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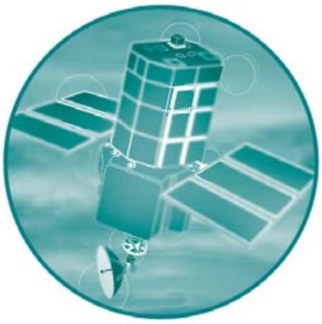
Flood and coastal erosion risk management
R&D Programme



Flood Warning for Vulnerable Groups:
Measuring & Mapping Vulnerability

R&D Technical Report W5C-018/4

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Department for Environment Food and Rural Affairs

Environment Agency

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Publishing organisation

ISBN: 1 84432 421 4 May 2005
Product Code: SCHO0505BJBV-E-P

Dissemination Status
Internal: released internally External: released to public domain

Statement of use
This report provides us with information about those groups most vulnerable to flooding. It considers their vulnerability in terms of their awareness of being at risk and their ability to respond to and recover from a flood event. The information helps us to target messages to these vulnerable groups to help them prepare for a flood event. It provides useful supporting information for planning communications with and flood warning services for the most vulnerable groups.

Keywords
flooding; flood warning; vulnerable; older people; parents; children; tenants; mapping; socio-economic; flood recovery

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EXECUTIVE SUMMARY

This technical report has been prepared as part of the outputs from the 'Flood Warning for Vulnerable Groups' project commissioned by the Environment Agency.

The first report comprises an overview of the literature covering issues of social inequality in natural hazard research. The second report presented the findings from a re-analysis of BMRB Surveys conducted on behalf of the Agency either as part of their annual programme of public surveys ('At Risk' Survey) or following a flood specific event ('Post Event' Survey). The third report presents the results of a qualitative enquiry into vulnerability with regard to flood warning awareness and response and vulnerability during a flood event.

This final, technical report provides a review of attempts to measure and map vulnerability to environmental hazards; a consideration of the potential for mapping vulnerability to flood risk in the UK and an illustration of the importance of selecting an appropriate areal unit of analysis.

Measuring Vulnerability
This section provides a review of existing literature on the construction of vulnerability indexes. Key conclusions are that all attempts to devise vulnerability indices for flood risk must begin by identifying the purpose of the index and for vulnerability indices to be useful, there must be an underlying conceptual model, a fixed set of tested indicators, and existing data that can be easily updated.

The Potential for Mapping Vulnerability and Exposure to Flood Hazard
This section identifies available data which could be used to create and map an index of vulnerability to flooding in the UK. When considering natural hazards and the effects they may have on the populations at risk, we need to consider two factors;

$ The nature and likelihood of exposure to the hazard: the vulnerability of place; the 'unsafe' place.
$ The characteristics of the affected populations and their ability to recover from such a hazard (i.e. the vulnerabilities of the population)

With regard to vulnerability to flooding the indicative floodplain maps supplied by the Agency could be used to estimate the vulnerability of place component of the risk equation, and the following census derived variables for the vulnerability of the population:

$ Census-derived variables: Area level deprivation indices, specifically the Jarman Index of Deprivation
$ Census derived variables: Area level classifications, specifically the GB Profiles

Methodological Considerations in Mapping Vulnerability
This section provides an illustration of the importance of choosing an appropriate areal unit of analysis in any attempt to map vulnerability to flooding.

Two methods were used to identify 'at risk' populations:

$ Area statistics of 'at risk' populations were aggregated to the UK Census enumeration districts (ED)
$ Population grid models which aggregated data to 200m grid squares (Martin 1989).

The two methods were compared and found to provide very different estimates of the percentage of households within floodplains,

$ The ED method found 30 % of households are in Enumeration Districts that either are within or intercept the floodplain
$ The population grid model shows only 9% of households were within 200m grid squares which intercept the floodplain

In addition the two methods furnish entirely contradictory results about the relationship between social class and likelihood of exposure to flood risk. The grid method indicates that those in lower social classes face an increased likelihood of exposure to flood risk, whereas the ED method suggests the exact opposite:

$ Using the grid method: in England and Wales, households in social class 1 and 2 are 8% less likely to be exposed to flood risk than the rest of the population and households in social class 4 or 5 are 9% more likely to be exposed to flood risk than the rest of the population
$ Using the ED method: in England and Wales, households in social class 1 and 2 are 11% more likely to be exposed to flood risk than the rest of the population and households in social class 4 or 5 are 3% less likely to be exposed to flood risk than the rest of the population

The analysis demonstrates the considerable effect that the choice of areal unit can have on statistics about the relationship between socio-economic status and exposure to environmental risks. We suggest that the grid method provides a more reliable method of assessing this relationship for three reasons:

$ The analysis is at a finer scale
$ The results produced by this method have 'face validity' that is they are supported by the body of existing research on the relationship between socio-economic status and exposure to environmental risk
$ the results produced by this method very closely match the Environment Agency's figures of the number of households at risk from flooding

1. INTRODUCTION

Conventionally in the disaster literature, risk is seen as a function of the physical, social, economic and environmental processes and factors, which increase the susceptibility of a community to the impact of hazards moderated by the resources and capacity of that community to cope in the event of a disaster (ISDR 2004). A disaster occurs when the numbers of people affected, and the impact on everyday life, both physical, structural and financial, is of such a magnitude that they are unlikely to be able to recover without external aid. Blaikie and others (Blaikie, Cannon et al. 1994; Wisner, Blaikie et al. 2003) have developed a comprehensive model of the factors and processes leading up to a disaster which, at the micro-level, may be expressed thus:

$$Risk \equiv Hazard \times \frac{vulnerability}{resources}$$

Here, the risk is of a disaster which is dependent on the characteristics of the hazard, moderated by the characteristics of the at-risk population and their access to resources which offset the effects of the hazard. In this model, people are vulnerable, places are 'unsafe'.

Thus when considering natural hazards and the effects they may have on the populations at risk, we need to consider two factors;

- Firstly, the nature and likelihood of exposure to the hazard - the vulnerability of place, the 'unsafe' place.
- and secondly, the characteristics of the affected populations and their ability to recover from such a hazard - ie. the vulnerability of the population - the resilience and coping strategies of individuals and/or communities.

Considering the exposure to flood hazard, there are five million people at risk from flooding in England and Wales and two million homes at risk (Environment Agency). This however, is not a static risk. Not only is the size of these vulnerable areas (floodplains) increasing due to the effects of global warming, especially in coastal areas, but more people are being placed at risk by moving into these 'unsafe' areas. According to a press release from the Council of Mortgage Lenders, 11% of all new houses built between 1997 and 2000 were built in areas defined as at-risk from flooding (Council of Mortgage Lenders, 6th June 2002). Whether one section of the population has an increased likelihood of exposure to flood hazard is debatable. Recent research for the Environment Agency (Walker, Fairburn et al. 2003) found no disproportionate distribution of the population in the lower (more deprived) deciles residing within the fluvial floodplain of England, although there did seem to be a relationship between more deprived ward populations and flood hazard in the tidal floodplains.

So, it may be that different sections of society are experiencing differential exposure to hazard by physically living in 'unsafe' or vulnerable areas but there is also evidence that this initial risk is compounded by even greater inequalities when we consider the social characteristics of those people and how they cope and recover *after* exposure to hazard. Research has shown that the speed of recovery from such a flood event and the potential for subsequent ill-health, both physical and mental, is often disproportionately borne by the very old, the disabled and the poorer individuals and communities (Buckle, Marsh et al. 2000; Enarson and Fordham 2001). In the short term, not only may poorer people be less likely to have available financial resources to cover them during such an emergency but they are often less able to carry on with their jobs if they are temporarily displaced from their homes. In addition, poorer people are less likely to be insured and therefore less likely to be able to recover all their lost assets or rebuild their damaged homes with the consequent physical and psychological stresses involved (Enarson and Fordham 2001). Even at the community level this disadvantage is felt where poorer communities are less likely to have the political voice to engage in community reconstruction. The adverse impacts of flooding are disproportionately felt even long after the original disaster event.

Vulnerability may be considered as the exposure to a given risk and the ability to cope within a framework of various social, spatial and temporal contexts. Thus conceptualised, vulnerability embodies two components; an initial 'external' exposure to risk, in this case flood, followed by a second, 'internal' phase which relies on the individuals', groups' or societies' resilience in the face of threat. An analysis of flood vulnerability may thus be seen as an analysis of difference not only in exposure to initial risk but also in coping strategies, both to be researched at the individual, group and community levels. In this context, resilience is not seen as the reverse of vulnerability but as mitigating circumstances which may attenuate the impact of the initial loss. This report discusses the measurement and methodological considerations in assessing the initial exposure to risk and of identifying the 'at risk' population.

2. MEASURING VULNERABILITY

This section discusses the measurement of vulnerability and highlights the necessity of embedding any measurement within a conceptual model of 'social vulnerability'. The work of three research teams from the UK, USA and Australia is presented and the potential uses made of 'vulnerability indices' discussed.

Hazard prediction of the occurrence and impact of initial external flood risk has been the main focus of research and public policy over many years, resulting in the establishment of building codes, warning systems and the building and maintenance of flood defences. The vulnerability of the communities who are exposed to these risks however, has only recently been the focus of attention.

Before one can measure community vulnerability however, one needs to define it in order to develop indicators. In addition, the indicators themselves are only a means to an end which also needs defining. In this section we discuss previous theoretical frameworks for community vulnerability and discuss how these indices were utilised.

2.1 Indicators of vulnerability

Many socio-economic and demographic characteristics have been identified as indicators of vulnerability. King summarises those factors (Exhibit 1) which are generally agreed to contribute to community vulnerability (King and MacGregor 2000):

Exhibit 1 Significant socio-economic and demographic characteristics

The very young
The very old
The disabled
Single parent households
One person households
Newcomers to the community and migrants
People lacking communication skills and language skills
Low income earners

Source: Keys, 1991; Salter,1995; Granger 1993, 1995; Buckle, 1995; Smith, 1995; Blaikie et al 1994 in King 2000

Most of these variables are readily available from Census data and with the ease of access, power of computing facilities and availability of statistical software and geographic information systems, the statistical and spatial analysis of such variables is relatively easy to carry out.

