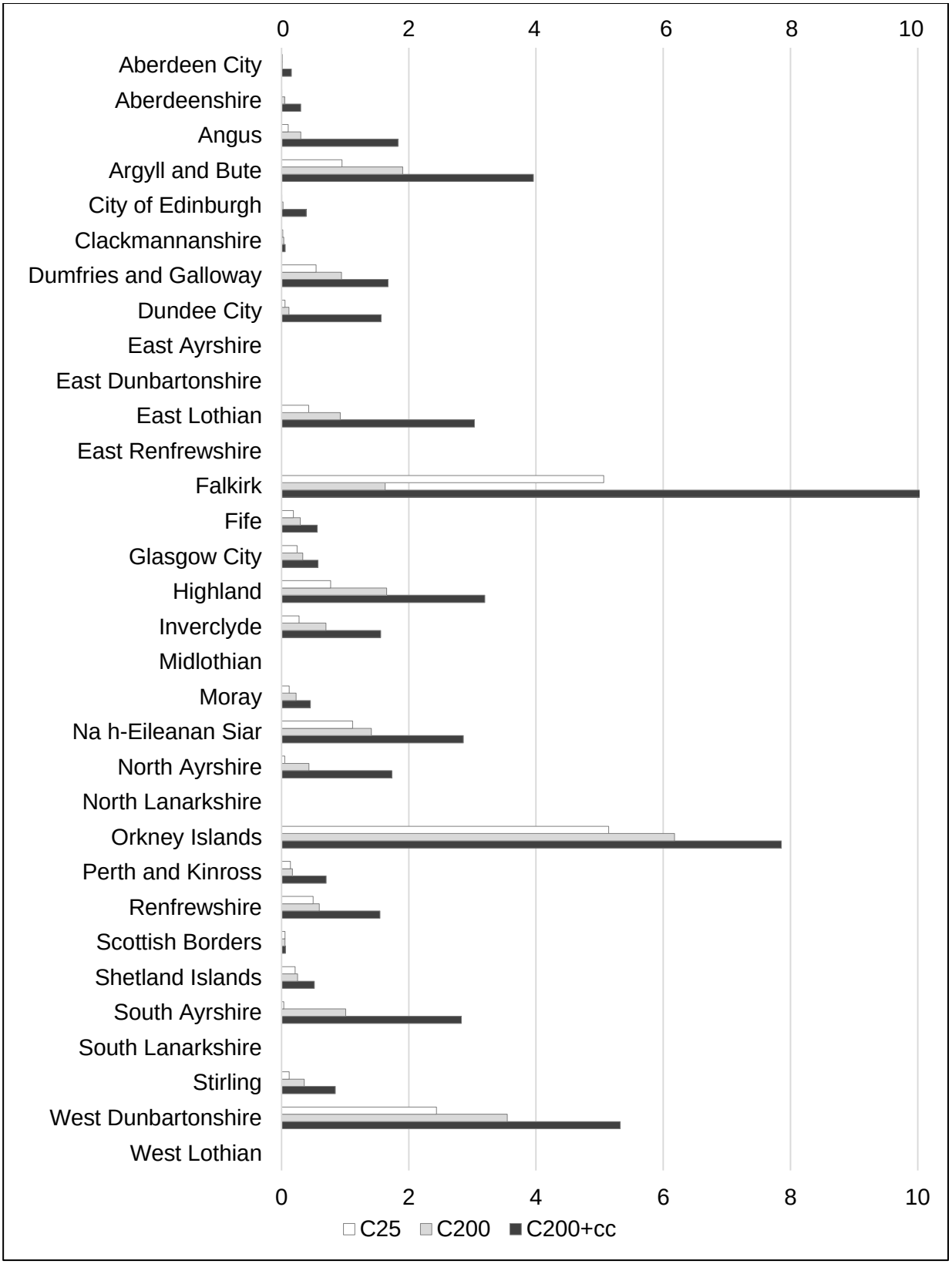

Figure 5. Percentage of residential properties in local authorities exposed to **coastal flooding**.[7]

[7] Where no bars are present, no residential properties are exposed to coastal flooding.

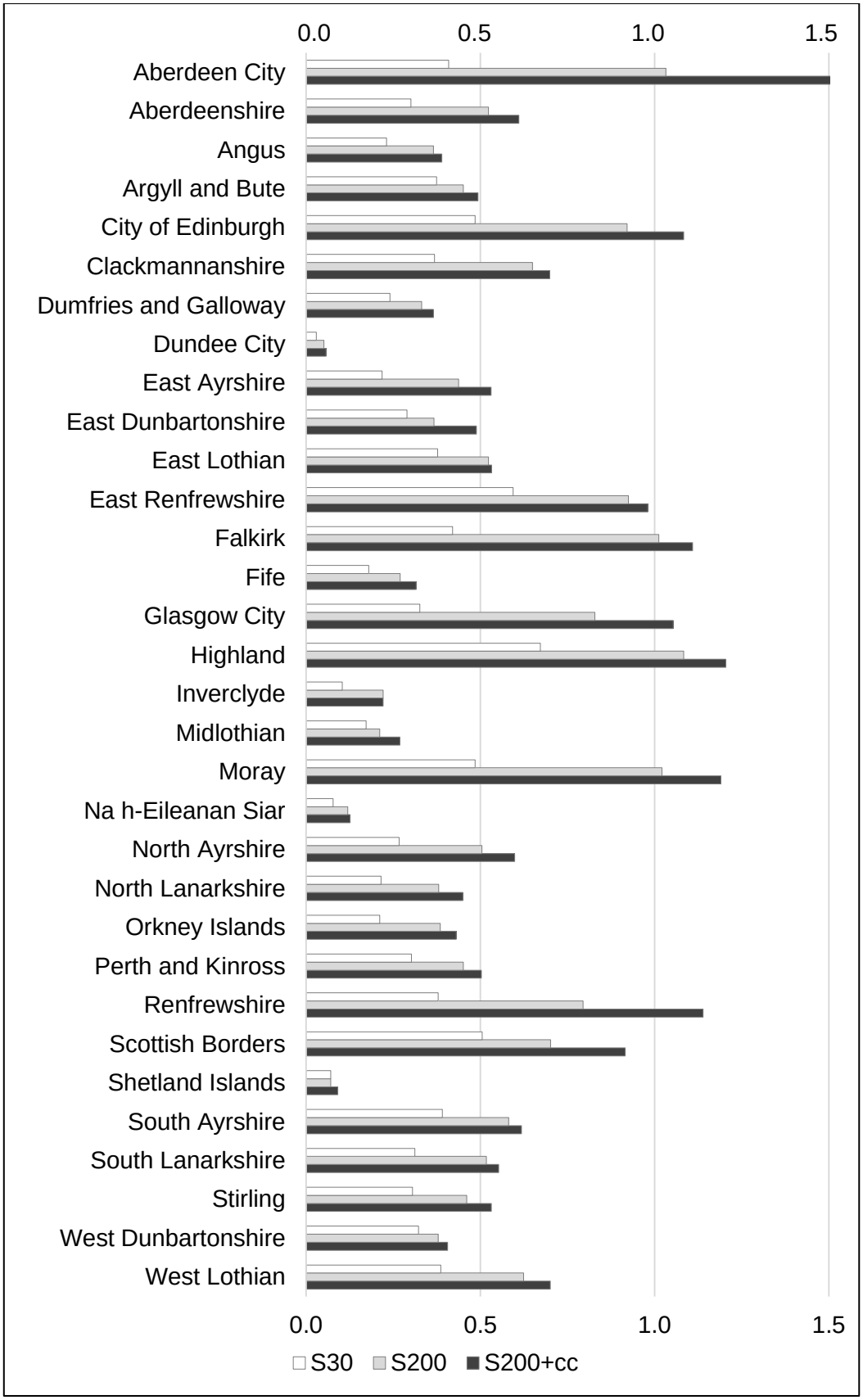

Figure 6. Percentage of residential properties in local authorities exposed to **surface water flooding**.

4.1.1. Recently constructed properties exposed to flooding

The Statement of Principles, the agreement currently in place between the Association of British Insurers (ABI) and the Scottish Government (2008), ensures that insurance is available to many previously flooded or at-risk customers. The ABI proposed a new scheme to safeguard the availability and affordability of flood insurance for those at high risk, called Flood Re. While this scheme is being developed, ABI members voluntarily continue to meet their commitments to their existing customers under the old Statement of Principles agreement. However, this commitment does not apply to any new property built after 1 January 2009 in order to discourage the development of properties on flood plains. Therefore, some of these properties may not be insured.

The extent of residential properties built or re-developed after 1st January 2009 that are exposed to flooding was therefore of interest, and was estimated from available data. Since no alternative data was available, residential addresses with a 'start date' on or after 1st January 2009 were identified in the OS AddressBase dataset.

It should be noted that this assessment is exploratory in character and therefore has a number of caveats including:

- Significant uncertainty on the property dataset used;
- The paucity of data on detailed flood risk assessments and management of coastal and surface water flooding around the property which may enable development that is appropriate within the context of Scottish planning policy; and,
- An absence of information on the property lowest floor level and any PLP present.

As such, it might only be concluded that, of around 100,000 properties noted in the database with a start date on or after 1 January 2009, a very small proportion (single-digit percentage) could potentially be located in areas affected by flooding. Further investigation is required to better understand such development, including the nature of the property dataset (to validate the records relating to new development) and into the supporting information that may enable appropriate development in line with Scottish planning policy. This is being further investigated by a number of ongoing projects (see section 5.2).

4.2. Social vulnerability to flooding in Scotland

A third of the neighbourhoods in Scotland have below average social vulnerability to flooding (table 6). Just below 8% of the data zones are classified as having an extremely high or acute vulnerability to flooding. These are mainly located within large Scottish cities, with Glasgow containing 191 such data zones, Edinburgh - 82; Dundee - 44 and Aberdeen - 27. Figure 7 presents the number of neighbourhoods with above average social vulnerability to flooding

per local authority. Section 4.6 provides more detailed information for case study local authorities (Dumfries and Galloway, Dundee City and Scottish Borders). Figure 8 presents the spatial distribution of social vulnerability to flooding in Scotland.

Table 6. Data zones of different levels of social vulnerability to flooding

Vulnerability	Number of data zones	Percentage of data zones
Extremely low	262	4.0
Relatively low	1881	28.9
Average	2620	40.3
Relatively high	1226	18.9
Extremely high	399	6.1
Acute	112	1.7

However, not all data zones classed as extremely or acutely vulnerable are likely to be exposed to flooding (see section 4.1). In fact, just under half of them are exposed to flooding. This means that disadvantage to flooding is only likely to occur in a small number of neighbourhoods. This is explored in the next section.

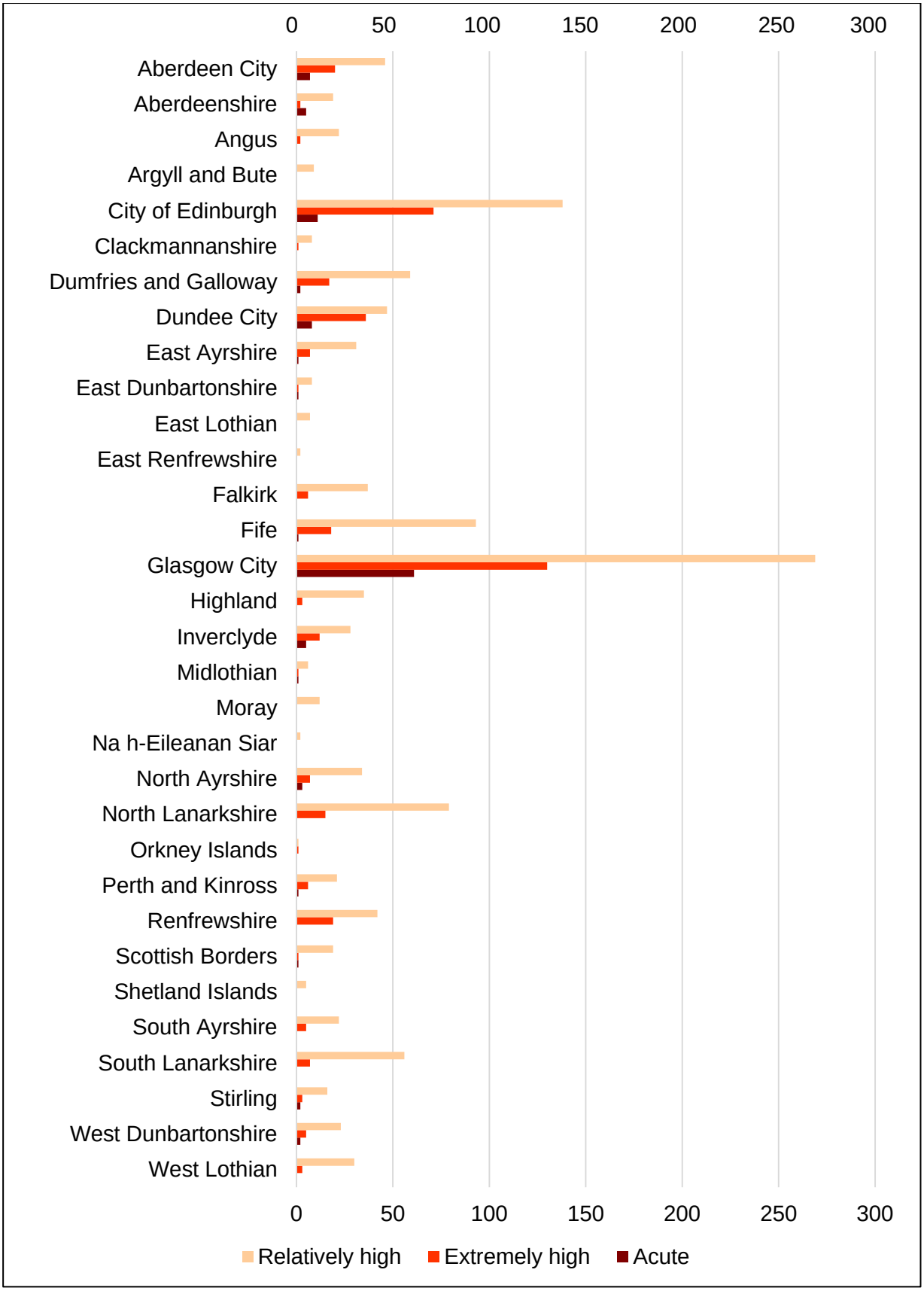

Figure 7. Number of data zones classified as having above average social vulnerability to flooding in local authorities.

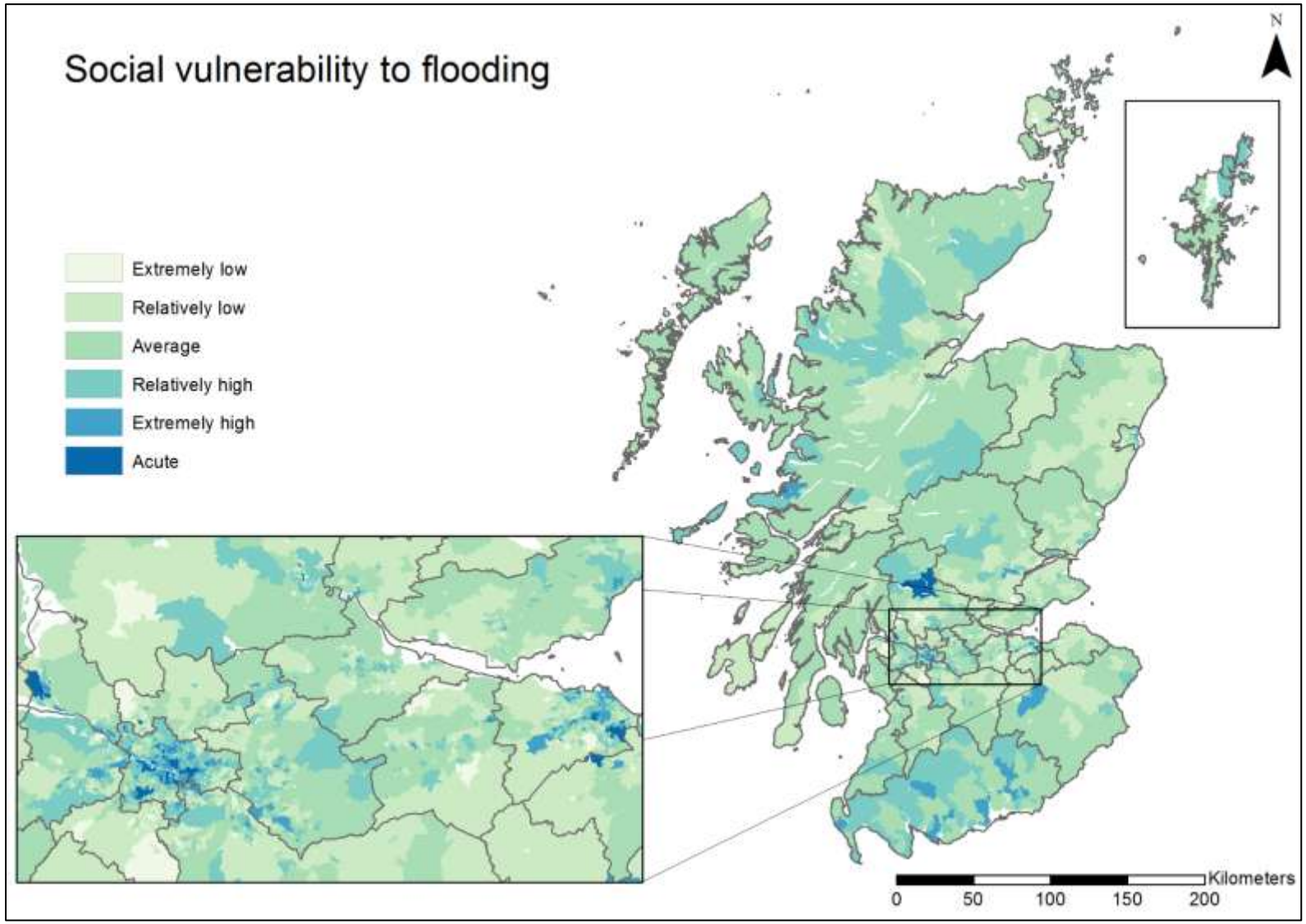

Figure 8. Social vulnerability to flooding in Scotland. Base map is Ordnance Survey data © Crown Copyright and database right 2015. Data sources used in developing the social vulnerability to flooding index are listed in Table 2.

4.3. Flood disadvantage in Scotland

Flood disadvantage occurs where high levels of social vulnerability to flooding coincide spatially with high level of hazard-exposure, i.e. areas where a high percentage of residential properties are exposed to flooding.

Flood disadvantage has been categorised into six classes (Table 3), where negative values indicate lower than average flood disadvantage. The higher the positive values, the higher the flood disadvantage; the highest values of the index are in the ‘acute’ category. The values close to zero are near the national average.

Flood disadvantage has only been calculated for the data zones exposed to a given type of flooding (see Table 4). Table 7 summarises the levels of flood disadvantage in Scotland with regard to different types of flooding. Figure 9 presents the spatial distribution of flood disadvantage in Scotland with regard to all types of flooding combined; the data zones not exposed to any type of flooding are shaded out in grey.