King recognises however, the considerable problems associated with simply using such variables as indicators and stresses the importance of the development of a theoretical framework to structure the analysis and to answer the research question(s) (King and MacGregor 2000). He also emphasizes the importance of developing conceptual models first and then developing indicators. In other words, the conceptual model drives the development of the indicators *not* the other way round. The creation of a "vulnerability index" is only a means to an end and what that "end" may be must be clear from the beginning.

Thus King argues that in the creation of any community vulnerability measures:

< social indicators should not be developed without an underlying conceptual model

< a standardised working model should rely on a fixed set of tested indicators

< such a model must be based on existing data that can be easily updated

2.2 Conceptual models of vulnerability and risk management

Following King's (2000) goals for good practice, the next section will explore models and measures of vulnerability that have been developed by three research groups.

2.2.1 Flood Hazard Research Centre

The Flood Hazard Research Centre have carried out extensive research into assessing vulnerability to flooding (Penning-Rowsell and Fordham 1994) (Green 1995) and have developed a sophisticated model of vulnerability of households to flooding (Exhibit 2). Clearly, the measurement of such a model of vulnerability would be a very complicated statistical task with many concepts requiring indicators. It is also important to note that this model is a model of the *household* vulnerability rather than a measure of community vulnerability, and has been developed from the perspective of the individual's and the household's experience of disaster rather than that of the susceptibility of the community.

It is interesting that in Green's attempt to calibrate their model he found that the extent and type of social support received by victims of flooding seemed to have no effect whatsoever on the victim's reported stress or extent of disruption caused during a flood event.

$$\mathbf{vulnerability} = f(\ [A / HSICEI_n]\ ,\ [S_cS_bI_t/S_t]\ ,\ [T_fD_cD_tS_dS_sWVP_1R]\ ,\ [1 / W_cW_tW_a]\ ,\ [T_fR_aR_q]\ )$$

where Socio-economic Characteristics of household

A	age profile
H	health staus
S	household savings
I	Household income
C	cohesiveness of community
E	expectations of flooding
I_n	Prior information

Property and infrastructure

S_c	susceptibility of contents to damage
S_b	susceptibility of building structure to damage
I_t	time taken to restore infrastructure
S_t	Number of stories

Community support

T	time taken for assistance to arrive
R_a	extent of assistance
R_q	quality of assistance

Flood characteristics

T_f	timing of flood
D_e	depth of flood
D_t	duration of flood
S_d	sediment concentration
S_s	sediment size
W	wave. wind force
V	velocity of flood water
P_1	pollution of flood waters
R	rate of rise of flooding during onset

Warning characteristics

W_o	Whether warning received
W_t	warning time provided
W_a	advice content of warning

Exhibit 2 Flood Hazard Warning Centre Model

Further research by this group has resulted in the development of a proposed Social Flood Vulnerability Index (SFVI) (Tapsell, Penning-Rowsell et al. 2002) using 1991 Census data aggregated to the enumeration district level. This proposed measure is a composite additive index based on three social characteristics and four financial factors. The rationale for an item being included in the index was based on previous qualitative research. The financial factors, based on the Townsend Index, include the following 1991 Census variables: unemployment, overcrowding, non-car ownership and non-home ownership. And the social factors, also 1991 Census variables, include: the long-term sick, single parents and the elderly. The rationale and measurement of these components are described in Exhibit 3, based on a table from the original research.

Exhibit 3 Components of the Flood Hazard Research Centre's SFVI

Census Variable	Rationale	Measurement	Weighting	Trans-formation
Unemployment	These four factors define the 'financial' factors of the SFVI and were chosen because they focus on deprivation outcome (such as unemployment) rather than any particular social group. The financially deprived less likely to have flood insurance.	Unemployed over 16 as a % of all economically active residents over 16	0.25	$\mathrm{Log}_n\,(x+1)$
Overcrowding		Households with 1+ person per room as a % of all households	0.25	$\mathrm{Log}_n\,(x+1)$
Non-car ownership		Households with no car as a % of all households	0.25	Square root
Non-home ownership		Households not owning their own home as a % of all households	0.25	Square root
The long-term sick	Previous FHRC research has shown that post-flood morbidity is significantly higher where the victims suffer from pre-existing health problems	Residents suffering form limiting long-term illness as a % of all residents	1	Square root
Lone parents	Previous FHRC research has shown that lone parents tend to have less income and are less able to cope with flood impact	lone parents as a % of all residents	1	$\mathrm{Log}_n\,(x+1)$
elderly	Epidemiological research has shown that over the age of 75 there is a sharp increase in incidence and severity of arthritis (and other conditions), conditions sensitive to damp conditions likely following a flood event	Residents over 75 as a % of all residents	1	$\mathrm{Log}_n\,(x+1)$

The authors map the SFV index in the floodplains surrounding Manchester and Maidenhead and clearly demonstrate, using chloropleth maps, that the community 'at risk' in Manchester is more 'vulnerable' than that living around Maidenhead. Although such visual inspection is of value at an exploratory level, data needs to be summarised to enable comparisons to be made between areas.

2.2.2 Cutter's (1996) Hazards of Place model of vulnerability

Cutter developed a hazards of place model to interrelate biophysical and social vulnerability in Georgetown County, South Carolina in the USA (Cutter, Mitchell et al. 2000). (Exhibit 4).

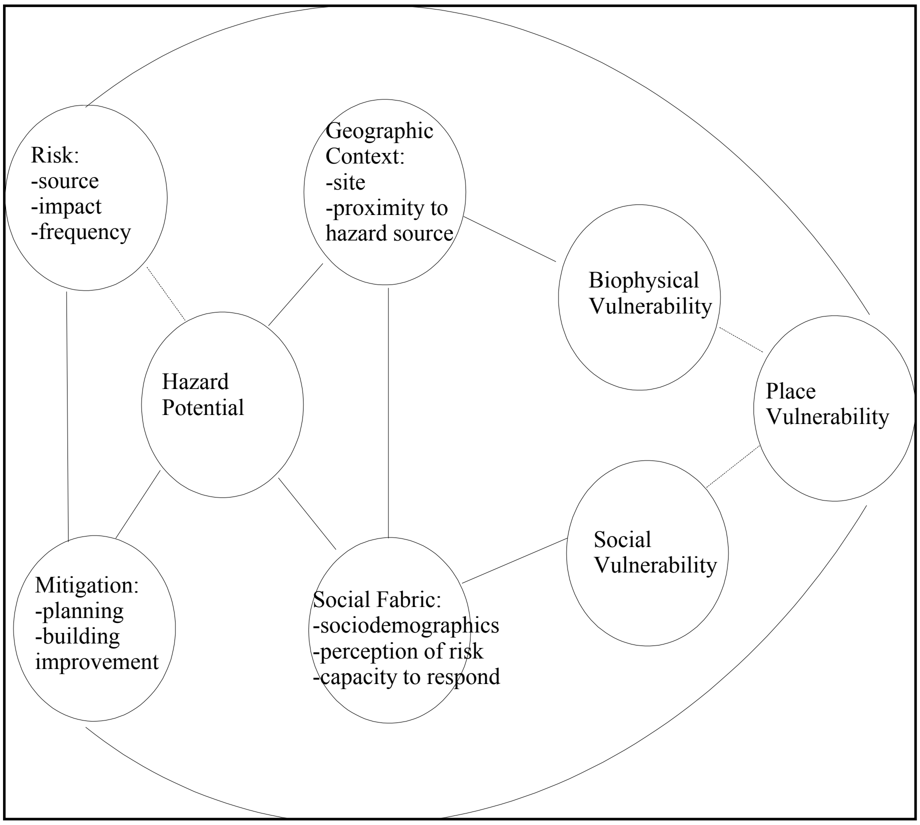


Exhibit 4 Hazard's of Place model of vulnerability

Indicators were developed for the last three factors, biophysical vulnerability, social vulnerability and place vulnerability to operationalise their conceptual model. Biophysical vulnerability was measured by the event frequency and delineation of hazard zones. Social vulnerability was measured by the socioeconomic and demographic variables seen in Exhibit 5. Place vulnerability was a measure of the interaction between biophysical and social vulnerability.

Exhibit 5 Cutter's (2000) measures of social

Characteristic	**Variable**
Population and structure	Total population Total housing units
Differential access to resources/greater susceptibility to hazards due to physical weakness	Number of females Number of non-white residents Number of people under 18 Number of people over 65
Wealth or poverty	Mean house value
Level of physical or structural vulnerability	Number of mobile homes

The data used was the 1990 US Census, and the areal unit of analysis was the census block. The proportion of the numbers of each social variable in each census block out of the total number for the county were determined to create "index" scores for each characteristic. Then a composite “social vulnerability” score was created by summing each characteristic’s “index score”. This aggregate measure was used to create a “social vulnerability” map.

Biophysical vulnerability maps, as defined by hazard zones, and the “social vulnerability” maps were then combined within a GIS. To create an overall hazard vulnerability map, the product of the two index scores (social and biophysical) were calculated to assess “place vulnerability”. Using this method Cutter found that areas of high biophysical vulnerability did not necessarily coincided with census blocks that demonstrated high “social vulnerability”.

Finally Cutter demonstrated that for these vulnerability maps to be meaningful they needed to be placed within social and infrastructural context which may emphasize the location of particularly vulnerable communities or “choke” points in potential evacuation routes . Thus the locations of social structures, such as day centres, hospitals and schools, were overlaid onto the “place vulnerability” maps along with the locations of roads, railways, bridges, utilities and evacuation/ response facilities. This analysis highlighted that many lifelines such as police and fire stations and schools were located in highly vulnerable places

Cutter has more recently developed a 'Social Vulnerability Index' (SoVI) for the whole of the US based on 1990 Census data (Cutter, Boruff et al. 2003). Utilising the hazards of place model of vulnerability and concentrating on the social vulnerability component, 42 independent variables were initially selected from the US 1990 Census as indicators of vulnerability aggregated to the county level. These 42 variables were reduced to 11 factors through factor analysis and are reproduced in Exhibit 6. The first three factors explain 35.5% of the variance between the counties and are concerned with personal wealth, age and the density of the built environment.