The next sections focus on the extreme and acute flood disadvantage (see Table 7) and its distribution among local authorities. The data zones where high social vulnerability to flooding coincides with high exposure to flooding should be prioritised for action to protect the most vulnerable communities from the impacts of flooding.

Table 7. Levels of flood disadvantage in Scotland

Flood type and return period	Number of data zones of varying level of flood disadvantage							% of extremely or acutely disadvantaged data zones	
	Acute	Extremely high	Relatively high	Average	Relatively low	Extremely low	Not exposed	Of all data zones	of data zones exposed to flooding
C25	11	13	33	134	95	0	6214	0.4	5.3
C200	12	18	54	162	129	0	6125	0.5	8.0
C200+cc	16	35	79	228	194	0	5948	0.8	9.2
R30	38	55	181	634	460	4	5128	1.4	6.8
R200	53	70	213	720	561	2	4881	1.9	6.8
R200+cc	55	78	264	780	638	6	4679	2.0	7.2
S30	27	57	192	718	433	4	5069	1.3	5.9
S200	42	72	278	899	623	10	4576	1.8	5.9
S200+cc	47	84	296	941	663	12	4457	2.0	6.4
Any 200+cc	98	138	444	1411	1055	20	3334	3.6	7.4

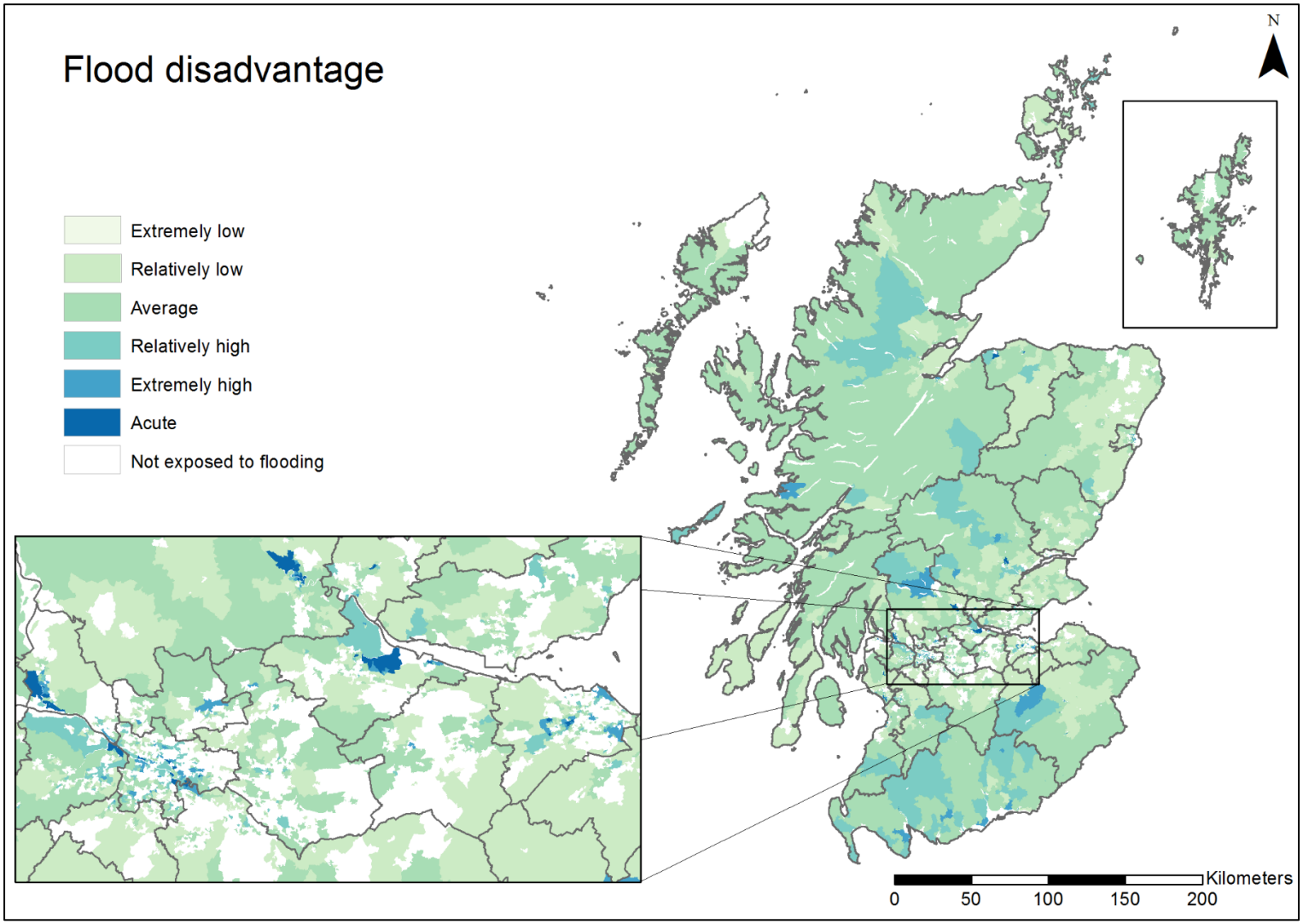

Figure 9. Flood disadvantage in Scotland (any flood source 1:200+cc). Base map is Ordnance Survey data © Crown Copyright and database right 2015. Derived from OS AddressBase, SEPA data and data sources listed in Table 2.

4.3.1. Extreme flood disadvantage - any type of flooding

With regard to any type of flooding, with the widest spatial extent considered, 236 neighbourhoods (3.6% of all data zones or 7.4% of those exposed to flooding) can be classified as extremely (138) or acutely (98) disadvantaged[8].

Figure 10 presents the number of extremely and acutely flood disadvantaged neighbourhoods with regard to any type of flooding per local authority. Four local authorities (Na h-Eileanan Siar, Fife, Midlothian and Shetland Islands) contain no data zones that would be extremely or acutely disadvantaged with regard to flooding and hence are not presented in figure 10. However, whilst the assessment at the data zone level shows no extreme disadvantage, individual households and people may still be vulnerable and exposed to flooding. Therefore, these local authorities should not be exempt from local assessment of flood risk.

The highest number of neighbourhoods with acute flood disadvantage are present in Falkirk, Glasgow, North Ayrshire and Stirling. Extremely high flood disadvantage is present mainly in Glasgow and Edinburgh, followed by Dumfries and Galloway.

The next sections look in more detail at levels of flood disadvantage in individual local authorities with regard to coastal, river and surface water flooding at different return periods. As highlighted in section 3.4, the disadvantage index has been calculated for each of the flood types and return periods separately, therefore whilst some of the local authorities do not contain acutely/extremely disadvantaged data zones in relation to 'any type of flooding', they may contain high levels of disadvantage with regard to individual flood types and return periods (for example, Fife).

Firstly, the number of extremely and acutely flood-disadvantaged neighbourhoods in all local authorities is presented. Secondly, the number of data zones is shown as a percentage of extremely and acutely flood-disadvantaged data zones in Scotland, therefore showing the relative contribution of the local authority to the overall flood disadvantage in Scotland.

[8] 'Acute disadvantage' refers to standardised disadvantage index values that are larger than the mean (Scottish average) value by more than 2.5 standard deviations. 'Extremely high disadvantage' relates to standardised disadvantage index values larger than the mean (Scottish average) value by between 1.5 and 2.5 standard deviations (see also Table 3).

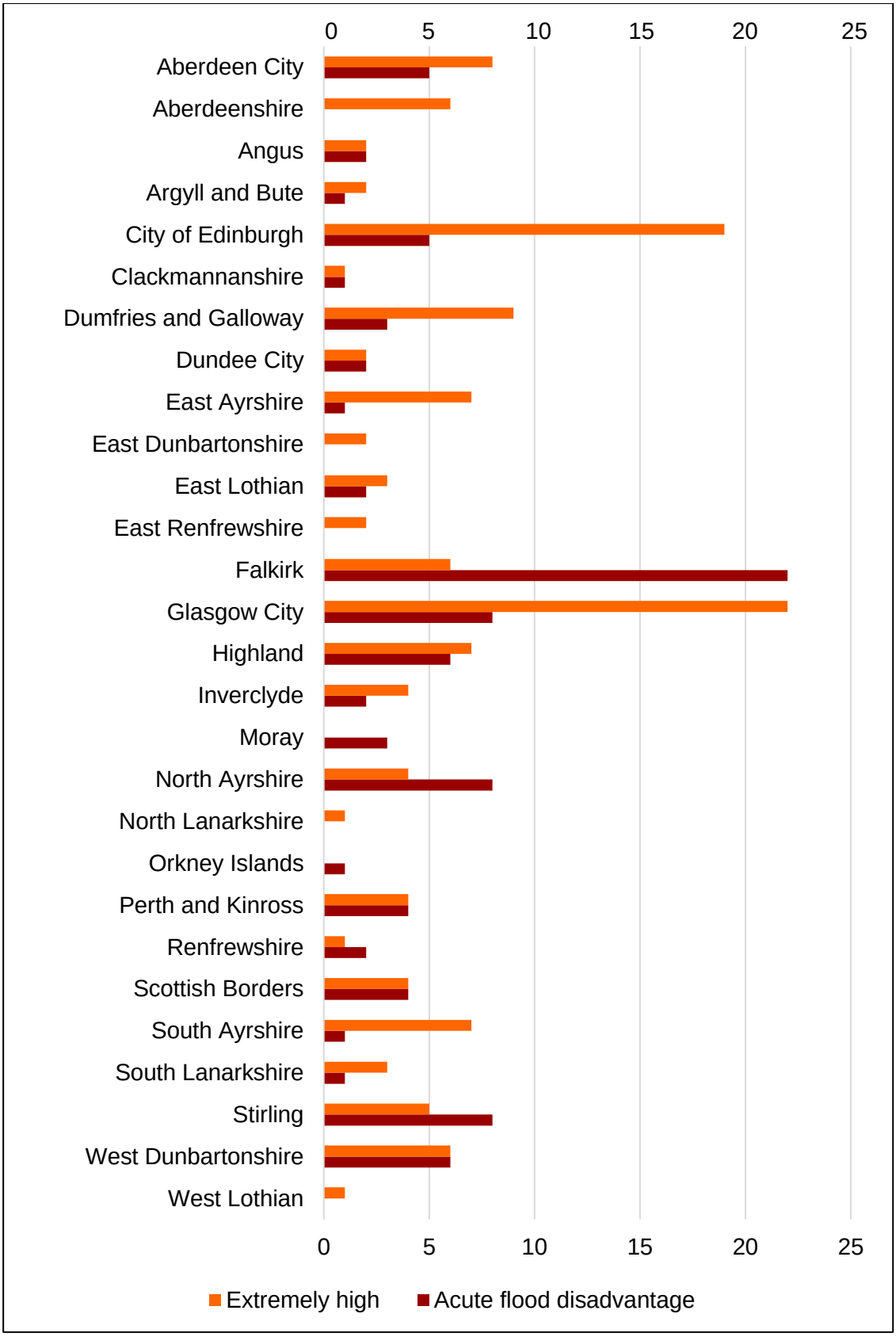

Figure 10. Number of data zones classified as acutely or extremely disadvantaged (any type of flooding, 1:200+cc) per local authority.

4.3.2. Extreme flood disadvantage - coastal flooding

With regard to coastal flooding, fifteen local authorities contain extremely and acutely disadvantaged data zones[9]. Falkirk, West Dunbartonshire and Orkney Islands have the highest percentage of data zones classified as extremely disadvantaged (Figure 11). Falkirk, West Dunbartonshire, Highland and Dumfries and Galloway contribute the highest proportion of extremely/acutely flood disadvantaged data zones in relation to Scotland as a whole (Figure 12).

4.3.3. Extreme flood disadvantage - river flooding

Considering river flooding, 26 local authorities contain extremely or acutely disadvantaged neighbourhoods. Aberdeen and Scottish Borders have the highest percentage of extremely/acutely disadvantaged neighbourhoods with regard to high probability (1:30) river flooding. Stirling, Moray, Scottish Borders and Aberdeen have the highest percentage of extremely/acutely disadvantaged neighbourhoods with regard to medium probability (1:200) river flooding. When the low probability (1:200+cc) river flood events are considered, Stirling, Scottish Borders and East Ayrshire have the highest percentage of extremely/acutely disadvantaged neighbourhoods (Figure 13).

Aberdeen City contains 16% of the extremely/acutely disadvantaged neighbourhoods in Scotland for the high probability (1:30) river flooding. It is followed by Glasgow, Dumfries and Galloway and North Ayrshire. When the medium probability of river flood events (1:200) is considered, Aberdeen City, Glasgow and Edinburgh contain over a quarter of extremely/acutely disadvantaged neighbourhoods in Scotland. When the low probability (1:200+cc) flooding is considered, the acute and extreme flood disadvantage concentrates in Edinburgh, Stirling and Highland, followed by Falkirk and Aberdeen (Figure 14).

4.3.4. Extreme flood disadvantage - surface water flooding

Six local authorities do not contain any neighbourhoods that are extremely/acutely disadvantaged with regard to surface water flooding (Dundee City, East Lothian, Midlothian, Moray, Na h-Eileanan Siar and Shetland Islands).

Glasgow, Aberdeen, Falkirk and Orkney Islands (Figure 15) have the highest percentage of extremely/acutely flood disadvantaged data zones at all return periods[10]. When the contribution of individual local authorities to the overall number of extremely/acutely disadvantaged neighbourhoods in Scotland is considered, Glasgow presents the highest concentration of flood disadvantage

[9] Local authorities not containing extremely or acutely disadvantaged data zones are not presented in the figures.

[10] Some inconsistencies in SEPA flood map data mean that no extremely/acutely disadvantaged data zones have been identified in Orkney Islands for high probability surface water flooding. The flood maps are currently being improved by SEPA.

with a third of the extremely disadvantaged neighbourhoods being located there (Figure 16). This is followed by City of Edinburgh and Aberdeen City.

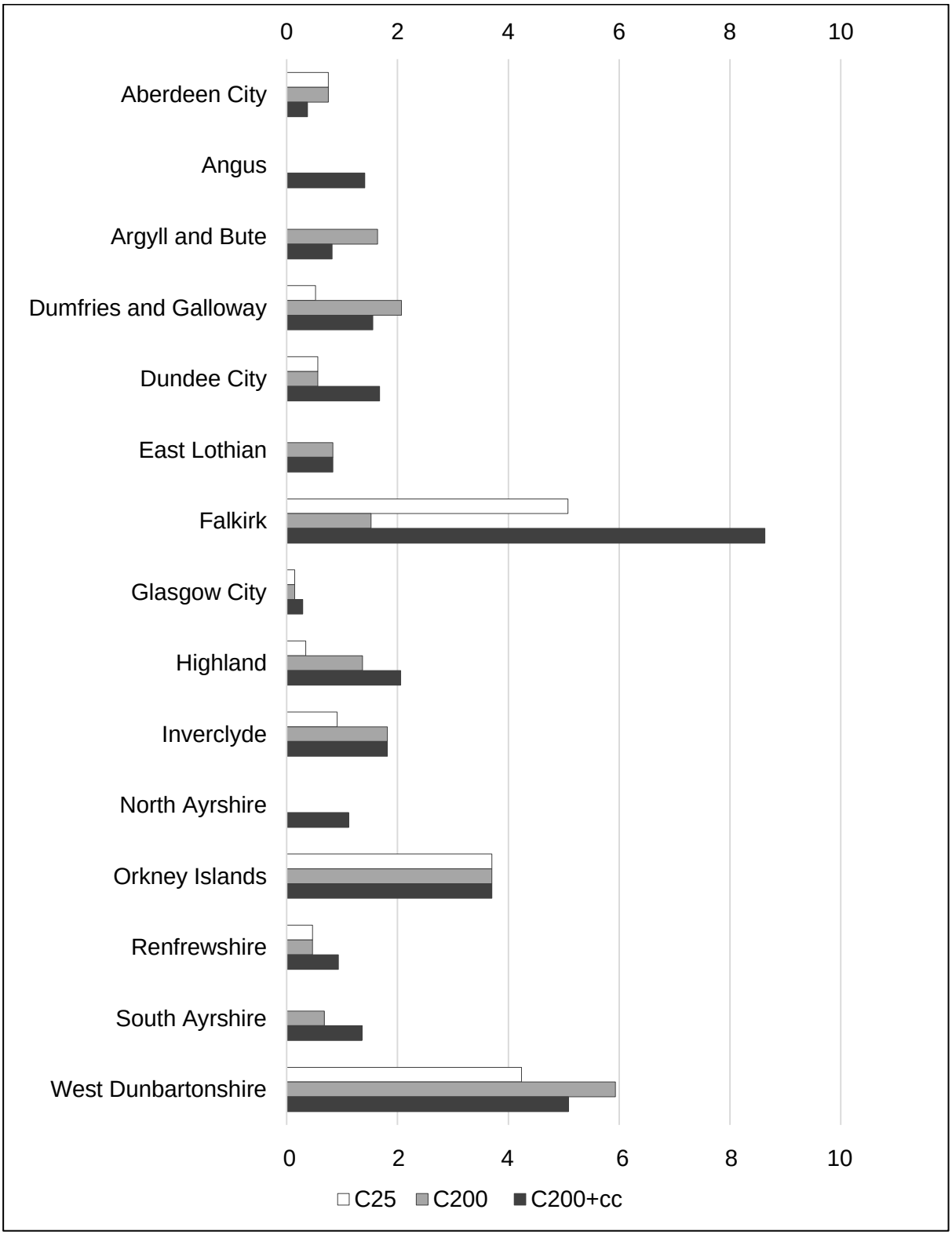

Figure 11. Percentage of data zones classed as extremely or acutely flood disadvantaged with regard to **coastal flooding** in local authorities.

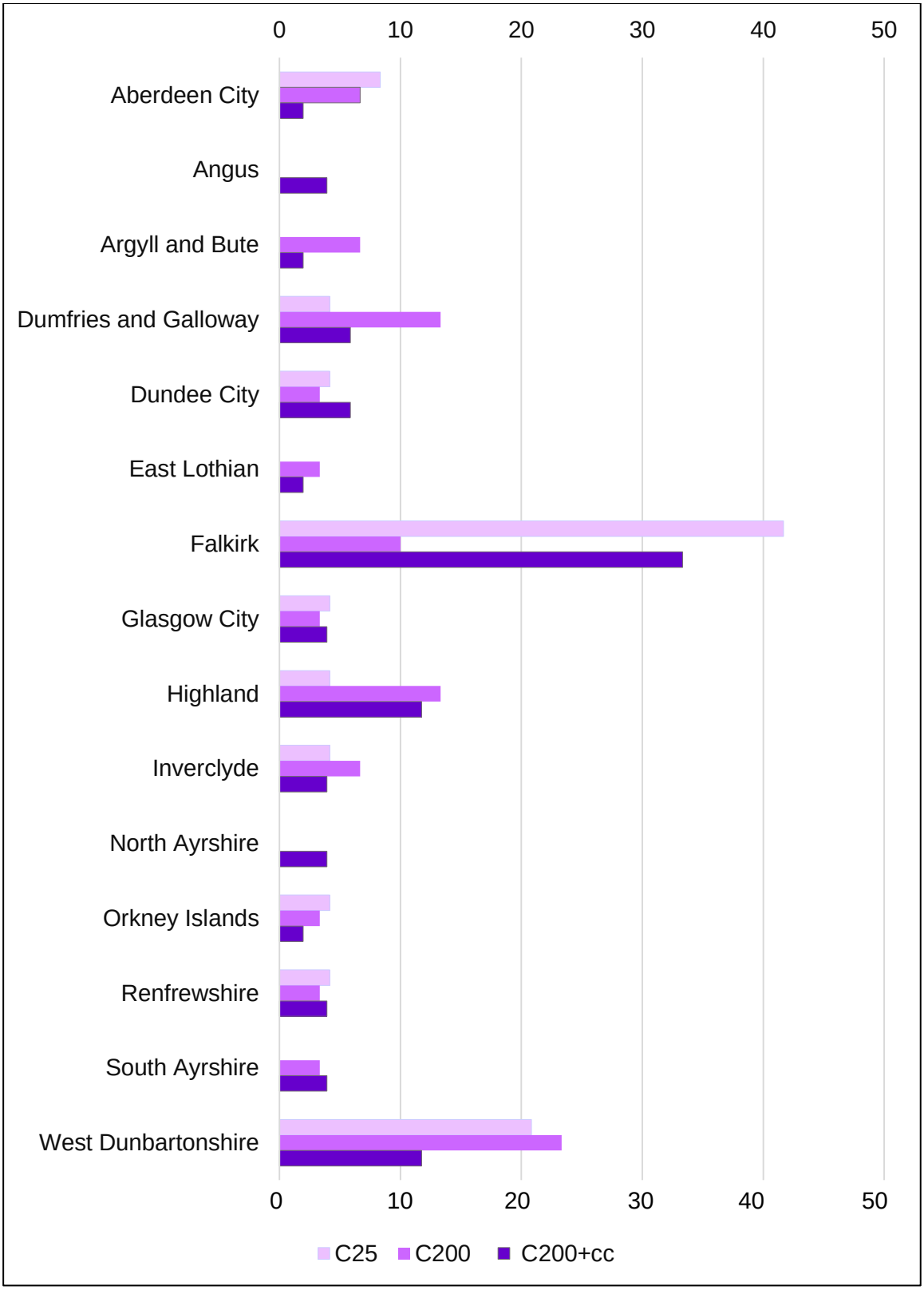

Figure 12. Relative contributions to Scotland's total number of extremely or acutely flood disadvantaged neighbourhoods from the named local authority with respect to **coastal flooding** (%).

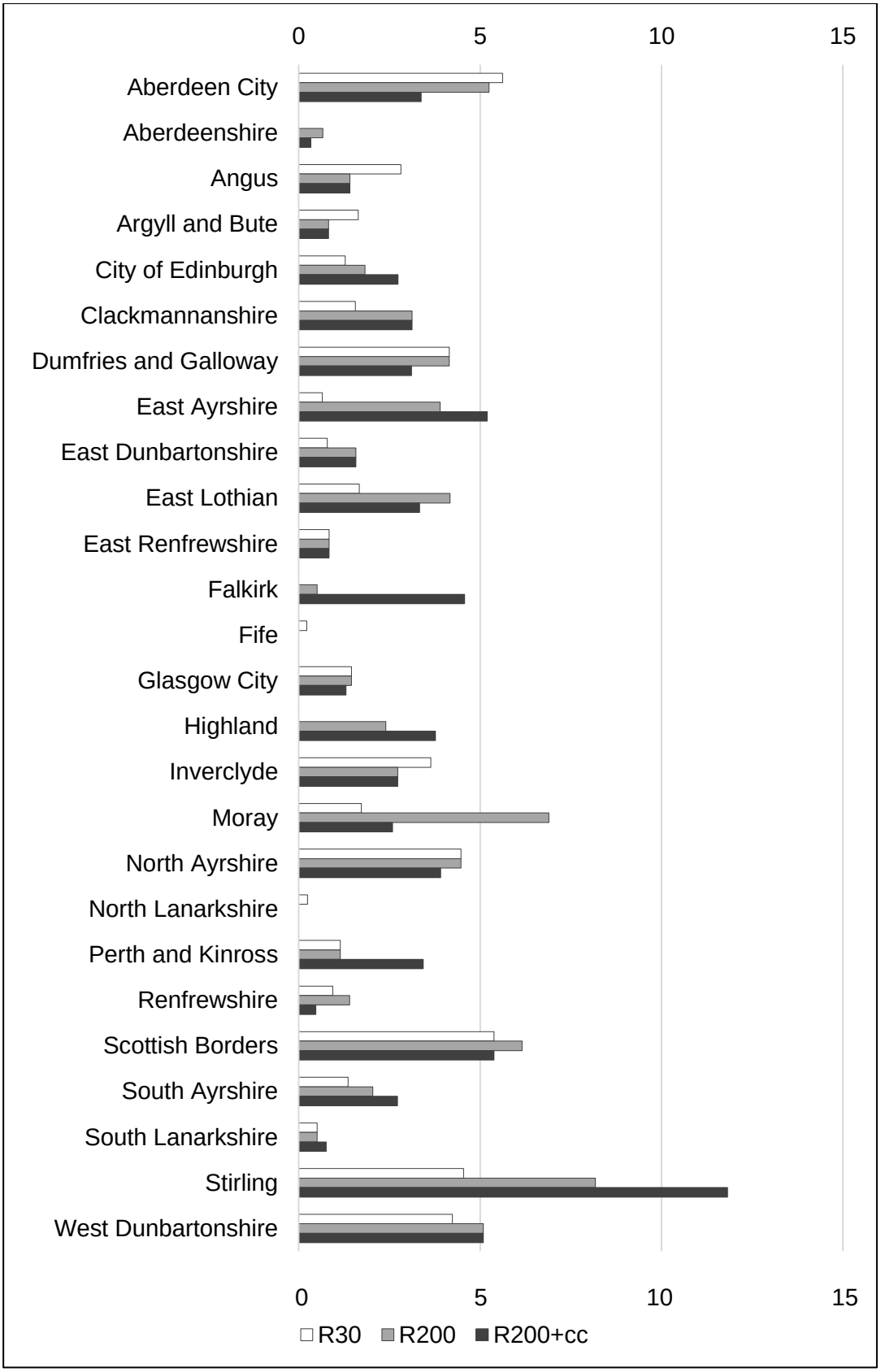

Figure 13. Percentage of extremely and acutely flood disadvantaged neighbourhoods with respect to **river flooding** in local authorities.

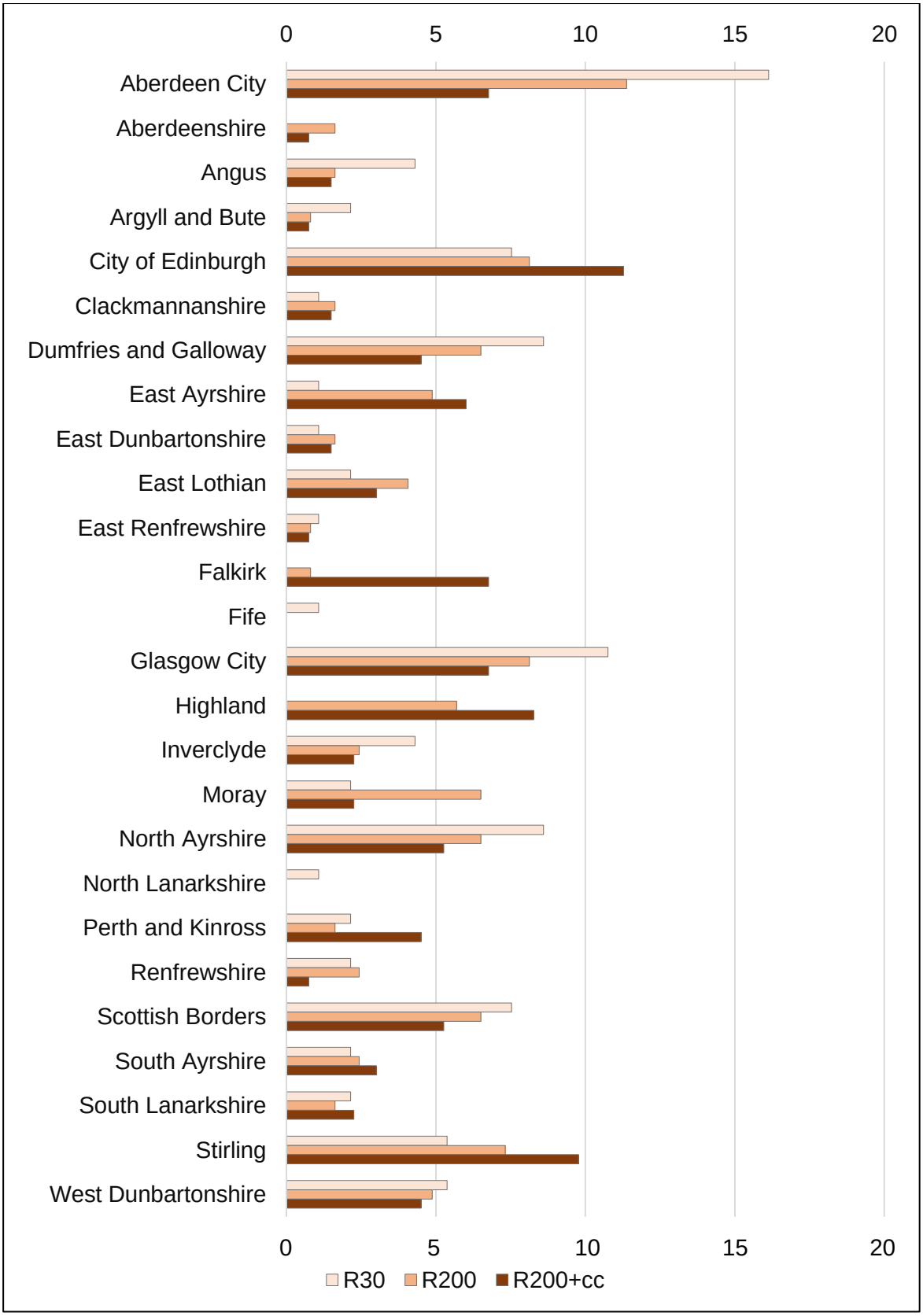

Figure 14. Relative contributions to Scotland's total number of extremely or acutely flood disadvantaged neighbourhoods from the named local authority with respect to **river flooding** (%).

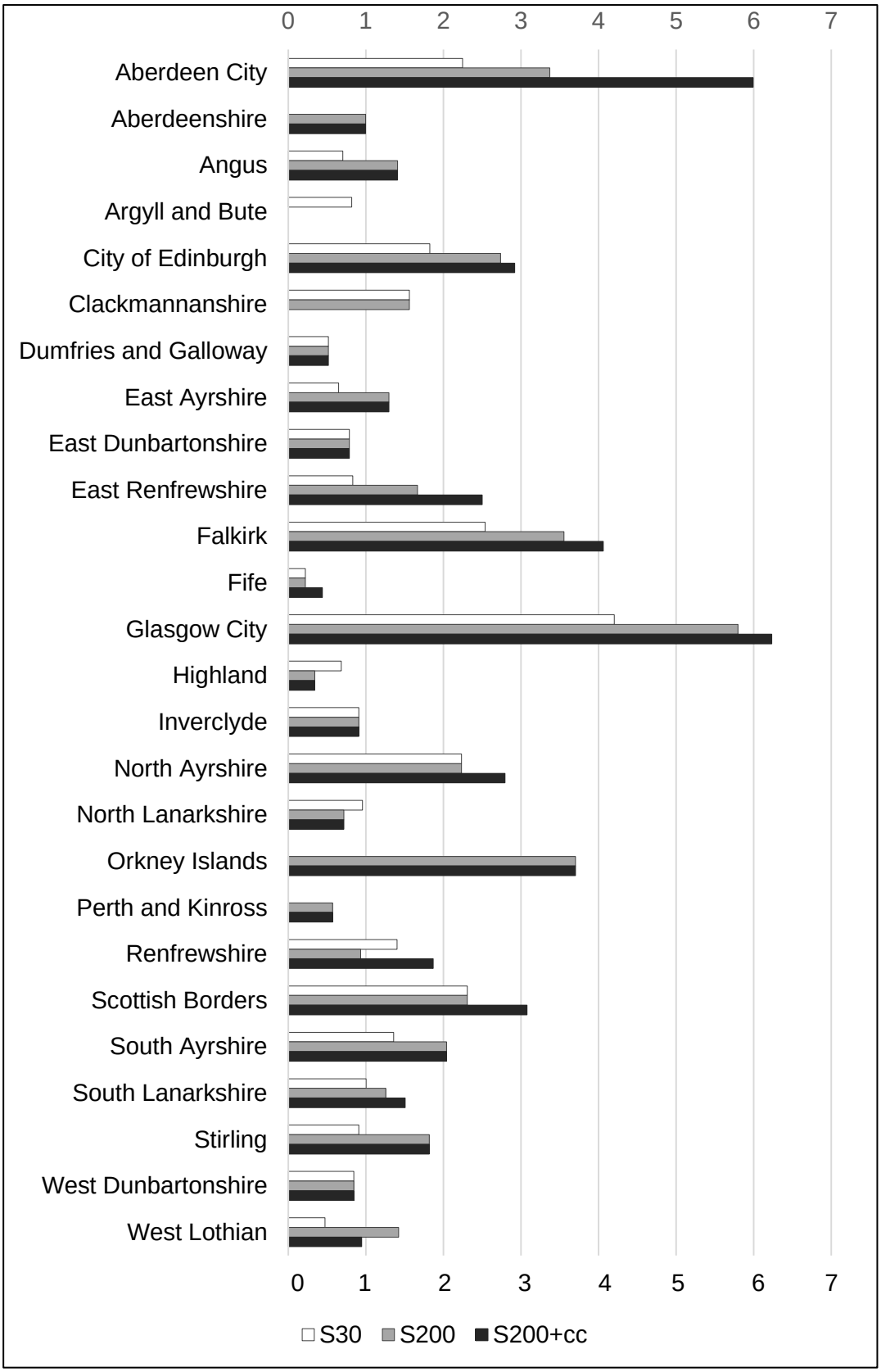

Figure 15. Percentage of extremely and acutely flood disadvantaged neighbourhoods with respect to **surface water flooding** in local authorities.

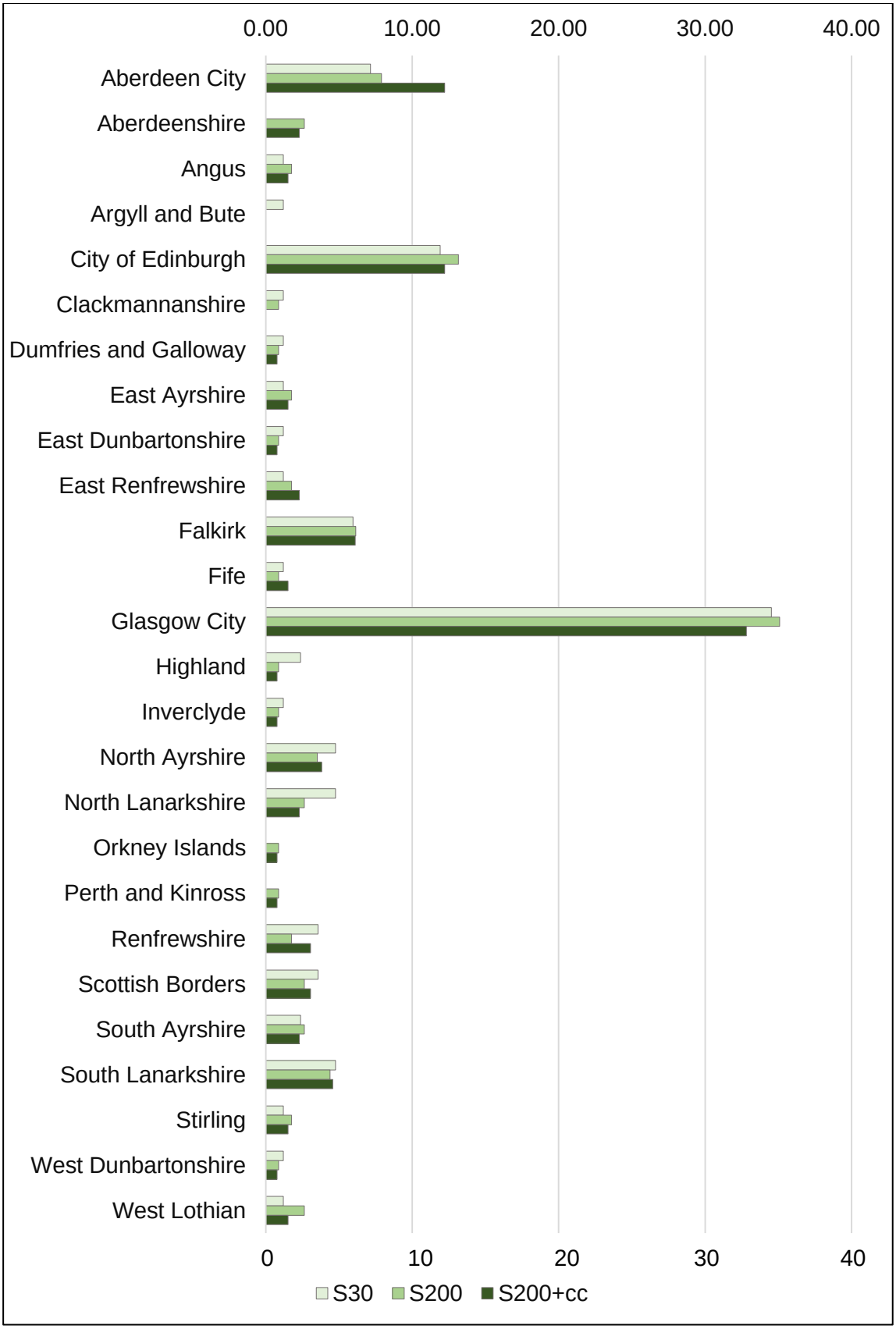

Figure 16. Relative contributions to Scotland's total number of extremely or acutely flood disadvantaged neighbourhoods from the named local authority with respect to **surface water flooding** (%).

4.3.5. Estimating flood-disadvantaged population

The flood disadvantage assessment has been carried out for the number of vulnerable households that may be exposed to flooding, rather than the number of people that may be affected. Some very cautious estimates of the number of people who may be exposed to flooding, or flood disadvantaged, can be provided based on the average household size in data zones. The uncertainty in estimating these figures is associated with the flood hazard data used and the use of a mean household size, which may vary considerably between individual households.

The average household size was estimated for each data zone based on the census 2011 data (population divided by number of households). This was multiplied by the number of households exposed to flooding using SEPA flood maps.

The total number of people that may be exposed to any type of flooding at low probability (1:200+cc) in Scotland (not differentiating between vulnerable and not vulnerable groups), is around 228,000. The highest number of people are likely to be exposed to river flooding (Figure 17). Whilst the number of people who may be exposed to medium probability (1:200) surface water flooding exceeds the number of people exposed to medium and high probability coastal flooding, the population numbers exposed to coastal flooding exceed those exposed to surface water flooding when low probability flood events are considered.