Exhibit 6 Cutter's (2003) dimensions of social vulnerability

Dimensions of Social Vulnerability

Factor	Name	% Variance Explained	Dominant Variable	Correlation
1	Personal wealth	12.4	Per capita income	0.87
2	Age	11.9	Median Age	-0.9
3	Density of the built environment	11.2	No. Commercial establishments/mi^2	0.98
4	Single-sector economic dependence	8.6	% employed in extractive industries	0.8
5	Housing stock and tenancy	7	% housing stock that are mobile homes	-0.75
6	Race- African American	6.9	% African American	0.8
7	Ethnicity- Hispanic	4.23	% Hispanic	0.89
8	Ethnicity - Native American	4.1	% Native American	0.75
9	Race- Asian	3.9	% Asian	0.71
10	Occupation	3.2	% employed in service	0.76
11	Infrastructure dependence	2.9	% employed in transportation, communication and public utilities	0.77
		76%		

Source: (Cutter, Boruff et al. 2003)

To create the SoV index, the 11 factor scores for each county were simply added together creating a scale where positive scores indicated higher levels of vulnerability which were then mapped. The geographic distribution of the SoVI by US county showed that those exhibiting higher social vulnerability tended to be in the metropolitan counties in the east, south Texas and the Mississippi delta while the counties rated as least vulnerable clustered in New England, the eastern slopes of the Appalachians and the Great Lakes states. As with the SFVI of the UK Flood Hazard Warning Centre research, this indicator is based solely on decennial Census data giving a 'snap shot' of social vulnerability and is very similar to the deprivation scores created from the UK Census which will be described later.

2.2.3 Granger's (1999) Multi-Hazard Risk Assessment in Cairns, Australia

The Cairns multi-hazard risk assessment is part of the *Cities Project*, set up in 1996 by the Australian Geological Survey Organisation to investigate mitigation of the risks posed by a range of geohazards faced by urban Australian communities (Granger, Jones et al. 1999). The conceptual model underlying their understanding of the process of risk management is outlined in Exhibit 7.

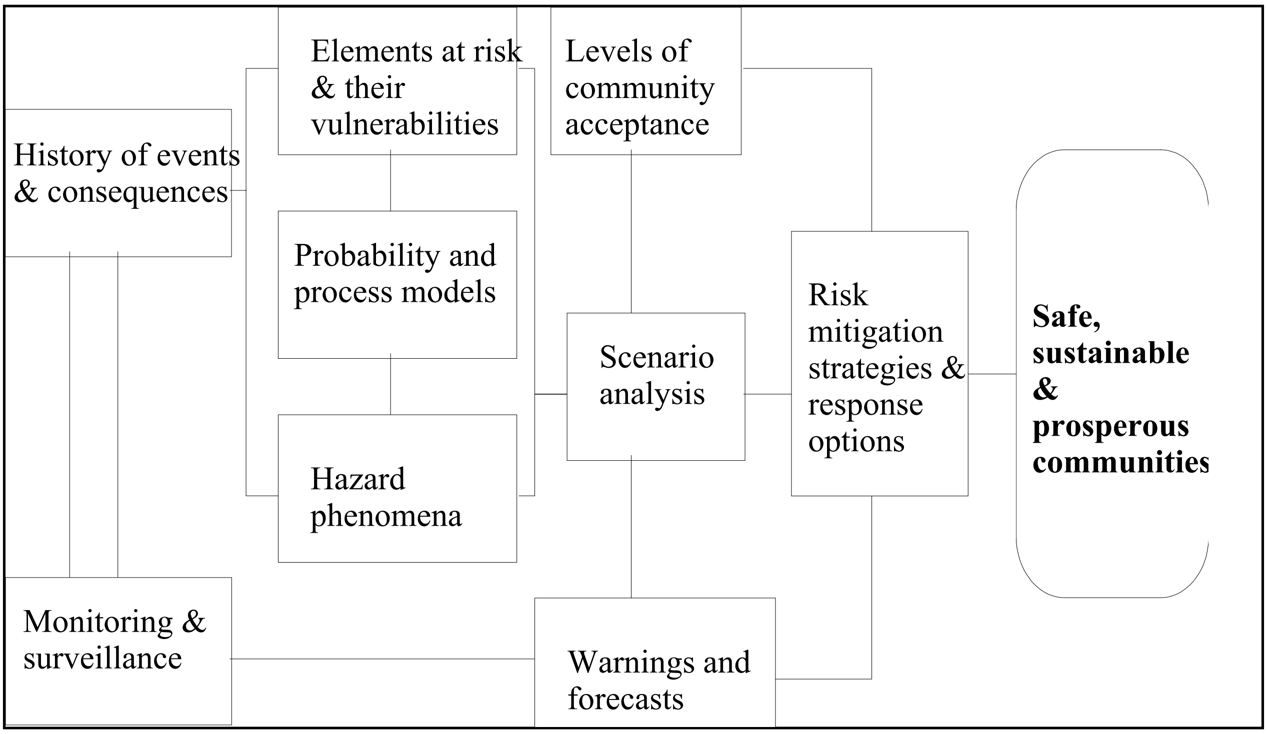


Exhibit 7 The *Cities Project* understanding of risk management

Source: Granger (1999)

To operationalise their conceptual model, Granger (1999) developed a view of total risk summarised by the following expression:

$$Risk_{(Total)} = Hazard \times Elements\ at\ Risk \times Vulnerability$$

The first two elements of this expression are relatively easily quantifiable in terms of more precise prediction of occurrence and magnitude of hazard and in terms of the number of buildings and facilities. Vulnerability, however, is many faceted and is reflected in what Granger termed his "five esses" approach, incorporating composite measures for the setting, shelter, sustenance, security and society. For each suburb-level composite measure Granger summed the ranks for each suburb on each individual variable in that composite measure (see Exhibit 8) and then expressed it as a percentage of the maximum possible rank sum. This way he obtained a ranking of the contribution made by each suburb within the community on each facet of vulnerability in relation to the overall community vulnerability on that facet. He then created an overall composite ranking to determine the relative contribution made by each suburb to overall community vulnerability. Granger was then able to map a "community vulnerability" profile. To complete the risk assessment for each hazard (cyclone, flood and earthquake), "hazard exposure profiles" were combined with the "community vulnerability" profile to create a series of "total risk profiles" for each potential hazard.

It is important to recognize, however, that Granger's analyses aimed to measure the relative proportion of risk born by each suburb within his area of research. The areal unit used to define each suburb, probably driven by the convenience of available Census data, was the Census Collection District (CCD). In the South-East Queensland region Granger used in his study, there were 3219 CCDs, of typically 200 households each.

Exhibit 8 Granger's composite measures for Community Vulnerability

Setting	Shelter	Sustenance	Security	Society
Terminal facilities (ie. Airports)	# Houses	# Logistic facilities (those that handle store or distribute food, fuel or other essential commodities)	Public safety (ie. # ambulance, fire, police etc. facilities)	Community facilities (ie. # libraries, churches, schools etc.)
population	Average House occupancy	# Water supply facilities	# Business premises	Families with 3+ dependents
Population density	# Flats	# Power supply facilities	Relative Socio-economic disadvantage (SEIFA index)*	Single parent families
gender ratio	Average Flat occupancy	# Telecommunications facilities	Index of Economic Resources (SEIFA)*	Visitors
	Residential ratio	Lifeline length (ie. Total road length)	Proportion of people under 5	Index of Education and Occupation (SEIFA)*
	Road network density		Proportion of people over 65	New residents
	# Cars		Proportion of rented accommodation	No religious adherence
	Households with no car		Unemployment	Elderly living alone

* Australian Bureau of Statistics Socio-economic Indicators for Areas

2.3 Use made of "vulnerability indices"

A key reported use of "vulnerability" indices is to provide inventories of hazard areas and of vulnerable populations providing essential data for pre-impact planning, damage assessment and postdisaster response. However, the geographic level at which the data is collected has implications on how useful the data really is. The vast quantities of data available in a GIS may sometimes give a false sense of knowledge about a local community . At the more local level the data becomes increasingly unreliable which emphasises the importance of grass roots knowledge in any flood awareness strategy.

Social vulnerability indices, such as those proposed in previous research generally result in a map which relies upon the assessment and subjective opinions of the viewer to deduce the differing levels of social vulnerability in the different shades of a chloropleth map. Yet, if a *comparison* of 'social vulnerability' between areas is an aim in this work (ie. between areas in the floodplain and areas outside the floodplain), then a logical consequence to these maps would be some form of quantification of these indices aggregated to the areas of research interest. This aggregation of data and the choice of aggregation unit is the topic of discussion below.

The indices described in the previous research are explorations of 'community vulnerability' - aggregate scores for areas; census area boundaries, which in all probability, bear no relationship to the 'community' boundaries. In addition, most scores rely on a simple addition of possibly weighted individual components with no consideration of any interaction between the components. Clearly social vulnerability is a very complex and multi-faceted concept which we believe cannot easily be subsumed under one measure. Areas may be declared vulnerable to flooding where several physical and geographical factors contribute to an expression of the likelihood and severity of a flood event happening in that area. People, though, display many different and interdependent vulnerabilities which are not so easily measured with available data. For instance, an area with a high proportion of lone pensioners may indeed score highly on a 'social vulnerability index', but if the same area also has a good social network and support system, this factor should mitigate and reduce social vulnerability. The social context of the areas' perceived 'vulnerability' is of vital importance; not just its material circumstance. This though, is not to say that such measures are without value, they are the best available indicators we have at present and as such, research should be continued in their development.