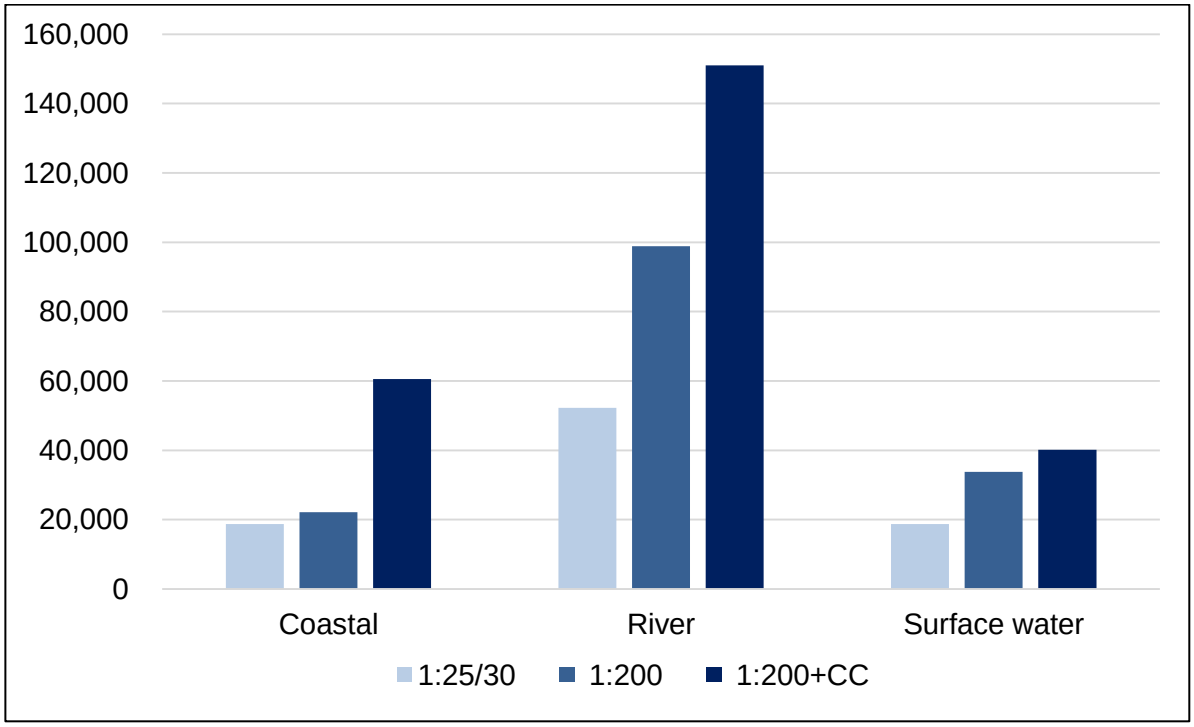

Figure 17. Estimated population that may be exposed to different types of flooding.

Flood disadvantage partially reflects the percentage of residential properties exposed to flooding within a data zone (see section 3.3). Therefore, generally the

higher the level of disadvantage, the higher the proportion of residential properties exposed. Figure 18 shows that even though the number of extremely high and acutely disadvantaged data zones is relatively low (138 and 98 respectively), they contain a disproportionate number of people that may be negatively affected by flooding due to their combined vulnerability and exposure (around 40,000 and 60,000 respectively). Flood risk managers may wish to focus on these areas when implementing management plans in order to reduce the impact of flooding on the well-being of a high number of vulnerable people.

An estimated 100,000 people in Scotland are acutely or extremely flood disadvantaged.

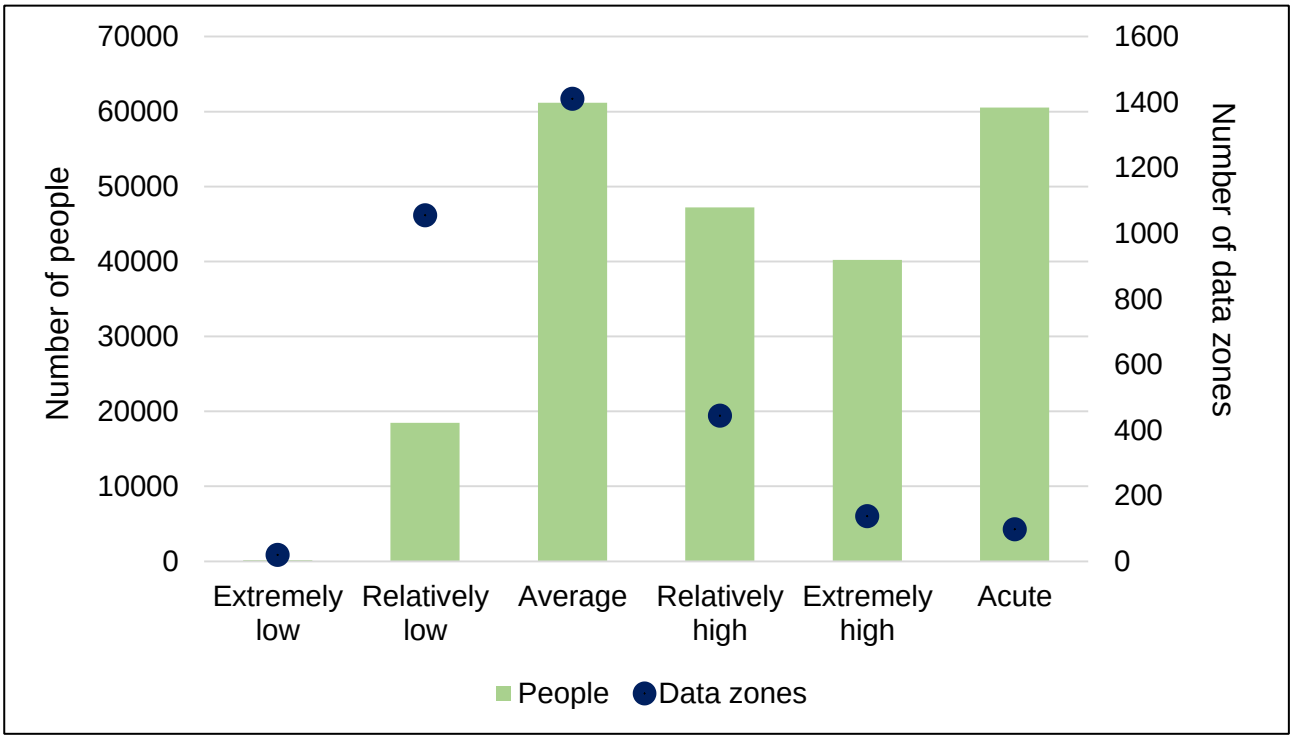

Figure 18. Number of people and data zones of different flood disadvantage levels (any type of flooding at low probability – 1:200+cc)

With regard high probability (1:30) coastal flooding, around 10,000 people are extremely or acutely flood disadvantaged; however, if the low probability (1:200+CC) flood risk is considered, over 28,000 people may be flood-disadvantaged.

In the case of river flooding, around 20,000 people are extremely or acutely flood-disadvantaged with regard to high probability (1:30) flood events. This number doubles for medium probability (1:200) and triples for low probability (1:200+cc).

Over 6,000 people are extremely or acutely flood-disadvantaged with regard to high probability (1:30) surface water flooding; over 10,000 in relation to the medium probability (1:200) and nearly 14,000 when low probability (1:200+cc) flooding is considered.

4.4. Geographical distribution of social vulnerability to flooding and flood disadvantage

The levels of social vulnerability to flooding and flood disadvantage were compared amongst data zones in different types of settlements, and for coastal versus inland areas, in order to identify any geographical patterns present and if any types of locations should be investigated further through analysis of fine-grained vulnerability and prioritised for consideration of flood management actions.

The six-fold Scottish Urban Rural Classification 2013-2014 (Table 8; Scottish Government, 2014c) was used, which differentiates between different sizes of settlements and different accessibility levels. Data zones were classified based on the location of the population-weighted centroids[11]. With regard to coastal areas, 1353 data zones were located within 1km of the coast and 2218 data zones were within 2km of the coast.

Table 8. Urban-rural classification of the data zones (Scottish Government, 2014c).

Class	Class name	Description	Number of data zones
1	Large urban areas	Settlements of 125,000 people and over.	2163
2	Other urban areas	Settlements of 10,000 to 124,999 people.	2327
3	Accessible small towns	Settlements of 3,000 to 9,999 people, and within a 30 minute drive time of a Settlement of 10,000 or more	614
4	Remote small towns	Settlements of 3,000 to 9,999 people, and with a drive time of over 30 minutes to a Settlement of 10,000 or more.	231
5	Accessible Rural Areas	Areas with a population of less than 3,000 people, and within a 30 minute drive time of a Settlement of 10,000 or more.	751
6	Remote Rural Areas	Areas with a population of less than 3,000 people, and with a drive time of over 30 minutes to a Settlement of 10,000 or more.	419

[11] Population-weighted centroid is a summary single reference point which represents how the population at census time was spatially distributed and grouped within the census unit.

4.4.1. Distribution of social vulnerability to flooding among urban and rural areas

Of the 511 extremely high or acutely vulnerable data zones, 373 were located in large urban areas and 116 in other urban areas. However, extremely low vulnerability also tended to focus in urban areas: of 262 data zones classed as having extremely low vulnerability, 76 were present in large urban areas and 130 were located in 'other urban' areas (Figure 19). Therefore, urban areas tend to contain the extremes of vulnerability. Local authorities in urban areas need to recognize the presence of contrasting areas, often in close proximity, and plan for the management of social vulnerability accordingly.

Social vulnerability to flooding has a strong urban component.

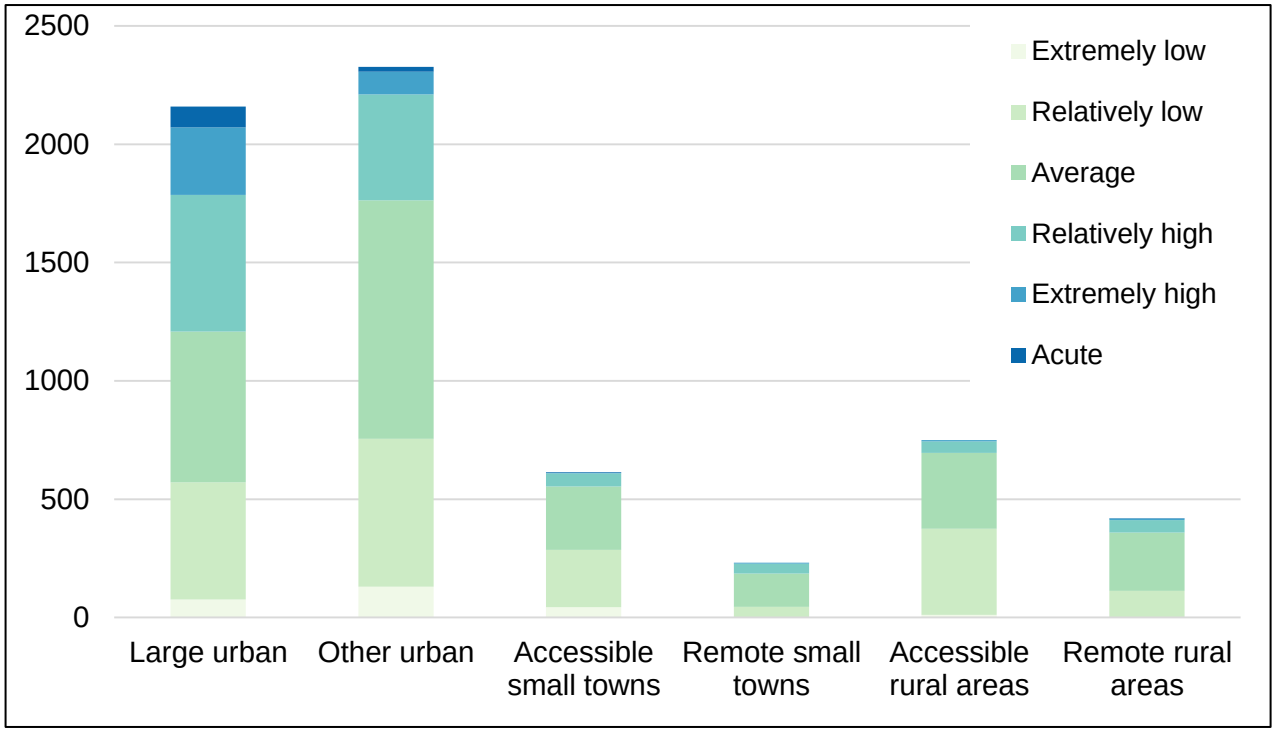

Figure 19. Social vulnerability to flooding: number of data zones by six-fold urban-rural classification.

Accessible small towns and accessible rural areas have the highest proportion of neighbourhoods of below-average social vulnerability to flooding. Remote small towns and remote rural areas tend to have social vulnerability around the average value for Scotland. However, this assessment has been carried out for the average values at the level of a neighbourhood which may mask highs and lows in vulnerability of individual households or people.

As for remote small towns, when the individual vulnerability indicators are explored, they emerge as having potential issues with social and physical isolation and mobility of people, which may raise issues with regard to responding to flood events. On average, they have the highest proportion of people living in care and

medical establishments and tend to have higher number of households without cars compared to accessible small towns, and both accessible and remote rural areas. They also have the highest proportion of single pensioner households. This raises issues with the provision of resources during the flood emergency. Also, remote small towns have the second highest proportion of people working far away from home (after remote rural areas). Therefore, whilst the communities living in small remote towns are usually regarded as close-knit and having strong levels of self-help, the high proportion of people with limited physical capabilities during the event of flooding, with a high proportion of the working-age population away from home, may require additional resources.

Remote small towns and remote rural areas tend to be vulnerable due to social and physical isolation combined with older populations

Also, the vulnerable populations in remote rural areas may be negatively affected by flooding. A high proportion of single pensioner households (second after remote small towns), combined with low road density, long distances to the nearest GP surgery, and a high proportion of people working far away from home again raises issues of the ability of the community to respond to and recover after flooding, and presents a challenge for local authorities to spread their resources over large, sparsely populated areas. However, remote rural areas also have the highest number of location- and community-specific charities; the literature suggests that non-governmental organizations can successfully target social isolation in remote rural areas. Thus, locally-based charities should be considered important stakeholders in actions aiming at reducing social vulnerability to flooding.

4.4.2. Distribution of flood disadvantage among urban and rural areas

Flood disadvantage in Scotland, when all types of flooding are considered, tends to be concentrated in urban areas; in particular the smaller urban areas (10,000 to 124,999 people) contain a high proportion of extremely and acutely disadvantaged neighbourhoods (Figure 20).

Flood disadvantage is concentrated in urban areas.

This pattern is also present for coastal flooding, with the highly disadvantaged data zones being predominantly in ‘other urban areas’; in contrast, rural areas do not contain any extremely or acutely disadvantaged data zones with regard to coastal flooding. River flood disadvantage also has a strong urban component, with acute levels of disadvantage concentrated in smaller urban settlements followed by large urban areas. Surface water flooding-related disadvantage is mainly present in large urban areas, as this is where surface water flooding tends to occur due to the high proportion of sealed surfaces and the pressure on the drainage systems. Table 9 summarises the number of extremely and acutely disadvantaged data zones with regard to different types of flooding and different return periods.

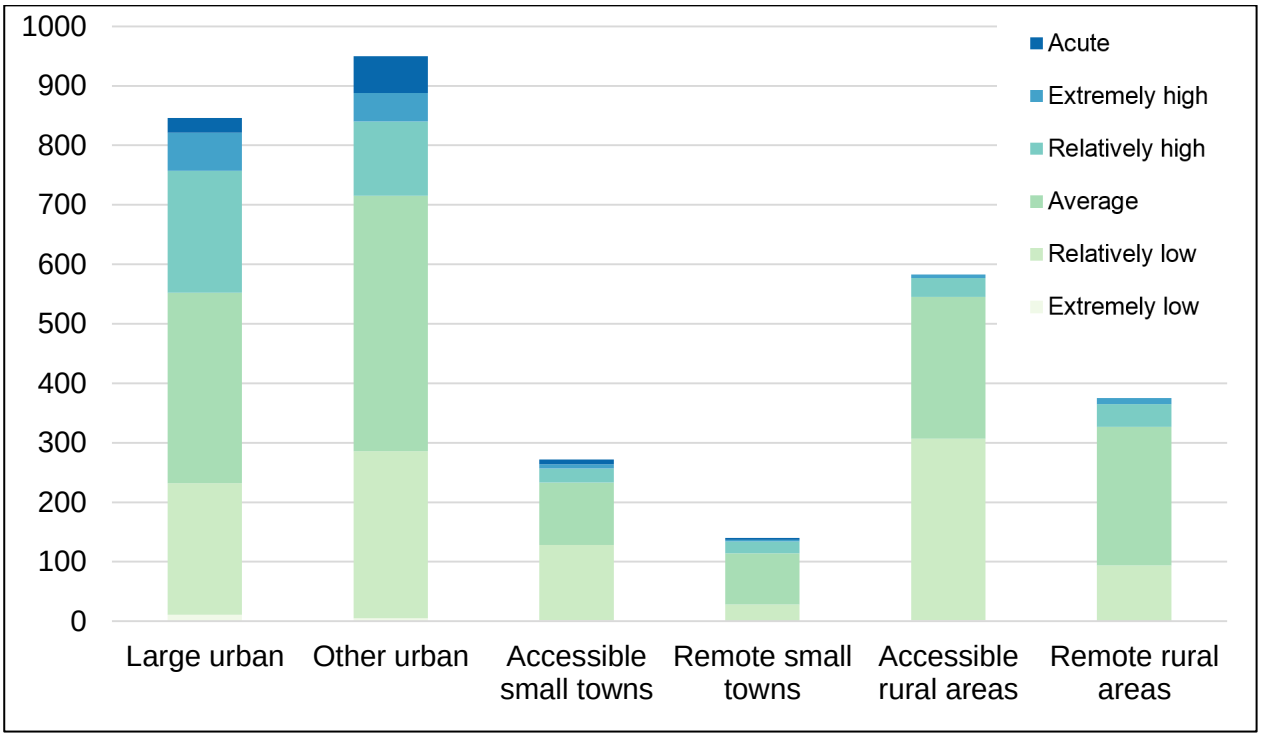

Figure 20: Levels of flood disadvantage for any type of flooding at low probability (1:200+cc) by six-fold urban-rural classification.

Table 9. Number of acutely and extremely disadvantaged data zones by six-fold urban-rural classification.

Flood type and return period	Number of extremely and acutely disadvantaged data zones					
	Large urban	Other urban	Accessible small towns	Remote small towns	Accessible rural areas	Remote rural areas
C25	5	18	0	1	0	0
C200	6	19	1	3	1	0
C200+cc	9	39	1	2	0	0
R30	41	29	7	4	2	10
R200	47	50	11	3	5	7
R200+cc	43	67	11	3	2	7
S30	53	27	3	0	0	1
S200	73	37	2	1	0	1
S200+cc	87	38	4	1	0	1
Any 200+cc	89	110	15	6	6	10

4.4.3. Comparison of coastal and inland areas

Coastal areas (defined as 2km distance from the coast) have a higher proportion of extremely and acutely vulnerable and disadvantaged data zones than areas located further inland (Figure 21). Therefore, coastal areas should be considered as a priority for flood risk management actions in order to reduce the impacts on vulnerable communities.

Social vulnerability to flooding and flood disadvantage have a strong coastal dimension.

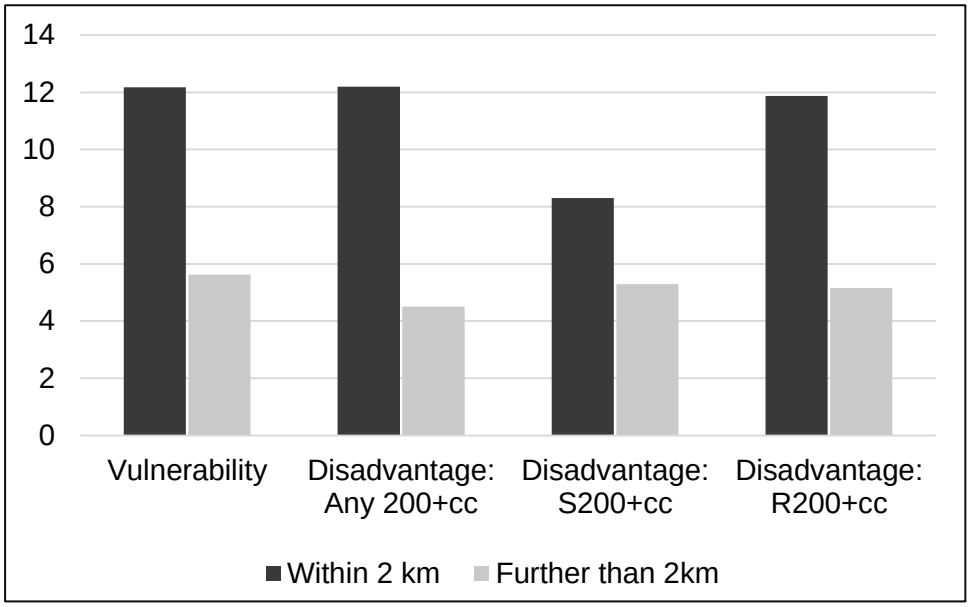

Figure 21. Percentage of data zones classified as extremely and acutely vulnerable or disadvantaged within and outside coastal areas

4.5. Social vulnerability to flooding and flood disadvantage in the context of NFRA

In Scotland, 243 Potentially Vulnerable Areas (PVAs) have been identified in the NFRA (Figure 22). They contain 92% of the total number of properties at risk within Scotland (SEPA, 2011a).

There are some substantial differences in the vulnerability assessment employed in NFRA and in this study. Whilst the assessment of social vulnerability to flooding and flood disadvantage in this project was focused largely on the characteristics of the population, the NFRA took into account the density of residential properties and the Social Flood Vulnerability Index (SFVI)[12] (Tapsell et al., 2002), which considers some of the vulnerability factors included in the assessment of social vulnerability to flooding reported here alongside a variety of other factors in delineating PVAs, including Economic Activity, Cultural Heritage and Environment (SEPA, 2011b).

[12] SFVI Score = ((Unemployed + Overcrowding + Non-car ownership + Non homeownership) / 4) + Single Parents + Over 75s + Long Term Sick)) (SEPA, 2011b after Tapsell et al., 2002).

In addition, the underlying social and environmental data differ between the two assessments. The flood maps produced by SEPA for the strategic flood risk assessment are being constantly updated and NFRA was developed based on a different version of flood maps, and the socio-economic data used is earlier than 2011.

Further, the spatial scale of the underlying data differs: this assessment is based on the averages for data zones, whilst SEPA used 1km^2 grid, adjusted to accommodate for Sub Catchment Unit boundaries (SEPA, 2011). Both approaches have their advantages: whilst the 1km^2 grid offers the equal-size unit approach to the assessment, most of the socio-economic data is reported for census or administrative units. In addition, in densely populated urban areas, where data zones are quite small, the 1km^2 grid may be too coarse to allow identification of fine-scale variability in social vulnerability to flooding or flood disadvantage.

In order to assess to what extent vulnerable and disadvantaged areas identified in this assessment reflect the results of NFRA, data zones were spatially overlaid with the PVAs[13].

The analysis indicates that over 82% (5349) of the data zones coincide with PVAs. The data zones identified as overlapping with PVAs were found to have higher levels of social vulnerability to flooding and flood disadvantage (in relation to any type of flooding) than the data zones located outside the PVAs (see Figures 23 and 24).

All 112 acutely vulnerable data zones were located within PVAs and 97.5% of the extremely vulnerable data zones were also located within PVAs. The remaining 10 extremely vulnerable data zones were in Dumfries and Galloway, Aberdeen City, Fife, Highland and Inverclyde (see Figure 21). When flood disadvantage in relation to any type of flooding (1:200+cc) is considered, only one of 98 acutely flood disadvantaged neighbourhoods and five of 138 extremely disadvantaged neighbourhoods fell outside PVAs. These were in Dumfries and Galloway, Highland and East Ayrshire (see Figure 22). These locations could be considered by SEPA in the next NFRA cycle for consideration as PVAs.

[13] The spatial coincidence of data zones and PVAs was determined based on location of the data zone population-weighted centroid within the spatial extent of PVA.

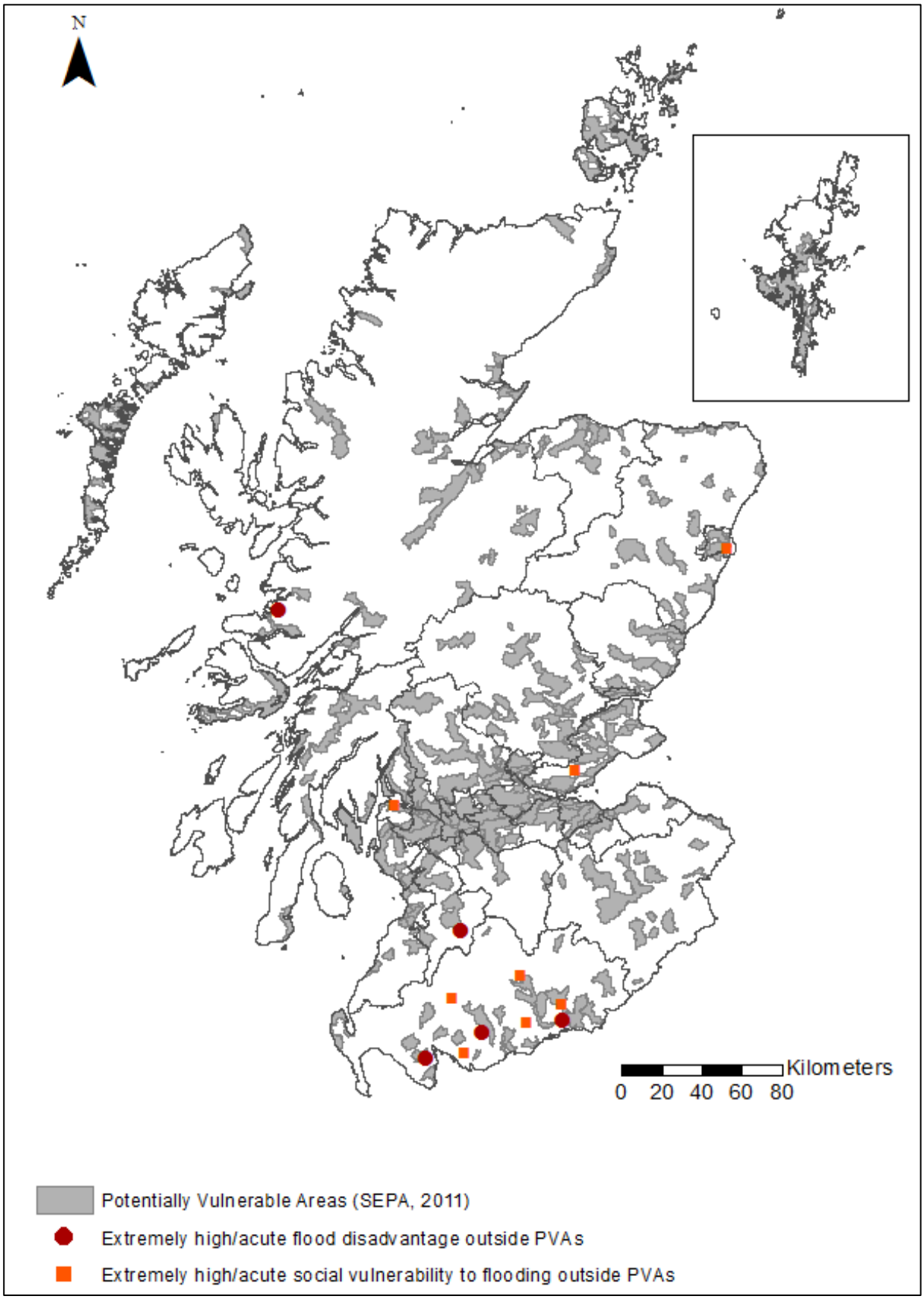

Figure 22. Flood disadvantaged and vulnerable areas located outside the Potentially Vulnerable Areas in Scotland (as identified in NFRA ((SEPA, 2011a)). Base map is Ordnance Survey data © Crown Copyright and database right 2015.

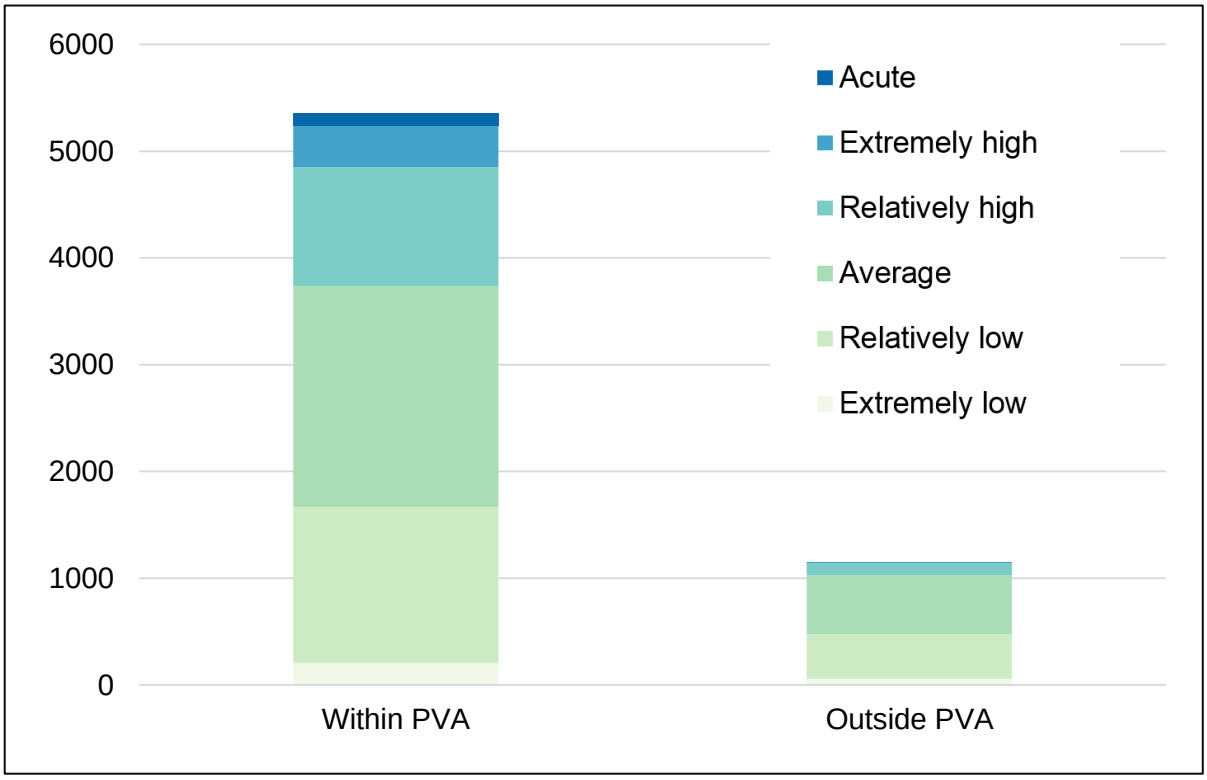

Figure 23. Social vulnerability to flooding within and outside PVAs

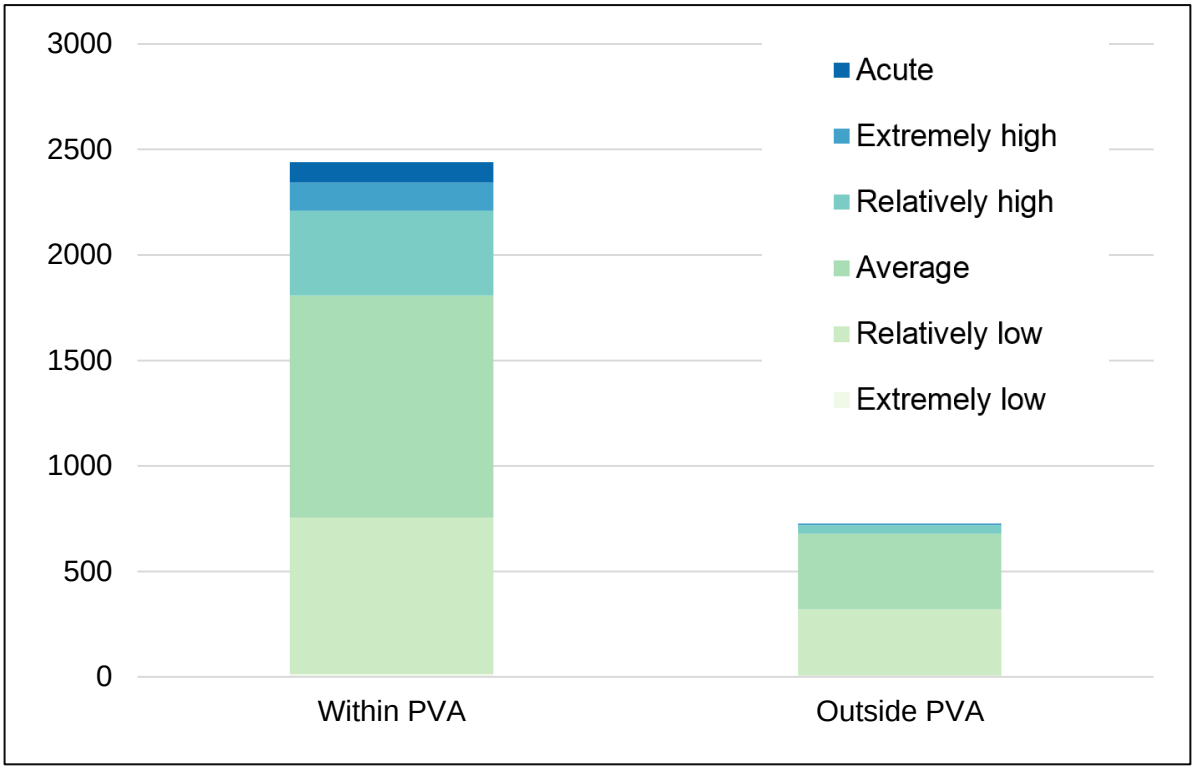

Figure 24. Flood disadvantage (any 1:200+cc) within and outside PVAs (for data zones exposed to flooding only).

4.6. Case studies of local authorities

4.6.1. Introduction

For the flood disadvantage assessment to be meaningfully translated into strategies which focus on preparing for, responding to, and recovering from flooding, local authorities or other agencies must recognise that they need to address vulnerability beyond emergency response.

Local authorities play a central role in leading and supporting local places to become more resilient to a range of future risks, and effective solutions on how to support vulnerable groups are recommended to be found and led by the local community or local council (The Scottish Government, 2012b). Therefore, local authority perceptions of the flood disadvantage assessment method and outputs, as well as the potential uses of the datasets, were gathered through engaging with three different local authorities: Dumfries and Galloway, Dundee City Council and the Scottish Borders.

The three case study local authorities have different characteristics. For instance, Dundee is an urban local authority. Dumfries and Galloway and the Scottish Borders have no large urban areas, but they both contain smaller urban settlements; Dumfries and Galloway contains a substantial proportion of remote rural areas (Figure 25).

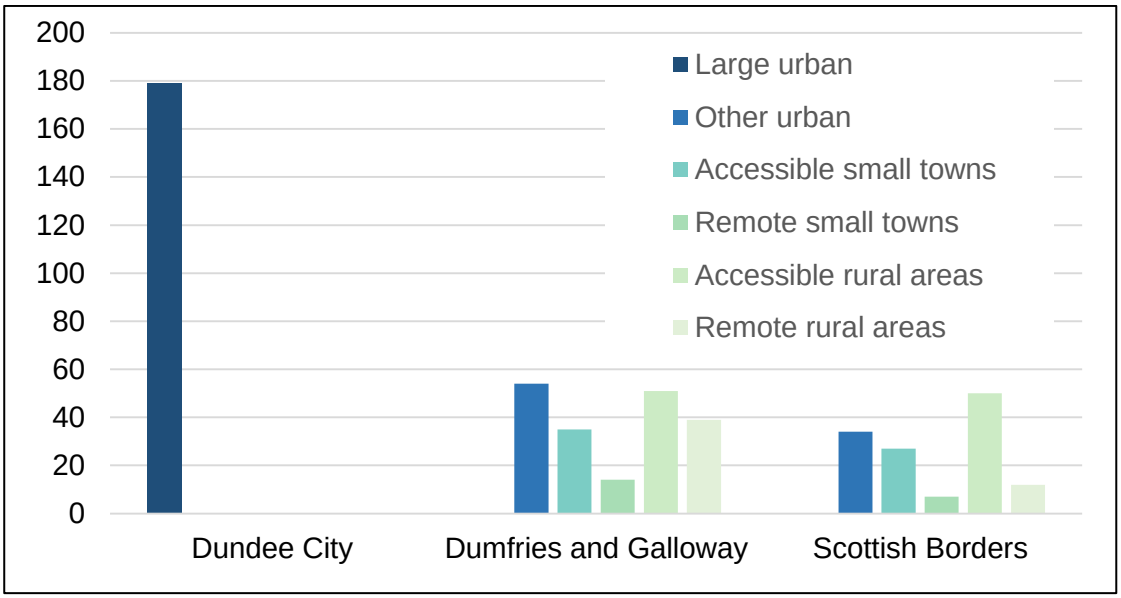

Figure 25. Number of data zones in case study areas by six-fold urban-rural classification (based on Scottish Government 2014c).

All three local authorities have access to the coast. In Dundee, two-thirds of the data zones are located within 2km from the coast. In Dumfries and Galloway, one-third of the data zones are located within 2km from the coast, whilst only 4% of the Scottish Borders' data zones are located within 2km from the coast.

All three local authorities are involved in Local Plan Districts where the draft Flood Risk Management strategies have been put out to consultation. These will be published in December 2015.