Another problem to consider in the development of any social vulnerability indicator is the 'ageing' of the data, an important factor where so many of the component of the indicators are taken from the decennial census. People move and people change. The model of the recently released Office of the Deputy Prime Minister (ODPM) Index of Multiple Deprivation (IMD 2004) and its predecessor, the Department of the Environment, Transport and the Regions (DETR) IMD 2000, which used several imputed mid-year estimates, could provide a useful methodological steer in the development of a model of social vulnerability, possibly using data simulation, to deliver a 'social vulnerability index' on demand.

3. THE POTENTIAL FOR MAPPING VULNERABILITY AND EXPOSURE TO FLOOD HAZARD

Clearly, the creation of a 'social vulnerability' index is very complex and the choice of components, while based on previous research findings, still seems to be a matter of data convenience. This next section considers the potential value of available data for mapping vulnerability to flooding in the UK but emphasises the descriptive characteristics of those 'at risk' rather than the creation of a composite measure. We consider that communities display many different vulnerabilities which are sometimes better understood as discrete, intuitive measures rather than as a composite score on a vulnerability scale.

3.1 Data available for measurement of "community vulnerability"

King (2000) provides a very useful table (reproduced in Exhibit 9 below) that shows the types of data that may need to be collected in order to create a comprehensive measure of community vulnerability.

Exhibit 9 Sources of indicators for measuring components of community vulnerability

Level of data collection	Population Characteristics	Hazard Attitudes	Behaviour and Preparation	Community and Values
Individuals	Census	Quantitative Survey	Quantitative & Post disaster Survey	Qualitative Research
Family/Household	Census	Quantitative Survey	Quantitative & Post disaster Survey	Qualitative Research
Community	Census	Quantitative Survey	Quantitative & Post disaster Survey	Qualitative Research

Source: (King and MacGregor 2000)

As can be seen from Exhibit 9, data informing public attitudes, behaviour and community values are not directly available from census data, and would generally require targeted surveys and interviews. King maintains that although much research has been conducted developing indicators of "community vulnerability", mainly using Census variables, it is vitally important that the relationship between "community vulnerability" and awareness and preparedness can be established through targeted surveys and qualitative research (King 2001).

The Environment Agency 'At Risk' and 'Post Event' Surveys are examples of just such targeted surveys. The data collected provide a useful picture of attitudes to flood warning and awareness within sampled areas and can provide very useful indicators of vulnerable populations, at least in measures of their awareness to, preparedness of and actions during flooding. For the data to be linked to the census data for their local area however, survey respondents would need to be geographically referenced (ie. by postcode or grid reference) and this is often not possible, for reasons of confidentiality.

3.2 Characterising those 'at risk'

While the previous research discussed may be seeking one value for a measure of community vulnerability, exploration of the factors that may make up such a measure provide a useful exercise in characterising those 'at risk' and should be the first step in considering any composite measure. The following section discusses sources of data that may go into a community vulnerability measure but in themselves provide a certain insight into the 'at risk' population. Thus this section discusses the three stages of this research:

- Identification of 'at risk' areas
- Identification of 'at risk' populations
- Exploring the social characteristics of the 'at risk' population

3.3 Identification of at-risk areas

The Environment Agency 1 in a 100 year return indicative floodplain maps and flood warning maps, which show areas serviced by the Environment Agency, were used to identify at-risk areas. These maps are only *indicative* of flood risk and as such, it has been argued, do not display the total at-risk areas (Brown and Damery 2002). For instance, these floodplain maps only show tidal and main river flood areas and do not include areas potentially at-risk from storm drain or secondary river sources. Conversely, they may include areas that because of the local topology are located well above the highest flood tide but are included as at-risk areas on the larger scale maps. Despite these limitations, these data are the most complete available for research although more precise flood maps are currently being developed (Environment Agency Flood Maps, 7th October 2004).

Floodplain maps may be understood to demonstrate the extent of areas 'at risk' from flooding but naturally include large areas of unpopulated terrain. The Environment Agency has also developed Flood Warning maps which indicate the extent of 'at risk' areas which are covered by the flood warning system. Exhibit 10 shows the Environment Agency, 1 in 100 indicative fluvial and tidal floodplains and Exhibit 11, the flood warning areas. Clearly, examination of Exhibits 10 and Exhibit 11 demonstrate that areas serviced by the Environment Agency are much smaller than that covered by the floodplains.

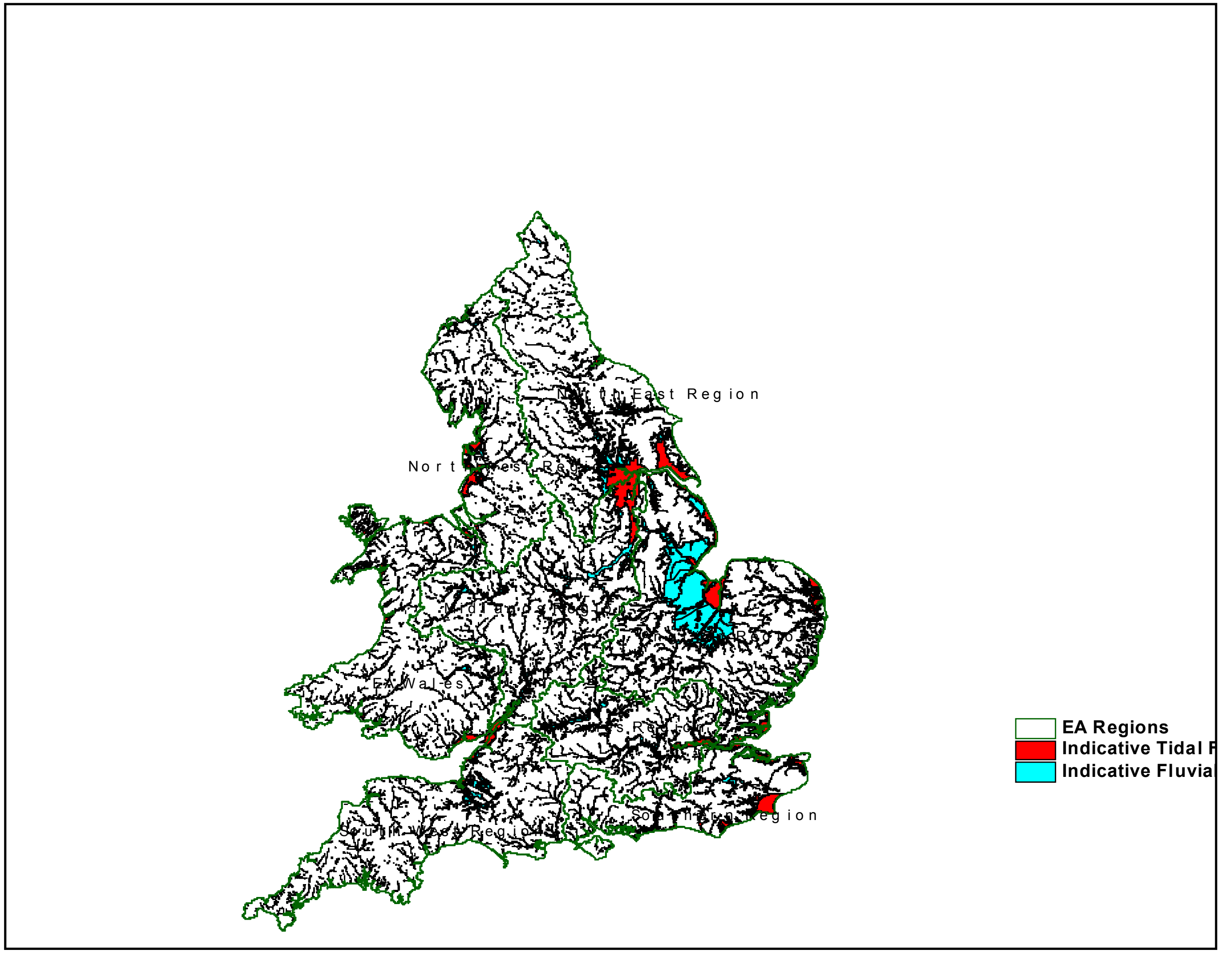


Exhibit 10 One in a hundred Year Return Indicative Floodplain

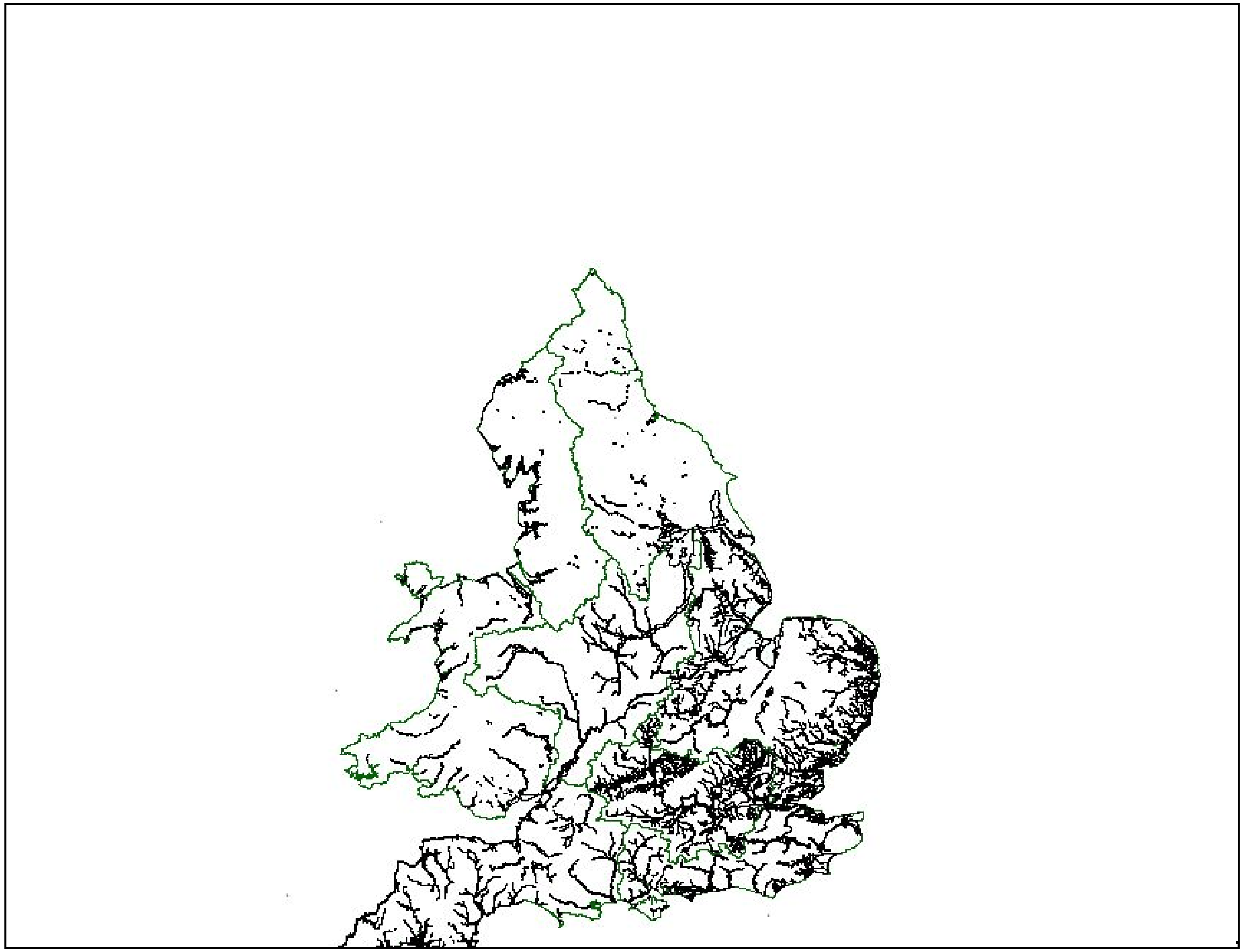


Exhibit 11 Flood Warning Areas in England and Wales

Exhibit 12 Percentage of Enumeration Districts within each Environment Agency area within the Indicative Floodplain or Flood Warning

Environment Agency Region	No. of EDs	% of EDs within* each EA Region in 1/100 Indicative Floodplain	% of EDs within* each EA Region in Flood Warning areas	% EDs overall in Floodplain	% EDs overall in Flood Warning Areas
Anglia	12374	46	38	16	20
Midlands	17688	31	14	15	10
North East	15205	31	12	13	8
North West	14231	25	6	10	4
Southern	9516	29	25	8	10
South West	9237	44	34	11	13
Thames	24332	28	28	19	29
Wales	6895	50	24	9	7
OVERALL	109478	34	22		
				100%	100%

* Note that minimal overlap of the EDs with the boundaries of the Floodplain or Flood Warning area resulted in inclusion.

3.4 Identification of 'at-risk' populations

At risk populations were initially identified by a simple intersection of enumeration districts within both the floodplain and flood warning maps. Enumeration districts were chosen as the areal unit since this was the smallest unit to which the 1991 census area statistics were aggregated.

Exhibit 12 displays the percentage of the total Enumeration Districts in each Environment Agency Region within the floodplain and within the flood warning areas. We see that while half of all EDs in Wales are in the floodplain, only a quarter of them are included within the flood warning areas. Similar reductions are seen in most areas, presumably reflecting populated areas where the flood warning systems operate. The difference between the percentage of enumeration districts within the floodplain and flood warning areas in the Thames and Southern Regions is reduced since these are relatively densely populated areas.

One caution needs to be expressed when considering this data however, which is that even if a small part of an ED overlapped with the boundaries of the floodplain, this caused the inclusion of that ED as within the floodplain. This issue of the use of enumeration districts as the unit of analysis is addressed subsequently and alternative methods of defining 'at risk' populations are proposed in a later section.

3.5 Exploring the social characteristics of the 'at risk' population

In the previous report (Secondary Analysis of BMRB data) we presented the results of a regression analysis of the 2001 "At Risk" and "Post Event" surveys collected by British Market and Research Bureau (BMRB) which showed that the factors is Exhibit 13 decrease the level of awareness.

Exhibit 13 Indicators of awareness to flooding

In "at risk" area	AND	(in order of impact) the following factors decrease awareness..
		Not been flooded before
		Social Class C, D, E
		Renting accommodation
		New to area (moved into the area in last year)
		Not Environment Agency serviced
		Not working
		Under 45 or over 55

In this report we argued that the lower one's 'awareness' about some kind of danger, the more one is vulnerable to it. We could extend that argument to suggest that the variables identified in our analysis as decreasing awareness could be measuring "social vulnerability". However, as we have previously stressed, the BMRB surveys did not include questions which may have had significant impact on awareness levels. For instance, questions concerning the family structure and presence of children were not asked. Neither were there questions about ethnicity (although there was a question about first language).

In this section we explore some of these characteristics of the 'at risk' populations by using standard composite measures derived from the 1991 Census data.

Thus the following data sources were explored:

! Census derived variables: Area level deprivation indices, specifically, the Jarman Index of Deprivation.
! Census derived variables: Area level classifications, specifically, the GB Profiles

In the following section, we further explore the characteristics of 'at risk' populations through the concept of social class. Thus we used:

! Census Area Statistics, specifically, social class of head of household

3.6 Data availability: Census data

It can be seen from the above models of vulnerability to hazard that many of the indicators rely on census data. This is perhaps not surprising considering the availability of the data at such small geographical units whose collection would otherwise entail a very costly and time-consuming exercise. However, there are several factors to be assessed before considering using such data. The first of these is the age of the data. In the UK, the last census was the 2001 census and data has now just become available, although analysis presented here has been conducted with the 1991 census. Secondly, thought should be given to the areal unit of measurement chosen for analysis. The smallest areal unit for which census data is available in the UK is the Enumeration District (ED), to be directly compared to the Census Collection District in Australia and the Census Block in the US. The ED was historically defined as the workload of a single census enumerator and originally was inhabited by approximately 200 households /approx 500 people. However, due to boundary changes and population migration, this approximation is no longer true. Enumeration Districts are not homogeneous and have a wide range of population densities. Some of these problems associated with the Enumeration District are expected to be resolved with the release of the UK 2001 Census area statistics where a new geographical basis for area statistics has been developed called the *output area*. The output area will be based on the automated mapping and aggregation of unit postcodes which will be optimised for statistical purposes, probably on the basis of tenure. This will give rise to 280,000 output areas in the UK which will contain 100-125 households in England & Wales & 50-80 households in Scotland.

3.6.1 Measures derived from the Census: *Measures of deprivation*

A readily available indicator, generally derived from Census data, is that of multiple deprivation. Such measures have traditionally been used by governments to explore multiple deprivation in order to target resources, assuming that deprivation is spatially determined. Deprivation however, is a controversial concept and may be construed to mean anything from poverty to inequality. It is important to be aware of the conceptual framework behind the construction of any measure to use the measure appropriately. These composite measures use a battery of variables which fall into two groups. Variables such as car ownership or presence of basic facilities, are more direct measures of deprivation while variables such as the percentages belonging to 'at risk' or vulnerable groups may be seen as more indirect measures of deprivation. The variable components and weightings of two indicators of multiple deprivation, the Jarman and the Townsend indicators, are outlined in Exhibit 14. These indicators were not necessarily originally devised to measure deprivation but are now used as such in many research situations. One measure, the Townsend indicator, composed entirely of equally-weighted directly measured variables, is a measure of the levels of material deprivation. While the Jarman Underprivileged Area Score, based on several weighted indirect measures, such as proportion of lone parents, is a General Practice workload measure. It was not originally constructed to measure deprivation but was derived from GPs subjective expressions of social factors in their patients that effected their workload. However, the Jarman index does contain several of the variables identified by previous research to contribute to 'social vulnerability' and will be explored below.

Exhibit 14 Constituent variables of the deprivation indices and their respective weightings

Social Variable	Jarman	Townsend
Unemployment	3.34	1
Overcrowding	2.88	1
No Car	-	1
Not Own Occ	-	1
Lone Pensioners	6.62	-
Single Parents	3.01	-
New Commonwealth	2.5	-
Children < 5	4.64	-
Low Social Class	3.74	-
One Year Migrants	2.68	-

(Jarman 1984’ Townsend, Phillimore et al. 1988)

In addition, the then Department of the Environment, Transport and Regions(DETR) developed an index of multiple deprivation in 2000 (IMD 2000) whose domains and weightings are seen in Exhibit 15. This measure has recently been updated by the Office of the Deputy Prime Minister (ODPM) and new domains added in the IMD 2004 (IMD 2004). The inclusion criteria, specified by the ODPM was that the variables

> '(s)hould be 'domain specific' and appropriate for the purpose (as direct as possible measures of that form of deprivation); measuring major features of that deprivation (not conditions just experienced by a very small number of people or areas); up-to-date; capable of being updated on a regular basis; statistically robust; and available for the whole of England at a small area level in a consistent form' .

All these are features of a well constructed 'vulnerability index' and the possibility of exploring the IMD 2004 or subdomains of the same should be further investigated in any 'vulnerability index' although it will be important to be aware of the conceptual framework around their construction. The IMD 2004 has many advantages over its predecessor, the IMD2000, not least because it is aggregated to smaller areas; Super Output Areas (SOA's) of between 1000 to 3000 population compared to the ward-based measure of the IMD2000 where the populations could range from 800 to 35,000.

For reference the specifications of the variables included in the DETR IMD 2000 and IMD 2004 are reproduced in Appendices 1 and 2 respectively.