4.6.2. Flood disadvantage in case study local authorities

Table 10 presents the number of data zones that are exposed to different types of flooding and return periods in the three case study authorities. The exposure to flooding varies. In Dundee, just over 17% of the data zones contain residential properties exposed to any type of flooding. By contrast, the exposure to flooding in Dumfries and Galloway is much more widespread with nearly 77% of the data zones containing residential properties located in flood risk areas.

Table 10. Number of data zones exposed to flooding in the case study authorities

Flood type and return period	Dundee City	Scottish Borders	Dumfries and Galloway
C25	2	1	31
C200	3	1	31
C200+cc	7	2	31
R30	8	70	110
R200	12	83	119
R200+cc	13	87	125
S30	9	42	53
S200	12	59	70
S200+cc	14	59	72
Any 200+cc	31	95	148
Total number of data zones	179	130	193

Dundee City contains the highest proportion of data zones characterised by extremely high or acute social vulnerability to flooding. By contrast, a very small proportion of the Scottish Borders' data zones are characterised as extremely vulnerable and this local authority has the highest proportion of data zones of below national average vulnerability (Figure 26). Dumfries and Galloway is located between these two local authorities in terms of the proportion of neighbourhoods of extreme social vulnerability to flooding.

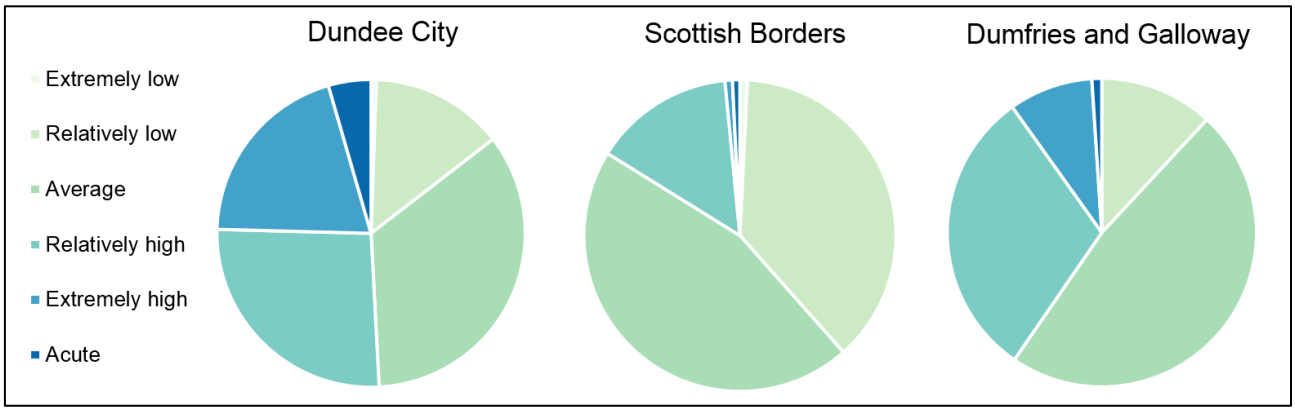

Figure 26**.** Levels of vulnerability in the three case study areas (percentage of data zones in different classes of social vulnerability to flooding).

Considering flood disadvantage gives more nuanced results. In Dundee City only four data zones have extremely high or acute flood disadvantage. Whilst high levels of vulnerability in Dundee City may be of concern to various council departments (high values of various vulnerability indicators suggesting high levels of material deprivation, social isolation, considerable proportion of sealed surfaces and so on), the majority of data zones classed as vulnerable are not exposed to any type of flooding (; see also Table 11). The levels of flood disadvantage are thus higher in the Scottish Borders and Dumfries and Galloway (8 and 12 data zones with extremely high or acute disadvantage respectively).

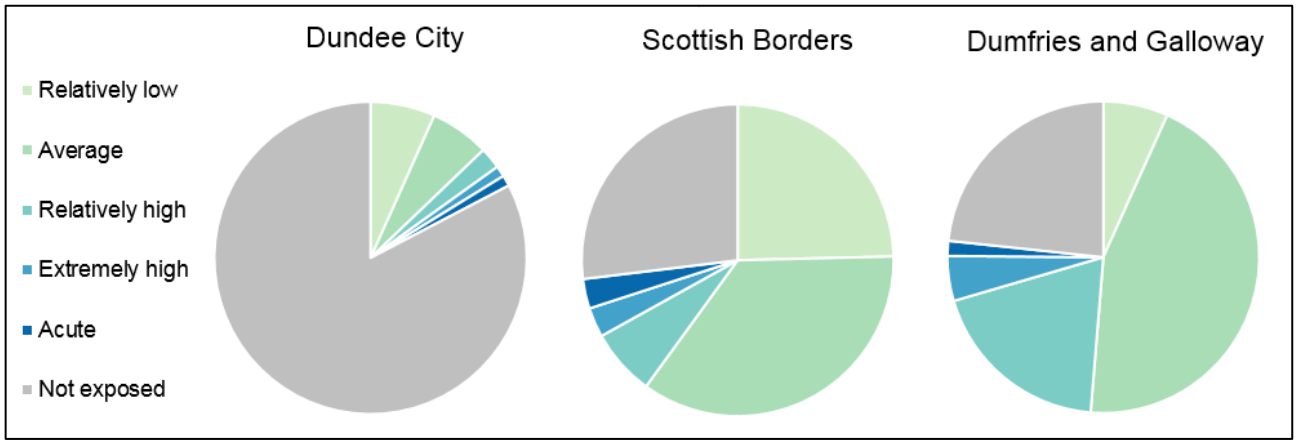

Figure 27. Levels of flood disadvantage (Any 200+cc) in the three case study local authorities.

Figures 28-30 present the disadvantage maps (in relation to any flooding of 1 in 200 years return period) for the three local authorities, including the disaggregation to different aspects of vulnerability for selected disadvantaged areas.

The coloured blocks in the bar chart represent the values of the vulnerability dimensions relative to the average Scottish neighbourhood (represented by the horizontal axis). Bars above the horizontal axis show positive vulnerability dimension values (greater than the Scottish average for each of the five dimensions

shown in the legend). Bars below the horizontal axis show negative vulnerability dimension values (lower than Scottish average for each of the five dimensions shown in the legend). Therefore, the bars pointing upwards indicate higher than average sensitivity (blue bar) and exposure (green bar), and high inability to prepare (yellow bar), respond (red bar) and recover (purple bar). Bars pointing downwards indicate lower than average sensitivity and exposure and higher than national average ability to prepare, respond and recover.

The dimensions of vulnerability and the underlying indicators were analysed for three data zones identified in the case study local authorities as having acute flood disadvantage (Figures 28-30). Table 11 presents the values of vulnerability indicators for the selected data zone for each local authority case study in relation to the national average. This is now discussed in depth to demonstrate how the dimensions of vulnerability, in conjunction with the individual indicators, can be analysed in order to learn more about the underlying reasons for vulnerability in a given location.

The Scottish Borders (Hawick)

In the selected data zone in Hawick (S01005374) the sensitivity levels are close to the national average (Figure 28). Therefore, when considering Table 11, Hawick does not have any particular issues with aspects relating to a high proportion of older people or those in ill-health. Furthermore, enhanced exposure levels are close to the national average primarily because the proportion of houses with the lowest level at ground level is much lower than the national average.

The inability to recover in Hawick is much higher than the national average, and higher than for any of the other neighbourhoods surrounding this particular data zone. Also the inability to prepare and respond to flooding are substantially higher than the national average. By looking at the values of individual indicators (Table 11), it can be seen that Hawick contains:

- **A higher number of pension credit claimants**. Whilst the older population is close to the national average, those in Hawick claim more pension credits, which suggests that they may be materially deprived. Additionally, the proportion of older people living alone is higher than the Scottish average. These groups may require extra assistance before, during and after flood events.
- **A high proportion of new addresses in a flood risk area.** Hawick is in Edinburgh's commuter belt which leads to pressures for new housing. Whilst the indicator should be treated with caution (see section 3.3.), it may indicate that a proportion of households will struggle to get insurance under the new Flood Re regime. They may also struggle to obtain affordable insurance presently because of the history of flooding in this area, judging from the number of historic flood events (Table 11).

- **A high proportion of houses rented from private landlords.** Tenanted properties are less likely to have contents insurance. In addition, tenants may not be able to install PLP. This may indicate a need to collaborate with landlords on making properties better prepared for flooding and encouraging landlords to help their tenants obtain contents insurance
- **In terms of its strengths, there is a high proportion of properties within SEPA's flood warning areas**, which suggests that there may be a higher awareness of flooding. In addition, there are a **higher number of locally-based charities than the national average**. Such charities may support the local authority in flood preparation, response and recovery – the local authorities have also confirmed that Hawick has an active flood group. Hawick has a **lower than average crime rate** which may make it easier to work with the community during a flood as people will be less fearful of leaving their homes unattended. Residents of Hawick also have **good access to GPs** which can aid the recovery of sensitive groups.

Dumfries and Galloway (Newton Stewart)

Data zone S01000960 in Newton Stewart, Dumfries and Galloway, has very high levels of sensitivity whilst the ability to prepare is close to the national average. These combine with higher than national average levels of the inability to respond and recover (Figure 29). The indicators show that there are:

- **High proportions of older people and those in poor health.** These groups are particularly sensitive to flood events. Compared to the national average, there is also a higher proportion of people living in medical and care establishments who may have more difficulty evacuating during a flood event.
- **There is a history of flood events but the area is not within SEPA's flood warning areas.** Households which are not in a flood warning area may have less awareness about flooding. SEPA is currently developing flood warnings for this area.
- **The neighbourhood has a settled population with few recent arrivals.** This may indicate that the community is close-knit and with good potential for self-help. However, there are a high proportion of people working away from home which means that the people remaining at home (for example older people, those with young children or in poor health) may be unable to help themselves. In this case, the high number of locally-based charities could provide assistance to those who cannot help themselves.
- **The selected area has a low density of roads.** This means that the area may get cut off in the event of flooding and it may be difficult to reach inhabitants during a flood event.

The analysis suggests that the local authority could focus on addressing the needs of the sensitive (older, poorer health) population during and after flood events.

City of Dundee, Waterfront area

The selected data zone for Dundee (S01001108) has different characteristics yet again. The levels of sensitivity are below the national average. However, the levels of inability to prepare for, respond to, and recover after flooding, are higher than the national average. Enhanced exposure is also higher than the national average (Figure 30). Analysis of the indicators demonstrates that:

- **There are high levels of enhanced exposure, which are linked to the low presence of green space.** The local authority may wish to investigate the surface sealing in that area and the type of housing present. Strategies to vary the land cover may be assessed, e.g. increasing green spaces and providing sustainable drainage systems (SUDS) that may help to mitigate the floods in the area.
- **The population are generally younger and healthier.** These groups are less sensitive with respect to floods.
- **The number of Job Seekers Allowance and Income Support claimants is higher than national average.** Those on low incomes may be less likely to have contents insurance and may be less likely to afford PLP to make their homes more resilient.
- **There are higher proportions of new arrivals from outside the UK.** In addition there is a **higher proportion of people not speaking English well**. This may mean that the communication of flood risk, flood warnings and preparation for flood events may not reach these groups. In addition, there are **high proportions of new residents from within the UK** and a **very high proportion of private lets**: both groups may not be familiar with the area. This could suggest the need for a tailored communication strategy that may utilise third sector organisations and/or landlords.
- **There has been a very high number of previous flood events.** Insurers may be reluctant to provide affordable insurance in these areas and therefore inhabitants may not have their buildings and contents insured.
- **Domestic break-ins are relatively high.** This has implications for the response and recovery phases of a flood event because people may be reluctant to leave their belongings behind. A higher police presence may be needed during flood events.
- **There is a relatively limited presence of voluntary organisations**. This was confirmed by workshop participants who noted the low provision of any community resources in this area (schools, nurseries and community centres). This may mean that social networks are poor and that there is little support to be garnered from the third sector should the area be flooded.

Table 11. Values of social vulnerability to flooding indicators for the selected data zones (identified by codes) in three case-study authorities

Indicator	Dundee, Waterfront S01001108	Dumfries & Galloway, Newton Stewart S01000960	Scottish Borders, Hawick S01005374	National average
% people under 5 years old	5.42	3.18	5.17	5.42
% people over 75 years old	1.07	20.85	12.53	7.92
% people whose day-to-day activities are limited	10.72	35.87	20.69	20.08
% households with at least one person with long term limiting illness	15.52	50.18	30.27	35.03
% people in routine or semi-routine occupations	14.78	34.17	40.75	29.37
% of people who are long term unemployed or who have never worked	4.16	4.27	3.58	5.10
% households with dependent children and no adults in employment	3.93	3.25	2.34	3.94
Number of Income Support claimants	40	14	15.00	20
Number of Job seeker allowance claimants	50	13	31.25	22
Total pension credit claimants	31	53	76.25	39
Total number of families receiving tax credits	65	25	70.00	63
% people with <1 year residency in the UK	9.11	0.00	0.46	0.93
% people who do not speak English/no not speak English well	2.35	1.81	1.07	1.41
% new addresses (01.01.2009) in flood risk areas	2.84	2.80	32.92	0.20
Number of historic flood events	34	6	7	1
% addresses in Flood Warning Target Areas	54.44	0.00	62.14	1.66
% new residents (< 1 year) arriving from outside the local area	23.61	4.80	8.78	8.04
% social rented households	20.33	19.13	11.72	23.75
% private rented households	57.27	14.08	27.93	11.43
% of Incapacity Benefit/Severe Disablement allowance claimants	2.23	19	2.87	23
% people living in medical and care establishments	0.83	6.89	0.0	0.75
% households with no car or van	43.39	24.91	37.50	29.12
% children of primary school age	4.35	2.65	3.79	8.20
Number of voluntary organisations focused on local community	5	12	12	8
% single pensioner households	2.30	21.66	18.95	13.13

Indicator	Dundee, Waterfront S01001108	Dumfries & Galloway, Newton Stewart S01000960	Scottish Borders, Hawick S01005374	National average
% people working further than 30km from home	4.66	13.44	7.82	6.05
Road density	32.86	9.81	22.03	13.86
Number of domestic break-ins	78	0	0	30
Travel time to GP surgery (private transport)	1.90	2.2	3.10	4.19
Travel time to GP surgery (public transport)	5.40	9.3	7.70	11.34
% households with the lowest floor level: ground floor	22.07	85.99	49.05	78.32
% households with the lowest floor level: basement or semi-basement	1.29	2.77	1.96	1.26
% caravan or other mobile or temporary structures in all households	0.00	0.00	0.0	0.17
% urban land cover	86.68	19.52	30.13	13.85

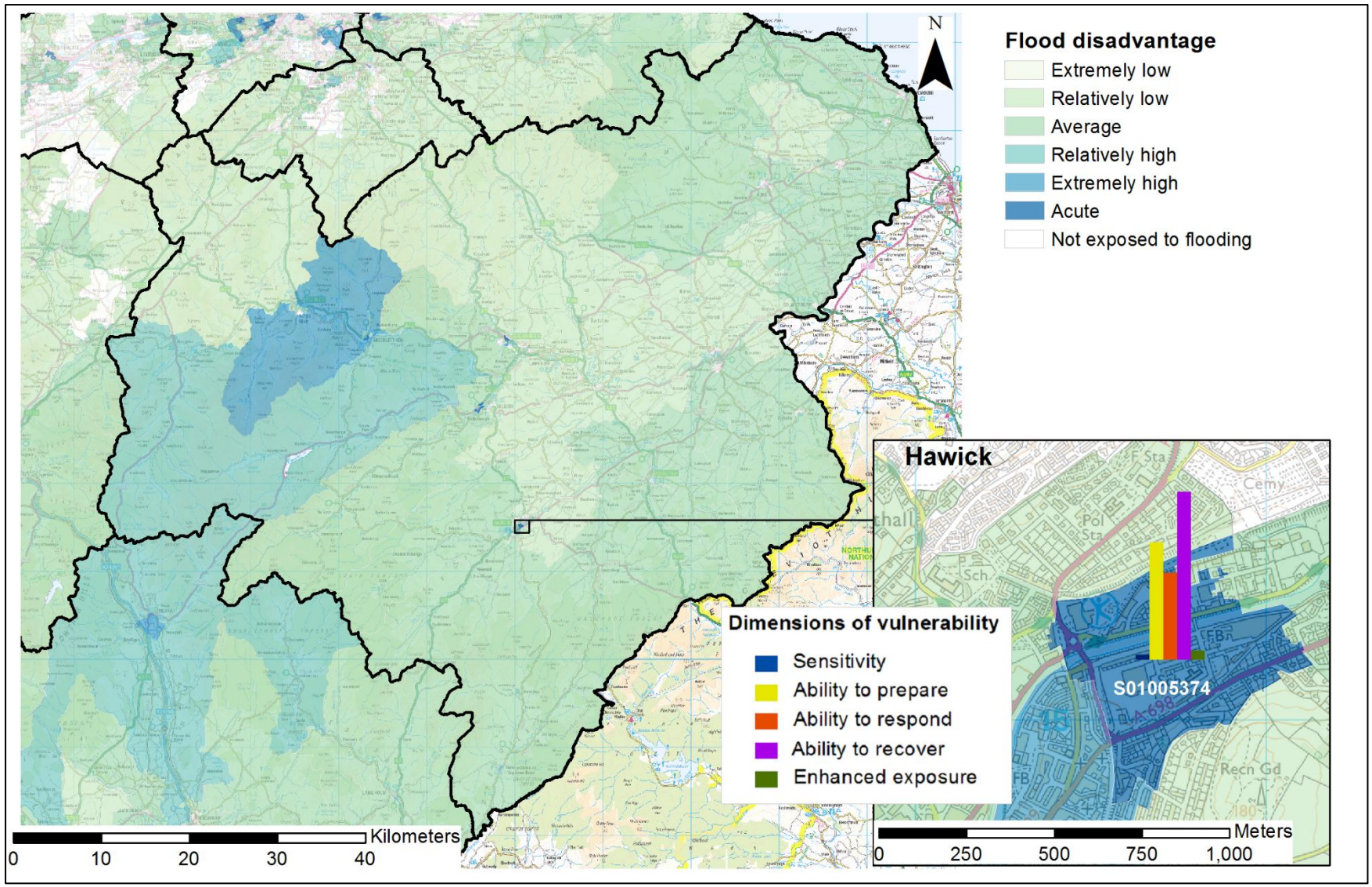

Figure 28. Flood disadvantage in Scottish Borders. Inset: Hawick. Base map is Ordnance Survey data © Crown Copyright and database right 2015. Derived from OS AddressBase, SEPA data and data sources listed in Table 2.