Exhibit 15 Domains and Weightings for the IMD 2000 and IMD 2004

	IMD 2000	IMD 2004*
Income	(25%)	22.5%
Employment	(25%)	22.5%
Health Deprivation and Disability	(15%)	13.5%
Education, Skills and Training	(15%)	13.5%
Housing	(10%)	
Geographical Access to Services	(10%)	
Barriers to Housing and Services		(9.3%)
Crime and Disorder		(9.3%)
Living Environment		(9.3%)

*http://www.odpm.gov.uk/stellent/groups/odpm_urbanpolicy/documents/page/odpm_urbpol_028471.pdf

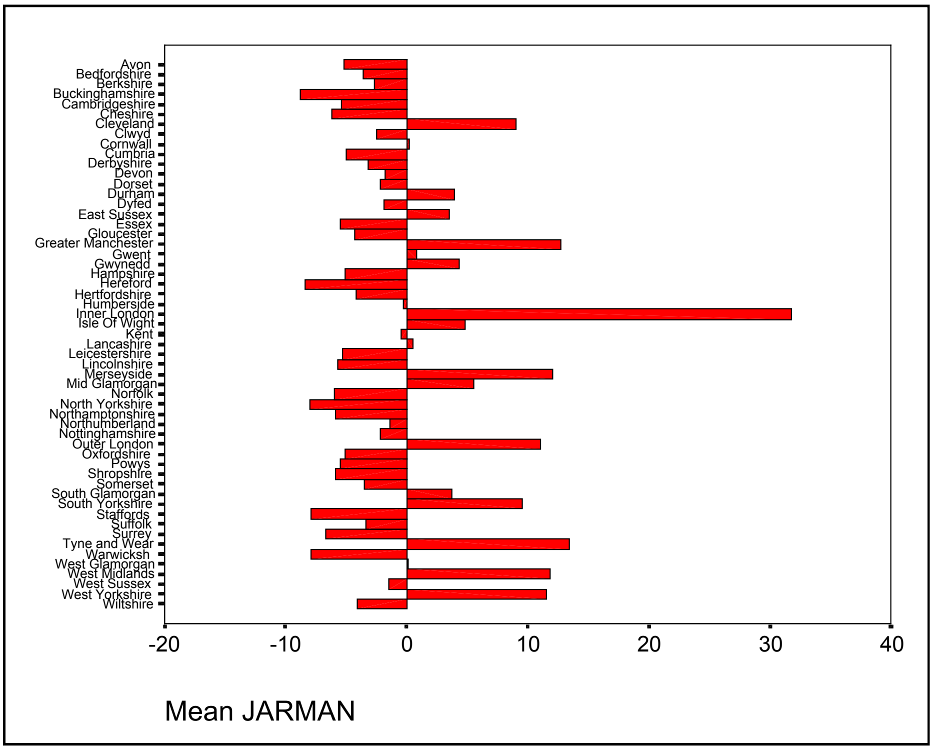
The Jarman Index of Deprivation
Using data taken from the 1991 Census of Population Local Base Statistics (LBS) for 9,363 wards in England and Wales (Shipping Wards were excluded), the Jarman index (Jarman 1984) was created using the variables and weightings in Exhibit 16

Exhibit 16 The Jarman Index of multiple deprivation

Characteristic	1991 Census variables
1. Unemployment -	unemployed residents aged 16+ as a proportion of all economically active residents aged 16+
2. Overcrowding -	persons in households with 1 and more persons per room as a proportion of all residents in households
3. Lone pensioners -	lone pensioner households as a proportion of all residents in households
4. Single parents -	lone 'parents' as a proportion of all residents in households
5. Born in New Commonwealth -	residents born in the New Commonwealth as a proportion of all residents
6. Children aged under 5 -	children aged 0-4 years of age as a proportion of all residents
7. Low social class -	persons in households with economically active head of household in socio-economic group 11 (unskilled manual workers) as a proportion of all persons in households
8. One year migrants -	residents with a different address one year before the Census as a proportion of all residents

The Jarman index seems particularly appropriate as a measure of 'social vulnerability' since it included several of the indicators identified by previous research. The standardised index ranges from minus 46 (low deprivation) to 66 (high deprivation) with a mean of zero. Exhibit 17 demonstrates the mean Jarman index for all counties in England and Wales. Clearly, there is a very wide range of area deprivation with Inner London being the most deprived area and Buckinghamshire, the least deprived using this measure. At a local area level, the Jarman index, aggregated to Census ward is presented in Exhibit 18 for one of the project sample sites (Woking, in the Thames Environment Agency Region). Clearly, the darker shading of the Sheerwater and Central and Maybury wards highlight them as the most deprived wards in Woking, although neither are in the floodplain. In fact, it seems that the floodplain transverses some of the more moderately deprived areas but whether these are built-up areas is not possible to tell from these maps.

Exhibit 17 Mean Jarman scores for counties in England and Wales



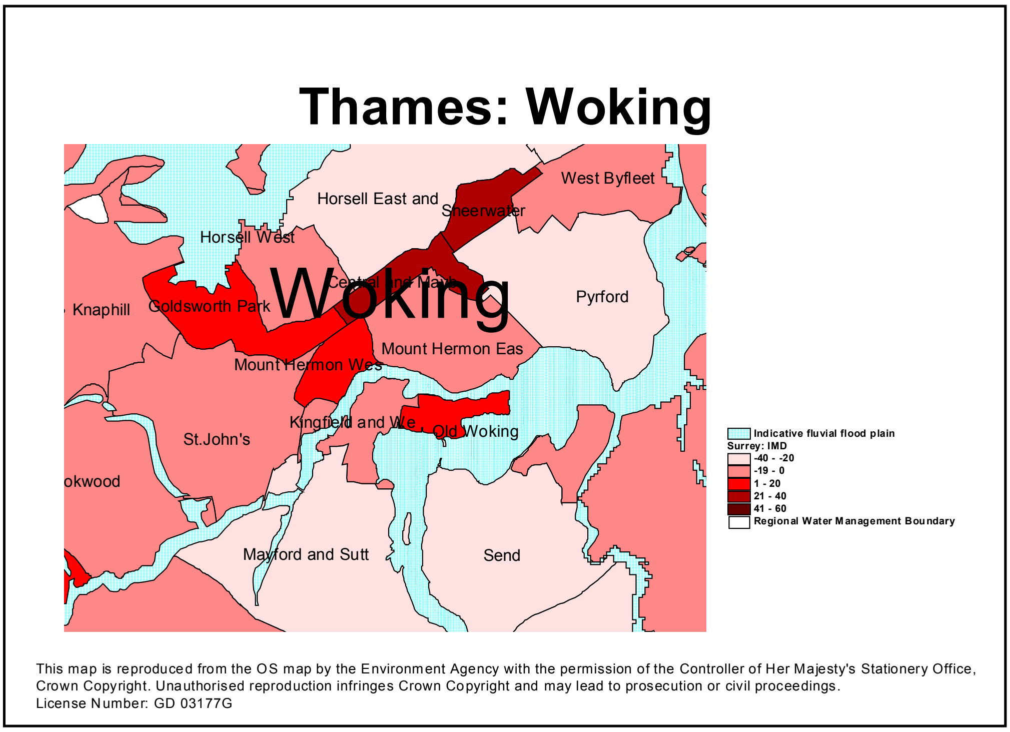


Exhibit 18 Jarman index of deprivation: Woking, Thames

3.6.2 Measures derived from the Census: *Area Classifications*

Area classification has been a popular tool for market researchers for many years and seemed another data source worth exploring to characterise 'at risk' populations.. The ACORN classification and Experian GB Mosaic classification are two such examples. However, in the academic field, (Openshaw 1994) developed an area classification, called GB Profiles, by using a neuroclassification procedure on eighty census variables. Openshaw developed 10 cluster, 49 cluster, 64 cluster and 100 cluster classifications. The classification in Exhibit 19 is based on the 10 cluster classification.

Exhibit 19 Ten cluster solution developed for GB Profiles

1 Struggling; Multi-ethnic Areas - Pensioners & single parents - high unemployment - LA rented flats
2 Struggling; Council Tenants - Blue collar families & single parents - LA rented terraces
3 Struggling; Less Prosperous Pensioner Areas - Retired blue collar residents - LA rented semi's
4 Struggling; Multi-ethnic Areas; Less Prosperous Private Renters - Young blue collar families with children - privately renting terraces & bedsits
5 Aspiring; Academic Centres & Student Areas - Young educated white collar singles & couples - privately rented bedsits & flats
6 Aspiring; Young Married Suburbia - Young well-off blue collar couples & families - mixed tenure terraces
7 Climbing; Well-Off Suburban Areas - Young white collar couples & families - buying semi's & detached houses
8 Established; Rural Farming Communities - Mature well-off self-employed couples & pensioners - owning or privately renting large detached houses
9 Prospering; Affluent Achievers - Mature educated professional families - owning & buying large detached houses
10 Established; Comfortable Middle Agers - Mature white collar couples & families - owning and buying semi's

The following analysis using area classifications is presented an another exemplar of a means to characterise the 'at risk' population. It was initially conducted at the county level, including an examination of the area classifications in England and Wales, within and without the indicative floodplains. This was then followed by an closer examination of two Environment Agency Regions (Exhibit 20), the Thames Region and the North East Environment Agency Region. Finally, area classifications were mapped for both these areas for visual inspection (Exhibits 21 and 22).