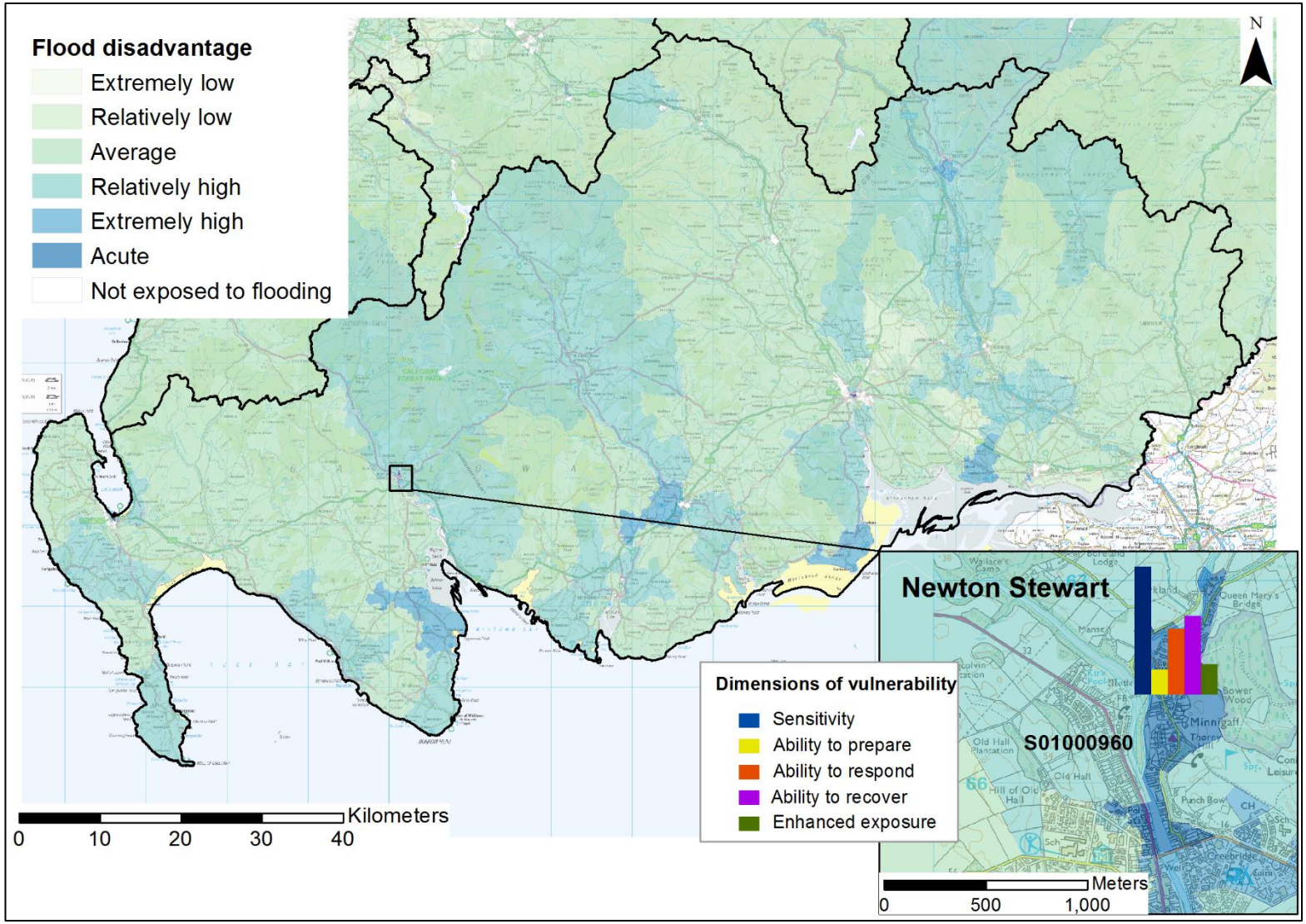

Figure 29. Flood disadvantage in Dumfries and Galloway. Inset: Newton Stewart. Base map is Ordnance Survey data © Crown Copyright and database right 2015. Derived from OS AddressBase, SEPA data and data sources listed in Table 2.

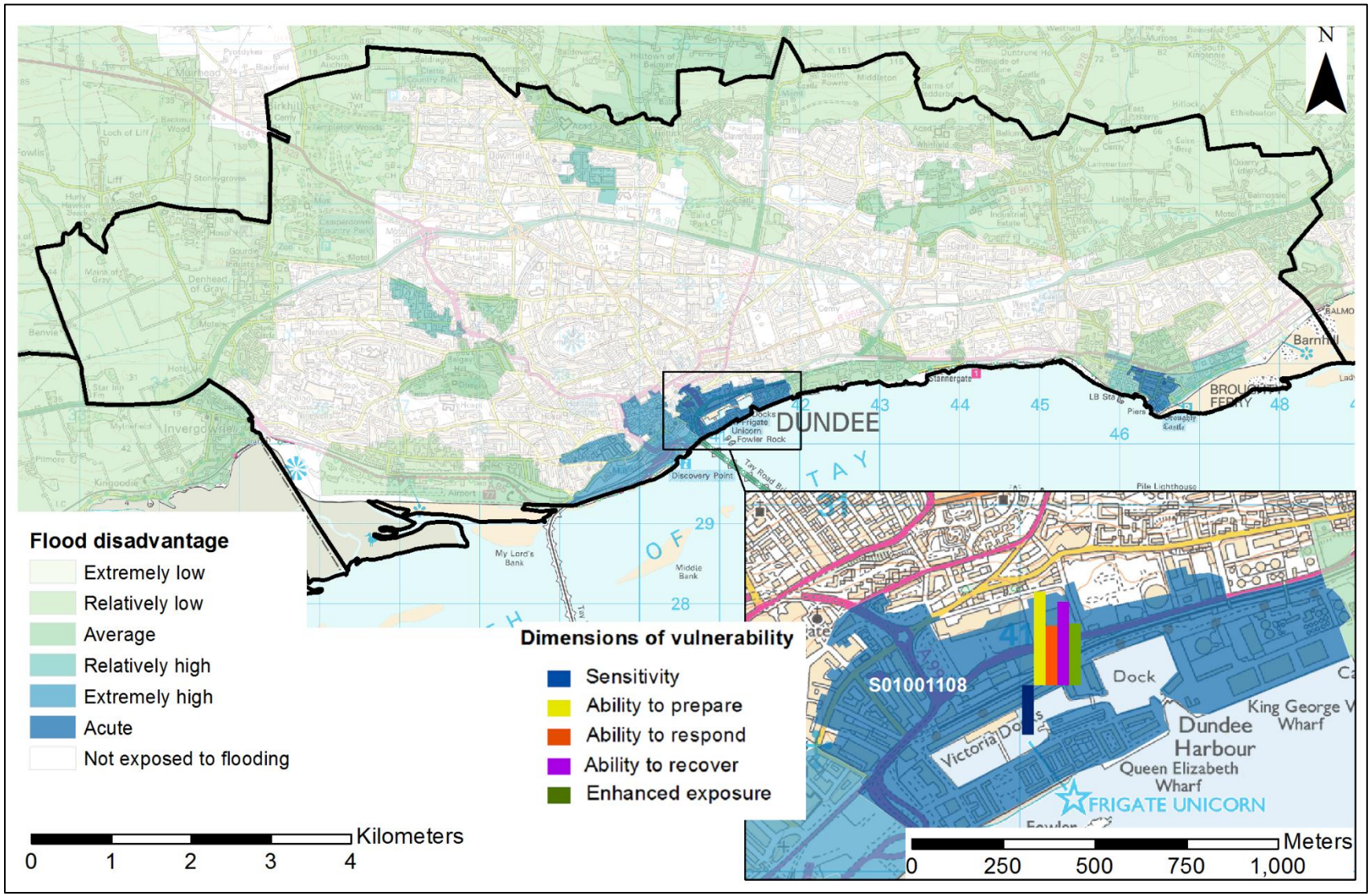

Figure 30. Flood disadvantage in Dundee City. Inset: Waterfront area. Base map is Ordnance Survey data © Crown Copyright and database right 2015. Derived from OS AddressBase, SEPA data and data sources listed in Table 2.

4.6.3. Local authorities' feedback on the flood disadvantage assessment

The project team met with representatives from each of the three local authorities. Attendance was varied across departments. In total there were 16 participants drawn from various departments (Table 12). The project team presented the maps and data (in a similar format to the information above) before asking a series of questions relating to:

- The local authorities' current flood risk management work and the extent to which vulnerability had been covered
- Ease of understanding the terminology
- Presentation of the maps and data
- How the data might be used
- Any other resources that they might find helpful.

The remainder of this section presents the participants' views.

Table 12. Case study local authority workshop participants

	Dumfries and Galloway	Dundee City Council	The Scottish Borders
Number of participants	**6**	**6**	**4**
Departments represented	**Planning and Infrastructure; Flood Risk Management; Economic Development; Community Resilience; Social Work; Chief Executive's office**	**City Engineer; Housing; Planning; Environment; Social Work**	**Community Resilience; Economic Development; Flood Risk Management**

The assessment framework

The local authorities examined were supportive of the framework used and of the explicit links made between the vulnerability of communities and the hazard of flooding, as these issues tend to be considered in separation in local authorities' work. Flooding, and climate change adaptation more broadly, is typically the remit of environmental departments. Particular sectors, such as social care, remain detached from this issue because they do not have a strong futures dimension. As one of the participants observed: '*it's a fundamental issue about capacity…this [agenda] has been very much been left to the flooding team to do it themselves…that's probably the same in most local authorities*' (The Scottish Borders Council).

At the same time, it was felt that there is a scope for closer links between the environmental hazards and social care: flooding, for one attendee, could be '*a new angle*' in terms of the council's work on reducing inequalities (Dumfries and Galloway).

Attendees were broadly supportive of the terminology due to existing policy: social justice, for example, has been used by the Scottish Government over the past twenty years. The notion of vulnerability was well-understood even though it was acknowledged that there was not as much focus on social vulnerability with regard to the local authorities' work on flood risk management. Vulnerability was mainly considered as the number of properties at risk. However, SEPA's methodology for identifying PVAs was well-recognised as all three local authorities are involved in Local Plan Districts where the draft Flood Risk Management strategies have been put to consultation.

None of the workshop attendees had previously encountered the term 'flood disadvantage' in the terms presented: '*Vulnerability has been one that people respond to…disadvantage I'm not sure, there is a question mark over that*' (The Scottish Borders Council).

It was noted that the language could therefore help to make direct links with work on inequality, particularly health inequality. However, while this is fairly well-developed in terms of Scottish policy: '*the use of the terminology is not new and we are still trying to work out how to translate it into practice*' (The Scottish Borders Council). The flood disadvantage assessment could therefore be usefully presented to public health representatives to feed into their work.

In the two local authorities where material deprivation is generally low (The Scottish Borders Council and Dumfries and Galloway), the framework allowed the identification of those who may not be in a difficult financial situation but have other issues that make them more vulnerable to flooding. Dumfries and Galloway raised the issue of fairly affluent retirees who move into attractive rural areas and within a few years of retirement become reliant on social care services, due to health issues and their social isolation from family. This emphasises that considering multiple factors contributing to vulnerability alongside material deprivation allows for a more comprehensive understanding of vulnerability.

Also, the participants broadly agreed that disaggregating the social vulnerability to flooding into sensitivity, ability to prepare, respond and recover, and exposure (enhanced) was a useful way of understanding the nuances of flood disadvantage.

Indicators and indices of vulnerability and disadvantage

Participants largely accepted the vulnerability indicators used in the assessment. There were no issues over the number of indicators or their selection. Some of the indicators required more explanation, for example the participants asked about the use of the number of domestic break-ins as an indicator for ability to respond to

flooding. One participant in Dundee suggested looking at single occupancy households (of any age) as those that may be more vulnerable to flooding due to having the sole responsibility for preparation and response to flood events. In Dumfries and Galloway, it was noted that the area has one of the highest levels of homelessness in Scotland, which is a real cause of concern from the point of view of social vulnerability; however, this issue is not picked up by the dataset. The paucity of information on the homeless poses a problem for mapping generally.

Further flood disadvantage assessments could usefully consider the presence of social infrastructure: for example, in Dundee, it was pointed out that the extremely high and acutely disadvantaged areas also had a low amount of community resources (e.g. schools, community centres, churches), which may further reduce the adaptive capacity of these areas. A representative from Social Work highlighted that it was important to identify the location of nursing and residential care homes. Whilst this information is to some extent captured in the current dataset through the indicator '*proportion of people living in medical and care establishments'*, future assessments could explicitly include the location of such institutions.

It was observed that analysing the flood impacts on commercial properties (particularly small businesses) would be useful, although this is outside of the scope of the current project. In addition, the indirect impact of flooding on the employment provided by affected businesses, in particular for casual workers or low-income groups, was thought to be an important angle in analysing flood disadvantage.

The insurance availability indicator relating to the number of properties built after 1st January 2009, which is a particular innovation in the current project, was received well. Whilst respecting the caveats, it was acknowledged that it was an intuitive (if crude) way of drawing attention to the areas containing properties that may be more difficult to insure: *'it certainly gives us something to work on'* (The Scottish Borders Council). However, in the other two authorities it was indicated that these buildings were made to be more resilient through urban design measures such as raising properties on stilts with car parking at ground floor level or inclusion of sustainable urban drainage systems (Dundee City Council); and that the Local Development Plan required 600mm minimum freeboard[14].

A number of reasons for properties built on flood plains after 1st January 2009 were suggested, including:

- Planning processes for these types of properties had been initiated long before they were constructed. This may mean that any flood risk assessment would have used earlier data that did not, for example, include surface water flooding.

[14] Freeboard is often defined as the difference between the flood defence level and the design flood level. It can also however be the difference between the design flood level and the finished floor levels of any development.

- There was a sense that there were many competing priorities besides flooding and planners often have to make pragmatic decisions.
- Elected members can go against the advice of their planning officers and approve planning applications.

Also, it was noted in one of the local authorities that the new coastal and riverside properties are relatively expensive and therefore are largely occupied by affluent, non-vulnerable people, thus not contributing to the overall flood disadvantage. Therefore, this indicator can be useful to highlight areas for attention but needs to be supplemented by local knowledge on the characteristics of the properties that have been built and the reasons why the development was given planning permission.

In Dundee and Scottish Borders the maps of hazard-exposure and social vulnerability to flooding broadly conformed to the local authorities' knowledge of the local area. Where local knowledge might differ, this was not necessarily a problem but a way of opening up discussions: *'In my experience of presenting such maps to stakeholders they immediately think how does this pertain to their experience on the ground (…) that may not match with what they know, but that's when you start to have the interesting conversations'* (The Scottish Borders Council).

The disaggregation of information from the high-level social vulnerability to flooding and flood disadvantage to individual indicators underpinning the assessment was thought to be particularly helpful: the dataset '*helps to understand what it means for a person living in Hawick'* (The Scottish Borders Council).

Contrary to this, the attendees in Dumfries and Galloway questioned the identification of areas as flood disadvantaged and indicated that it did not cohere with their knowledge. It was felt that the data sources led to a focus on the more urban areas of that local authority; the national data sources often fail to pick up the more fine-grained disadvantages in rural areas. For example, small pockets of extreme deprivation are often not highlighted and, similarly, the social isolation of some living in sparsely populated rural areas can be overlooked: *'statistics are very problematic for us…for data to be useful for us we need to know vulnerability at a smaller scale'* (Dumfries and Galloway). Therefore, whilst the methodology was not questioned, it became clear that the ability to supplement the data developed in this project with local information would be more useful.

Presentation of the maps

The visual immediacy of the maps was recognised to be a powerful tool and maps generated a high level of interest and discussion among the workshop participants. However, there were suggestions for improvement. For example, attention was drawn to the 'red, amber, green' colour coding for identifying areas as disadvantaged. It was felt that an area marked red may raise negative associations and the colour scheme may need to be revised[15]. Also, participants considered the

[15] The map colour scheme was revised in the final report.

presentation of the bar charts to be quite difficult to read and interpret although thought they were *'helpful'* once explained.

The majority of issues associated with maps were linked to the static character of maps. Participants were presented with hard copies that were limited in terms of the amount of information that could be presented. Participants expressed a wish to be able to zoom in to view the smaller data zones more clearly.

The ability to see different indices behind the maps was regarded as important in order to understand an area in detail. It was suggested that the different indicators used in the social vulnerability to flooding could be presented on maps as that medium is *'powerful'*. This is difficult to achieve on a standard, 2D map, but could be assisted if the map was presented on a spatial portal where users could see a separate call out box when, for example, they hovered over a particular area.

Therefore, a strong recommendation emerging from the meetings with local authorities is for the development of a spatial portal which would allow displaying selected layers of information and would bring together the underlying spreadsheets containing the data with the maps[16].

Potential use of the data

There was a strong recognition that the project outputs could support cross-departmental working – one local authority had already been making steps in that direction through linking local development and flood risk management together to a greater extent. Indeed, in the 24 hours following one workshop, confirmation was received that an attendee had contacted someone in another department regarding their learning from the presentation. At another workshop, the participants stated that this was the first time they had come together in order to discuss flood risk management issues.

One workshop indicated that the presence of a 'champion' within the local authority was crucial for taking the work forward and making connections between different departments. Therefore, identifying such individuals in local authorities and providing an opportunity for them to become familiar with the data produced could help to progress the consideration of flood disadvantage in local authorities.

Workshop attendees indicated that the dataset would be useful to emergency services to highlight areas for greater attention. For example, the emergency services need to know where people whose health and well-being may be affected by electricity shortages are (Dundee City Council). This dataset also helps to identify where people with limited support networks are.

[16] This has been addressed to some extent – web maps were created, presenting social vulnerability to flooding, flood disadvantage and hazard-exposure for the flood types and return periods considered in the project.

However, Dumfries and Galloway indicated that, in terms of community resilience, their social work department held a 'persons at risk' database and, in the event of a flooding, this could be used to prioritise who might need assistance before, during and after the flood. Thus, the maps and dataset '*would be of interest, but I am not sure [how] high up the agenda it would be*' (Dumfries and Galloway).

The use of maps as a way into community planning in order to open up discussions was positively regarded in one workshop. For example, landlords were identified as an important group who are: '*very much focussed about what goes on inside their properties, this provides a starting point to begin to get them to think about the wider picture…about how their properties relate to others*' (The Scottish Borders Council).

A number of participants highlighted potential challenges for them in terms of responding to questions regarding the identification of areas as flood disadvantaged when the maps are published. There was concern that elected members may also simply demand greater resources to be spent on particular areas. Thus, it will be important to ensure that elected members fully understand the data and its limitations. There needs to be a clear disclaimer attached to the mapping and datasets that highlights the broad nature of the work. The caveats need to be presented clearly and explicitly to the public. If used for wider public communications, the method of presentation would have to be changed to take into account the discrepancies between the data zone level statistics versus, for example, local knowledge of small-scale flooding.

Further support

In terms of further support, workshop attendees highlighted that a list of examples of how others have used the data would be incredibly useful. This could be also supported by the information of the use of data generated within the ClimateJust project for England. A set of easy to understand and simple recommendations and basic advice on 'what to do next' would also benefit the end users of the dataset.

Closer connections should be made between the maps of flood disadvantage generated in this project and SEPA's flood maps and the PVAs identified in NFRA, in particular considering the focus on catchment wide flood plans beyond the local authority. This is to some extent addressed in section 4.5., where the results of mapping social vulnerability to flooding and flood disadvantage are spatially analysed against the location of PVAs and areas identified as vulnerable with regard to human health.