Exhibit 20 Percentage of Census Enumeration Districts in each area classification within the floodplain and Flood Warning Areas

	Floodplain		Flood Warning Area		
Area Classification	% EDs Not in FP	%EDs in FP	% EDs Not in FWA	%EDs in FWA	Total % EDs
1.00 Struggling; Multi-ethnic Areas - Pensioners & single parent	6.7%	4.7%	5.9%	6.5%	6.0%
2.00 Struggling; Council Tenants - Blue collar families & single	9.8%	4.9%	9.0%	5.1%	8.2%
3.00 Struggling; Less Prosperous Pensioner Areas - Retired blue c	13.0%	7.7%	12.5%	6.8%	11.3%
4.00 Struggling; Multi-ethnic Areas; Less Prosperous Private Rent	3.2%	1.4%	2.9%	1.5%	2.6%
5.00 Aspiring; Academic Centres & Student Areas - Young educated	10.8%	6.9%	9.3%	10.1%	9.5%
6.00 Aspiring; Young Married Suburbia - Young well-off blue colla	14.6%	12.9%	14.1%	13.9%	14.1%
7.00 Climbing; Well-Off Suburban Areas - Young white collar coupl	7.3%	6.0%	7.2%	5.6%	6.9%
8.00 Established; Rural Farming Communities - Mature well-off sel	10.7%	31.5%	14.5%	29.0%	17.6%
9.00 Prospering; Affluent Achievers - Mature educated professional	8.1%	13.6%	9.3%	12.2%	9.9%
10.00 Established; Comfortable Middle Agers - Mature white collar	15.8%	10.3%	15.2%	9.3%	14.0%
	100%	100%	100%	100%	100%
Total Number of EDs	72017	35558	84254	23321	107575
Percentage of Total EDs	66%	34%	78%	22%	100%

Exhibit 20 shows that overall, 34 percent of the EDs in England and Wales are within or intersecting the indicative floodplain. But by far the greatest proportion of classifications within the floodplain are those EDs classified as ‘established rural farming communities’. In fact three times the proportion of EDs in this classification are in the floodplain than are not. The only other area classification whose proportion of EDs in the floodplain exceed those that are not are those classified as ‘prospering affluent achievers’. For comparison, the percentage of EDs within flood warning areas (22% of EDs overall) is also presented in Exhibit 20. Here the results mirror those obtained for the floodplains, except that in addition, those areas classified as 'struggling multi-ethnic areas-pensioners and single parents' and those classified as' aspiring academic centres' both show marginally greater likelihood of EDs within the flood warning areas. These results are a first indication that some 'at risk' vulnerable populations are disproportionately represented in 'at risk' areas, especially in flood warning areas.

Following analysis of England and Wales, area classifications in two contrasting Environment Agency Regions are compared below. Exhibits 21 and 22 show the percentage of EDs in each area classification in the Thames and North East Environment Agency regions.

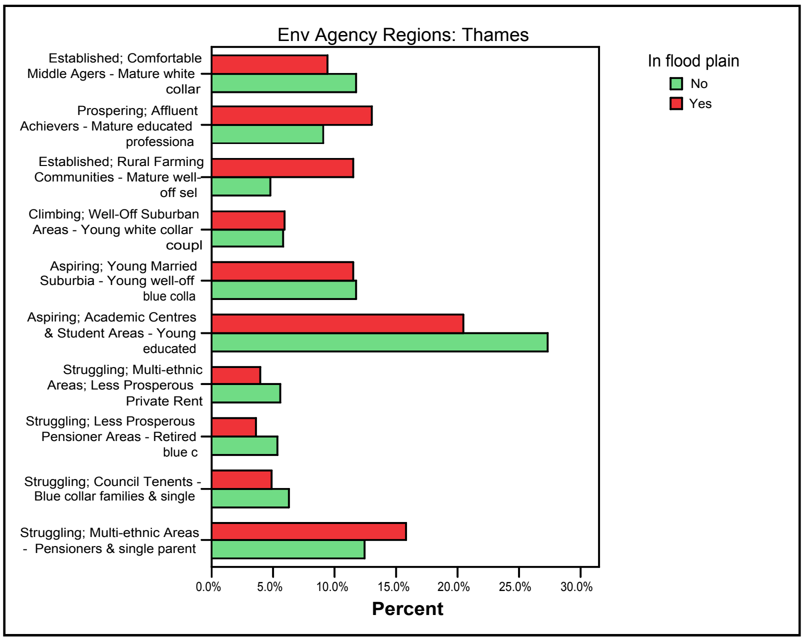


Exhibit 21 Area classifications of Enumeration Districts within the Thames Environment Agency Region

Source: Census 1991

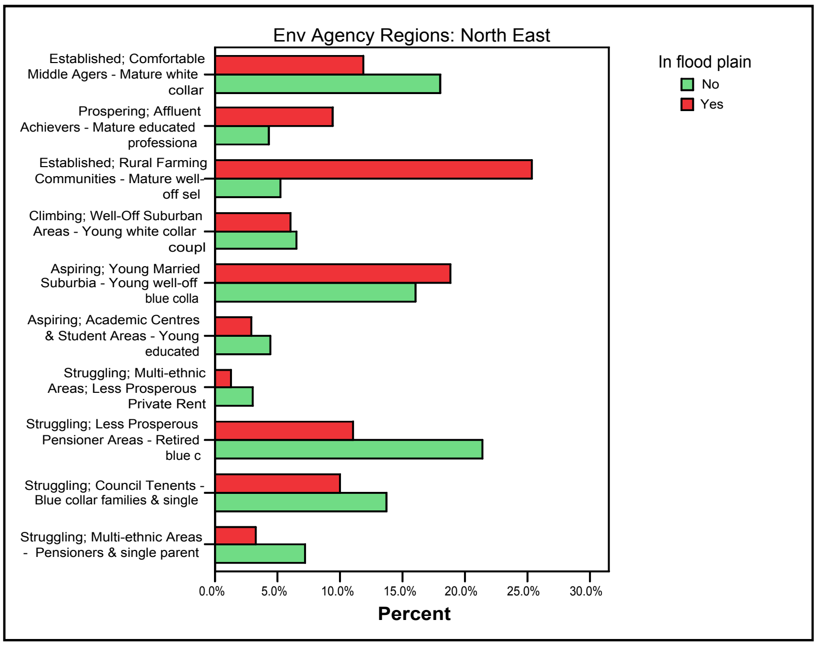


Exhibit 22 Area classifications of Enumeration Districts within the North East Environment Agency Region

Source: Census 1991

To understand these charts, we can compare the height of each pair of bars within each classification. Thus, the Thames region contains a greater percentage of EDs classified as 'aspiring academics' than any other classification but more of these EDs are not in the floodplain (27% compared with 20% in the floodplain). However, the percentage of EDs within the floodplain does *exceed* the percentage not in the floodplain in those EDs classified as 'struggling multiethnic: pensioners and single parents', 'prospering affluent achievers' and 'established rural farmers'. So is appears with this analysis that there maybe a certain social bias of those living in floodplain at both ends of the social spectrum.

In the North East Region, while there are greater percentages of EDs classified as 'struggling', than in the Thames region, each of these classifications shows greater proportions of EDs not in the floodplain. Clearly, the greatest proportion of EDs in the floodplain in the North East are those classified as 'established rural farming communities' followed by 'aspiring young married'. As with the Thames region, the 'prosperous affluent achievers' are also disproportionally represented within the floodplain. However, this analysis was conducted using Enumeration Districts as the basic areal unit and classification of these areas as 'in the floodplain' and therefore 'at risk' was defined if *any* part, no matter how small, of the ED intersected the indicative floodplain maps. This method tends to overestimate those areas' at risk' and therefore caution must be exercised before any conclusions may be drawn. An alternative, and possibly more accurate, approach of capturing 'at risk' populations will be discussed later in this report.

Mapping area classifications

Exhibits 23 and 24 display the area classifications *for EDs in flood warning areas* in two contrasting regions of England and Wales. Exhibit 23 shows the urban 'at risk' areas of Stockbridge near Keighley in the North East Environment Agency region to be classified as 'struggling private renters', although much of the surrounding rural area in the floodplain is more affluent. In Exhibit 24, Woking, in the Thames Environment Agency region, most of the enumeration districts within the flood warning area are classified as relatively affluent, although some 'at risk' town centre areas are classified as 'struggling'.

At present, the analysis of such census data mapping has only been descriptive - by visual inspection. However, should map data be available that locates important infra structural facilities such as hospitals, schools, roads, rail and other vital services, as in Cutter's work described above, then a more sophisticated spatial analysis may be possible. Such an analysis could document the conjunctions of high social vulnerability and the location of essential facilities that may require special treatment should an emergency situation arise.

However, as has already been discussed, going beyond the visual inspection to quantify the results requires aggregation to some areal unit (enumeration district, Census ward etc) captured within the research areas (floodplain) and as will be shown, the choice of method and aggregation unit may have great implications for the final result.