5. Conclusions

5.1. Summary of the project findings

This report has presented the research carried out into the assessment of social vulnerability to flooding and flood disadvantage, based on the assessment framework developed by Lindley et al (2011). It is an update of an assessment of flood disadvantage carried out by Lindley and O'Neill (2013).The main changes are the incorporation of surface water flooding and defended flood extents, and the use of a reviewed set of indicators of social vulnerability to flooding. Therefore, the report moves the understanding of social vulnerability to flooding and flood disadvantage in Scotland forward by taking account of the most current data and stakeholder views.

The investigation into the flood hazard-exposure index confirms that flooding is a substantial risk in Scotland: just over 108,000 residential properties are estimated to be exposed to one or more sources of flooding of low probability (1 in 200 years including the impacts of climate change), with a minor number constructed since 1st January 2009.

The residential properties that may be exposed to flooding are spread across Scotland and nearly half of all data zones are exposed to flooding. Nonetheless, some of the local authorities have higher proportions of data zones exposed to flooding. For example Falkirk, the Orkney Islands and West Dunbartonshire have the highest average proportion of residential properties exposed to coastal flooding. Stirling, the Scottish Borders, and Perth and Kinross and Moray have the highest average proportion of residential properties exposed to river flooding. In Aberdeen City, Highland and Moray surface water flooding is likely to affect the highest proportion of residential properties.

The assessment of the levels of social vulnerability has revealed that just below 8% of all data zones are classified as having an extremely high or acute vulnerability to flooding. These are mainly located in large urban areas (Glasgow, Edinburgh, Dundee and Aberdeen). Social vulnerability has a strong urban focus: 73% of extremely or acutely vulnerable data zones are located in large urban areas and further 23% in other urban areas. However, extremely low vulnerability is also mainly present in cities: 79% of data zones classed as having extremely low social vulnerability to flooding are in urban areas. This emphasises the need for spatially detailed investigations into vulnerability to flooding and flood disadvantage, going below local authority or ward level, as larger spatial units may mask the differences in vulnerability and disadvantage.

Accessible countryside and accessible small towns (within a 30 minute drive time of a settlement of 10,000 or more people) were found to have the lowest levels of vulnerability, which may be explained by higher proportions of relatively wealthy, young and healthy people living within commuting distance from cities compared to

those living within the urban areas themselves. In contrast, remote small towns and remote rural areas emerge as having potential issues with social and physical isolation and mobility of people, which may raise concerns regarding the response to flood events in those areas. Coastal areas have also emerged as having higher levels of vulnerability than inland areas.

With regard to any type of flooding (1:200+cc), 3.6% of all data zones in Scotland can be classified as extremely (138) or acutely (98) disadvantaged. Extreme and acute flood disadvantage (from any type of flooding) may affect an estimated 100,000 people; over 28,000 of these people may be extremely or acutely disadvantaged in relation to coastal flooding. Over 60,000 people may be extremely or acutely disadvantaged in relation to river flooding, and 14,000 people with regard to surface water flooding. The scale of flood disadvantage suggests urgent action is needed to address the risks to highly vulnerable communities exposed to flooding.

When the distribution of flood disadvantage among local authorities is considered, Falkirk, West Dunbartonshire and the Orkney Islands have the highest percentage of data zones classified as extremely or acutely disadvantaged with regard to coastal flooding. Considering river flooding, Stirling, the Scottish Borders and East Ayrshire have the highest percentage of extremely/acutely disadvantaged neighbourhoods. However, the highest number of data zones with acute and extreme flood disadvantage with respect to river flooding are found in Edinburgh, Stirling and Highland, followed by Falkirk and Aberdeen. Glasgow presents the highest concentration of surface water flood disadvantage, with one-third of the extremely disadvantaged neighbourhoods (Figure 15). This is followed by City of Edinburgh and Aberdeen City. Flood disadvantage tends to be concentrated in urban areas; smaller urban areas (10,000 to 124,999 people) particularly contain a high proportion of extremely and acutely flood disadvantaged neighbourhoods.

The case studies for Dundee City, Dumfries and Galloway and Scottish Borders explored the results of the assessment of social vulnerability to flooding and flood disadvantage in more detail. The local authorities examined were supportive of the framework used and of the explicit links made between the vulnerability of communities and the hazard of flooding, as these issues tend to be considered in separation in local authorities' work. Also, the comprehensive approach to vulnerability assessment in the framework allows for identification of those who may not be in a difficult financial situation but have other issues that make them more vulnerable to flooding. In two out of three local authorities the data broadly reflected the participants' knowledge of where exposure and vulnerability coincide. However, fine-grained differences that were not picked up by the assessment at the data zone level were highlighted in the third local authority, emphasising the importance of using local knowledge against the maps developed using national-level datasets.

Nonetheless, the disadvantage assessment was thought to potentially support cross-departmental working on flood disadvantage; the results were also considered as useful to emergency services to identify areas where resources

should be targeted. The maps were considered to be a useful tool to open up discussions with communities.

To utilise the social vulnerability to flooding and flood disadvantage maps and information to their fullest, the case study local authorities highlighted the need to provide concrete examples showing how the dataset has been used. In addition, more explicit connections should be made between this project's maps of flood disadvantage, SEPA's flood maps and the PVAs identified in NFRA (for example, identifying where they overlap and where disadvantage is present outside PVAs, see also Figure 24) in order to support work on LFRMPs. Finally, presenting the results in a manner that would allow displaying selected layers of information and would bring the maps and the underlying spreadsheets containing the data together was suggested.

5.2. Related research

The results of the flood disadvantage assessment are consistent with the NFRA (SEPA, 2011) results. Nearly all of the acutely and extremely socially vulnerable and flood-disadvantaged data zones were located within PVAs, despite differences in the underlying data and methodology. Therefore, the results of the disadvantage assessment can be used to support Flood Risk Management Strategies developed for each of the 14 Local Plan Districts covering Scotland that take into account PVAs.

Also, the recent assessment of property level protection (PLP) for Scotland (JBA Consulting 2014) resonates with this study. PLP includes resistance measures, which aim to prevent water ingress (door guards and air brick covers for example), and resilience measures which reduce the damage costs should water enter a property (by elevating valuable goods or installing concrete floors). PLP was identified by JBA Consulting (2014) as a potentially fairer means of distributing scarce flood defence resources, which could be used:

- as an interim measure whilst a community is awaiting a larger flood defence scheme;
- in sparsely populated rural areas where it is difficult to justify the costs of capital works;

The JBA Consulting report identified the number of properties at risk of flooding in Scotland which might benefit from PLP as a cost-effective measure. However, the characteristics of communities and individuals may affect their ability to accept PLP in their properties or their implementation in a flood situation (Bichard and Kazmierczak, 2012).

When combined with the concepts underpinning this study, a number of targeted PLP policy initiatives may be identified:

- By identifying those areas where there are issues with the ability to prepare (particularly tenants and those who are not linked to the local area), there may

need to be more targeted information and awareness raising campaigns amongst vulnerable groups as they may be less linked to social networks or have a poorer knowledge of local issues.

- In addition, private and social housing landlords may need to be identified and worked with in order to implement these measures. Dumfries and Galloway, for example, works closely with a registered social landlord in order to integrate PLP measures in social housing.
- In terms of the ability to respond, PLP (particularly manual measures) rely on individuals and communities to operationalise them. Thus, individuals in poor health and those who are mobility-impaired may require assistance with manually deploying PLP. In addition, adequate and timely flood warnings should be in place to allow timely deployment of PLPs.
- PLP is less of an issue in terms of ability to recover.
- Enhanced exposure can be lowered overall should a property be fitted with PLP yet become poorly maintained over time as other water ingress routes may appear that are not covered by the PLP.

This project included exploratory research into the number of properties that may be exempt from insurance under Flood Re, i.e. those that have been constructed after the 1st of January 2009 (see section 3.3).The methodology used has a number of limitations and only allows for broad-brush estimates of the recent development in flood risk areas. However, this is the subject of a project commissioned by ClimateXChange (CXC), which aims to assess the rate of residential and non-residential property development in flood risk areas across Scotland over the past decade. The project is part of the overall Adaptation Indicators project. The project's remit includes the analysis of development rates in flood risk areas for different reference dates, considered also in relation to overall rates of development in Scotland over the period, to allow an understanding of the change in proportion of properties being developed in flood risk areas. The project will report its findings in August 2015.

Further, CXC has commissioned Land Use Consultants (LUC) to carry out a study of how current and future flood risk is being accounted for in land-use planning decisions in Scotland. This research will improve understanding of the effectiveness of national and local planning policy in ensuring new development is avoided in areas at risk of flooding. The project is focussing on the two stages of land-use policy: development planning and development management. The project will report its findings in Spring 2016.

5.3. Notes on the methodology

Whilst the methodology applied in this assessment addresses some of the shortcomings of the first flood disadvantage assessment for Scotland, it still has certain limitations. The assessment at the data zone level, whilst providing a useful picture for strategic planning and responses, aggregates the households by finding an average rather than identifying individual vulnerabilities. This may be

problematic in places where data zones are likely to contain communities of diverse characteristics, for example in rural areas, where the population density is low and data zones are large. Therefore, it is important that the outputs of this assessment are verified against and supplemented by local, up-to-date information in order to provide a finer-grain understanding of vulnerability, down to the level of individual households or people.

Also, certain groups which could be considered as very vulnerable are not included in this assessment due to data paucity, for example the homeless. Further, some of the data used is out of date and no alternatives are present: for example, census 2011 did not collect the information on the lowest level of dwellings, which is an important enhanced exposure factor. Thus, data from 2001 was used instead which may not accurately reflect the situation in areas that have undergone redevelopment in the last decade. More up-to date sources of information should be sought in future assessments. The Scottish Property Dataset, a national level property dataset commissioned by SEPA and used for the baseline appraisal of flood hazards was considered. However, it was not available to the project team within the timeframe of the project. In addition, whilst it provides information on the dwelling levels, a large proportion of properties are recorded as 'probable' rather than definite. Therefore, currently there seems to be no dataset available that would provide accurate information on the lowest property level.

Further, some of the properties located within flood risk areas may be equipped with PLPs and thus the impact of flooding may be reduced. Thus, we strongly encourage local authorities and service providers making use of the data to verify the dataset against locally sourced, up-to-date information on the property- or neighbourhood-level flood mitigation systems.

Nonetheless, to date, no methodological 'best practice' in assessment and mapping of social vulnerability to flooding and to climate-related events more broadly has been established (Preston et al., 2011). Therefore, this report makes a valid contribution to the understanding of social vulnerability to flooding and flood disadvantage in Scotland.

5.4. Recommendations

5.4.1. Policy and practice

This project has provided a strategic-level estimate of the numbers of people, residential properties and neighbourhoods associated with flood disadvantage, and the underpinning information on the factors influencing flood disadvantage. The high number of people (estimated 100,000) whose well-being may be adversely affected by flooding due to their personal, social and environmental circumstances, suggests that closer links should be made between policies related to flooding and health, aiming to reduce the impact of flooding on vulnerable communities.

The information on the concentrations of residential properties and neighbourhoods characterised by acute and extreme flood disadvantage can be used by SEPA to

provide additional information supporting Flood Risk Management Strategies for Local Plan Districts. Further, the data on flood disadvantage can be fed by the Lead Local Authorities into the LFRMPs that turn FRMSs into Local Delivery Plans.

The spatial distribution of flood disadvantage can be used to support or evaluate decisions made on flood risk investment. The recent Joseph Rowntree Foundation report suggests that in England there is not a strong link between those local authorities which contain the most flood disadvantaged neighbourhoods, and levels of planned expenditure on flood protection (England and Knox, 2015). Therefore, the information on flood disadvantage can assist with targeting national investment into flood-risk areas in Scotland in a socially-just manner. Based on the findings, two areas require particular attention: the acute and extreme disadvantage in coastal urban areas and reducing the risks associated with physical and social isolation of communities in remote towns and rural areas (see section 4.3. for particularly flood-disadvantaged local authorities).

The flood disadvantage data could be used to increase preparedness for emergencies. Regional Resilience Partnerships can utilise the data to support the development of Community Risk Registers. The data can additionally assist community groups in the development of Community Emergency Plans.

Based on the results of the exploratory research into the number of recently built residential properties in flood risk areas (all caveats considered), it is recommended that the findings, in combination with the forthcoming reports commissioned by ClimateXChange (see section 5.3), are used as a basis to develop regulations and guidance for local authorities that would tighten development control at the local level and minimise the rates of development in flood risk areas.

There is currently no data available on the presence of PLP measures in either new developments or existing residential properties in flood risk areas. It is recommended that a project is commissioned to estimate the current levels of provision of flood resistance and resilience measures. A feasibility study with a view to developing a property flood resilience database for insurers has been funded by Innovate UK and is carried out by the Building Research Establishment (with Lexis Nexis and AXA Insurance). In addition, recording the presence of SUDS in residential developments by SEPA (in line with the requirements of the FRM Act) would help to understand better the levels of their exposure to flooding.

The increasing number of people renting rather than owning their houses in Scotland, and the high number of tenanted properties in some of the flood risk areas, calls for regulations on the provision of information on the risk of flooding provided by the landlord to the tenant. Also, tighter flood insurance regulations for rented properties are needed. In the meantime, local authorities with a particularly high number of rented properties should provide information on the risk of flooding to tenants and what measures can be taken.

For local authorities, mapped flood disadvantage provides a useful framework for planning actions in anticipation of the increased risk of flooding (e.g. redevelopment that alters the use of the ground floor to minimise damage if a flood happens) and developing recovery strategies in the aftermath of flooding (e.g. targeting financial assistance to groups least likely to have flood insurance).

Further, the extensive set of indicators compiled in the vulnerability assessment may be used by various departments to identify areas for action. For example, areas with high proportions of older people living on their own could be targeted for development or re-siting of day centres for elderly, whilst places with low mobility levels and poor physical access could be considered for 'ring and ride' services.

It is recommended that local authorities actively collaborate with third-sector organisations that may support local communities in the event of flooding. This is particularly important in remote rural areas and remote small towns, which have a relatively higher presence of locally-focused charities, to increase the self-help potential of the communities that may include physically or socially isolated individuals. Also, in inner-city areas, particularly within more deprived locations or those that are currently being regenerated, there are currently fewer locally-focused community organisations. It is important to ensure that some community resources are located in these areas to help social networks develop and provide a focal point for the community in the case of flooding.

SEPA can use the dataset developed in this project to assess where flood disadvantage is present outside their current flood warning target areas. The locations with high disadvantage should be prioritised as those where the flood warning service is needed the most. Also, the information about the characteristics of the community (e.g. the number of people not speaking English, number of people who have moved in recently from outside the local area, number of people with limiting long-term illnesses) could guide the manner in which flood warnings are provided. The areas of high disadvantage falling outside the current PVA boundaries could be considered by SEPA against the candidate PVAs for the next cycle NFRA.

Some inconsistencies were found in the flood data provided by SEPA, whereby the higher probability, lower magnitude flood extents are not completely within the lower probability, higher magnitude flood extents. It is recommended that SEPA within its Flood Map development plan reviews the flood data in order to identify the reasons for these inconsistencies and address them in future revisions of flood maps.

How the dataset, maps and report are used by local authorities and other decision-makers should be monitored. The case study local authorities consulted within this project emphasised the need for examples of how the information can be used. It is recommended that the Scottish Government devises a method of collecting information from local authorities on their use of the datasets produced in this project.

Case study local authorities strongly recommended development of an online spatial portal to enable the display of selected layers of the information developed in this project. Such a spatial portal should bring together the underlying spreadsheets containing the data with the maps, together with comprehensive guidance materials. Climate Just (www.climatejust.org.uk) contains an example of such a spatial portal. It would be optimal if the online maps allowed locally available (potentially sensitive and confidential) data to be incorporated into the assessment of social vulnerability to flooding and flood disadvantage in order to enhance the results. Also, the datasets developed in this project could usefully complement the information provided on SEPA's NFRA website[17].

Further recommendations for actions on reducing flood disadvantage can be found in the Climate Just online resource: www.climatejust.org.uk.

5.4.2. Further research

It is recommended that future research on mapping social vulnerability and flood disadvantage in Scotland includes data that was not available within this project. Such data might include:

- Estimates of the number of homeless people and rough sleepers as one of the most vulnerable groups in relation to extreme weather events;
- Data on flood-related insurance claims in order to identify areas with probable high insurance premiums;
- Up-to-date information on the number of properties with the lowest dwelling level at ground floor or in the basement. This could for example be based on the Scottish property dataset, or similar;
- Information on the number of houses equipped with PLP measures (both resistance and resilience) for inclusion in the enhanced exposure index;
- More direct measures of social networks.

Further, whilst this research considered a number of indicators in the assessment of social vulnerability to flooding and flood disadvantage, they are considered independently of each other. Indicators identifying interconnected problems or the most disadvantaged groups (e.g. identifying older people with health problems living in one-floor properties or private tenants that are on low incomes) would be helpful in carrying out the future assessments of vulnerability and disadvantage.

It is important to consider the fine-grained variability in levels of social vulnerability to flooding and flood disadvantage utilizing local knowledge. Even using relatively small Census units, e.g. compared to a similar analysis for England where geographical units were ten times larger, some of the case study workshop participants still felt that the spatial units and the use of national sources used led to a focus on the more urban areas within their local authority. In their view, national

[17] http://map.sepa.org.uk/nfra/map.htm

data sources often fail to pick up the disadvantages found in rural areas. Therefore, supplementing the national-level data with locally available information is crucial to progressing the understanding of flood disadvantage.

Exploring the future dimension of flood disadvantage is important for adequate planning of flood risk management. Therefore, it is advised that in further flood disadvantage assessments, the data on flood risk that includes climate change impacts is complemented by future projections of demographic and socio-economic characteristics of communities. Considering different scenarios of socio-economic development could be helpful to explore the potential futures. An analysis of ongoing and retrospective temporal changes in flood disadvantage would be helpful in identifying the direction of change and building scenarios.

In addition, the impact of flooding on businesses providing employment for local communities was considered to be important for future assessments by the case study workshop participants. This is because temporary closure of affected businesses, or even the withdrawal of employers from a flood-risk area, may have significant consequences for people relying on them for work. Easily laid-off casual workers or low-income groups may be amongst those most affected. Also investigating the impact of flooding on Small and Medium-size Enterprises (SMEs) was considered an important angle to social vulnerability assessment, in particular in areas with a high proportion of people working in SMEs, as these businesses tend to be under-insured and rarely have contingency plans (Crichton, 2006).

Whilst the scope of this research was limited to assessing the levels of flood disadvantage, further research could usefully include the analysis of the resources available to manage flood risk. It is recommended that the distribution and resources of emergency services are reviewed in this respect. Mapping of rest centres and other social infrastructure that could be used locally in response to flooding and in the recovery phase would offer an additional layer of information. In addition, understanding of community responses, e.g. the distribution of flood groups or the presence of active flood wardens, could provide valuable information. Finally, it is important to check whether the investment in flood risk management follows the areas with high social vulnerability and flood disadvantage.

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How to access background or source data

The accompanying methodology report, available on the Scottish Government website, provides further detail on the data used for this research. Please contact socialresearch@gov.scot for further information.

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