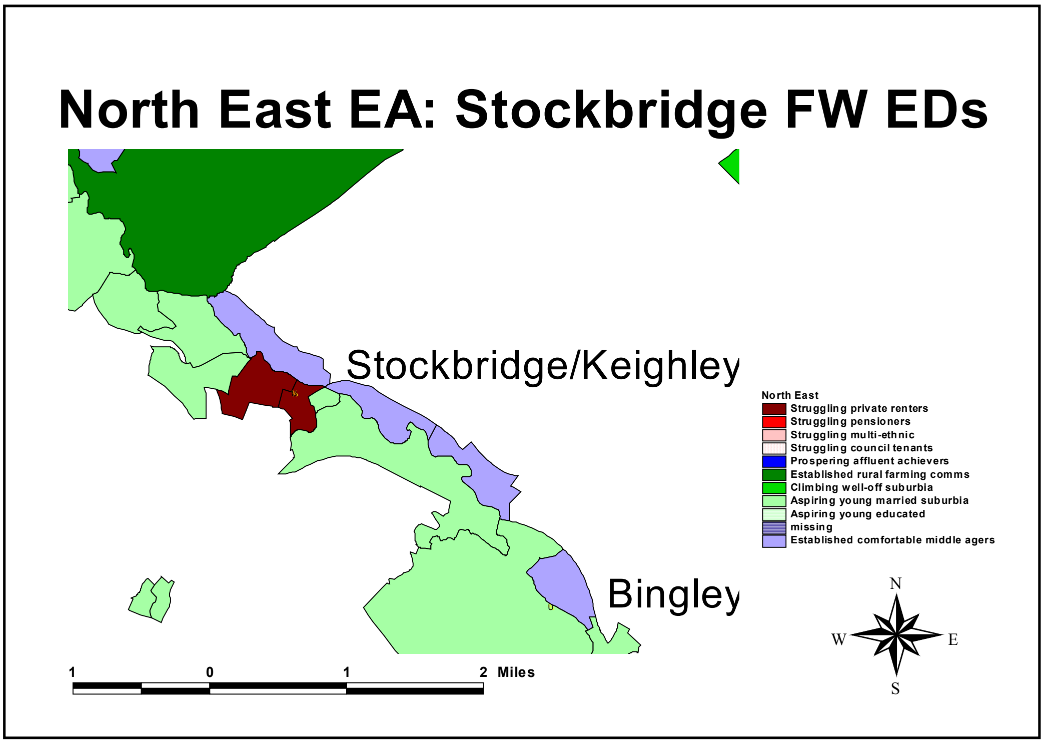


Exhibit 23 GB profiles geodemographic classification: Stockbridge, North East

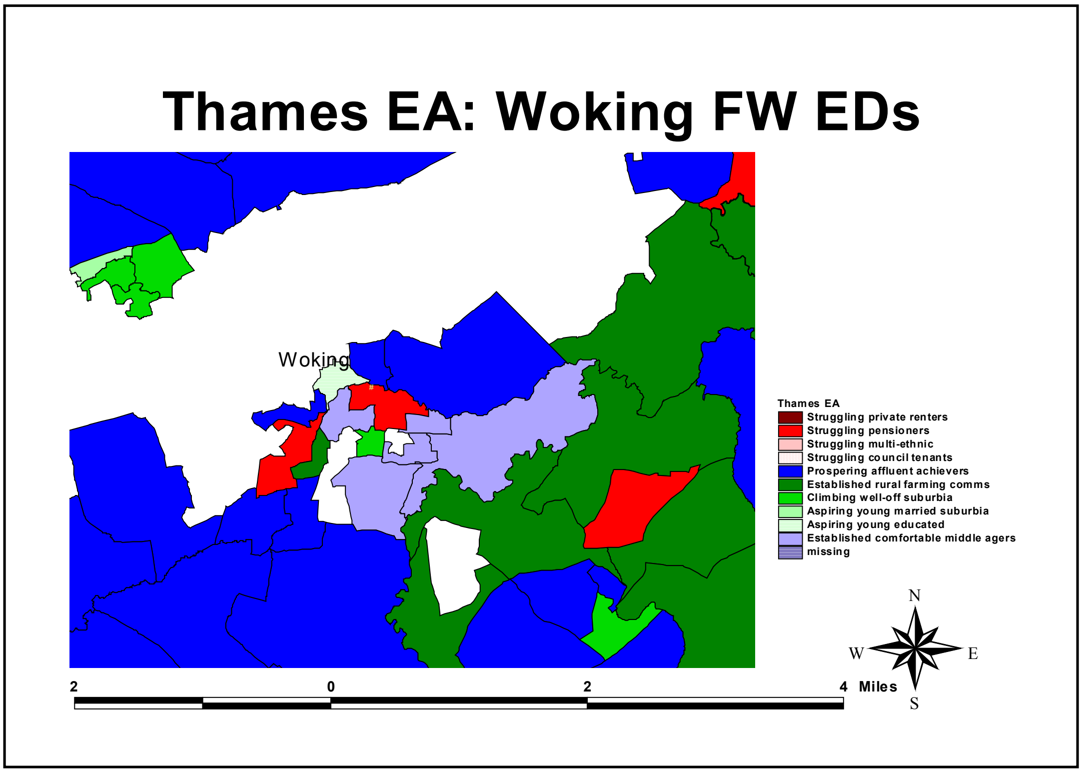


Exhibit 24 GB profiles geodemographic classification: Woking, Thames Measures derived from the Census: Measures of social capital

Despite the widening of topics covered in National Censuses there are still some factors, identified as relating to “community vulnerability” that are not available within the census. One factor which has attracted increasing attention over recent years is that of “community cohesiveness” or the idea of social capital. Social capital has been variously defined to be concerned with social networks, social trust, neighbourliness, involvement in the community, participation in society and community spirit. Several government departments, including the Home Office and the Office for National Statistics, are now exploring means to develop a harmonised core set of questions to develop indicators at both the national and local level. However, it is unlikely that the National data sets that would contain such sets of questions, (eg. the General Household Survey) would contain geographically referencing data to enable small area statistics to be calculated. However, a proxy Census variable, popularly used in measures of social capital, and used by Granger to measure community ties, is that of religious affiliation (Granger, Jones et al. 1999) and could be explored as a measure of social cohesion.

Measures derived from the Census: Household mobility

One of the factors that has been shown to have the greatest impact on levels of “awareness” is lack of previous flooding experience. Clearly, if someone is new to the area they may not have experienced a flood event before. This could be explored using Census data employing the response to the question about concerning the respondents' usual address the year before. Another partial measure of household mobility may be obtained from the Experian database relating to Total House sales in the previous year obtained from Land Registry databases. Of course this would not include the renting population who are also significantly less aware than the owner/occupiers.

3.7 Conclusions

Thus it is clear that many of the factors that previous research have shown to relate to 'social vulnerability' may be investigated using Census and other data sources. In most examples given so far however, this exploration has resulted in a simple inspection of the data, usually in the form of a map. If however, one wishes to make statements about the greater or lesser likelihood of any one section of the population to be exposed to flood hazard, then the data usually needs to be further aggregated and statistical techniques used to make comparisons. This next section demonstrates the problems and methodological considerations in an analysis which explores one Census variable, social class, in order to make comparisons between the percentages living in 'at risk' areas and those not at risk.

4. METHODOLOGICAL CONSIDERATIONS IN MAPPING VULNERABILITY

Having used exploratory data analytic techniques to spatially visualise the distribution of various Census derived variables, this section sets out to explore social inequality within the floodplain through the concept of social class.

Many of the variables identified by previous research as contributing to higher 'social vulnerability' (pensioner status/ lone parents/ unemployment) may also be considered to relate to social class. Indeed, social class was one of the variables that we identified as an important factor leading to lower awareness of flood warning, and we would argue, higher 'vulnerability' to the negative consequences of a flood event.

Thus, the distribution of social class within and without the floodplain was considered an important analysis step towards assessing social vulnerability. Thus if the characteristics of the 'at risk' population can be identified and compared with those 'not at-risk', then some measure of social inequality may be deduced. Clearly, though, the definition of the 'at risk' population is crucial to this analysis. Previously, we have been defining the 'at -risk' population as those residing within Enumeration Districts within or intersecting the floodplains. However, using this crude method does appear to overestimate the population 'at risk', and may lead to bias in any subsequent analysis when larger areas are aggregated. Thus the following section highlights the problems encountered when considering spatial analysis and considers and compares alternative approaches to capturing the 'at-risk' population. .

4.1 Problems of spatial analysis

The problem with any spatial analysis is the choice of the areal unit to use. As has been mentioned before, this choice is often defined by the available data which in many cases is based on official administrative boundaries ranging from large areas such as the county, through local authority regions to wards. In the case of UK Census data prior to 2001, the smallest area aggregation for spatial analysis was the enumeration district (ED) which was historically defined as that area most conveniently covered for census enumeration consisting of approximately 200 households. Using such data, social characteristics, aggregated to the enumeration district, may then be spatially represented by chloropleth maps, shading the areas according to the concentration of the characteristic. Although such maps provide a useful, overall view of the distribution of population characteristics they must also be viewed with caution. In chloropleth maps each areal unit is treated as a homogeneous area for the characteristic of interest and each area will seemingly have at least some population. Yet, over the years, administrative boundary changes and population migration have led to a mixing of characteristics within each area as well as changes in the household base. Enumeration districts can no longer be considered to consist of 200 households with uniform characteristics. Despite, these problems though, the enumeration district is still used as an areal unit for much research, especially when using the 1991 Census data. The release of the 2001 Census data, and its automated aggregation of output areas based on unit postcodes, should improve the homogeneity of spatial units. However, despite this forecast improvement in the areal unit of analysis, there is still the problem that displaying data using chloropleth maps will always give the impression of a uniform distribution within any particular area.

This issue is compounded in our research since we not only wish to explore the characteristics of the population where the available data is aggregated to enumeration districts, but we also need to identify the 'at-risk' population using floodplain maps to define the extent of the analysis, defining areas which clearly do not coincide with the boundaries of enumeration districts. For this reason, alternative methods to 'capture' and analyse 'at-risk' population characteristics based on Census Area Statistics are desirable.

4.2 Alternative methods of spatial analysis

Another approach to the problem of representing population characteristics in an area was to develop surface population models which redistribute the area population over a grid surface of the area of interest. There are several approaches to developing surface population models but that developed by Martin in the 1980's (Brackan and Martin 1989; Martin 1989) using an adaptive kernel estimation method to redistribute enumeration district population was adopted for this report. This technique mathematically redistributes the ED population over the whole ED area so that the population is concentrated near the one, previously defined, population centre (the population centroid). Then one needs to imagine a regular grid 'mesh' (for this report a 'mesh' with 200 m grid squares was used) being placed over the whole area and counting the resulting population now residing within each grid square. SurfaceBuilder[1], developed from Martin's research, was used in conjunction with Census data, to provide easily available grids of population characteristics. The population estimate method used by SurfaceBuilder naturally leads to unpopulated grid cells in some parts of the area of interest in contrast to the chloropleth map display of EDs which assumes an evenly (within individual enumeration districts) and totally populated surface. Maps of the Thames Environment Agency Region showing household density in the floodplain comparing a chloropleth map with a population grid map for the same region is presented in Exhibits 25 and 26. These two maps clearly demonstrate the visual differences between these two methods of displaying data spatially where in the grid map the household density is almost too sparse to print at this scale. Such surface population models have been used in previous environmental justice research in the US to address this problem of the scale of analysis (eg. Mennis (2002)).

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[1] http://www.geog.soton.ac.uk/users/martindj/davehome/software/SBProgram.zip

Exhibit 25 Total household populations in Enumeration Districts intersecting the floodplain within the Thames Environment Agency Region
Source: 10% sample 1991 Census

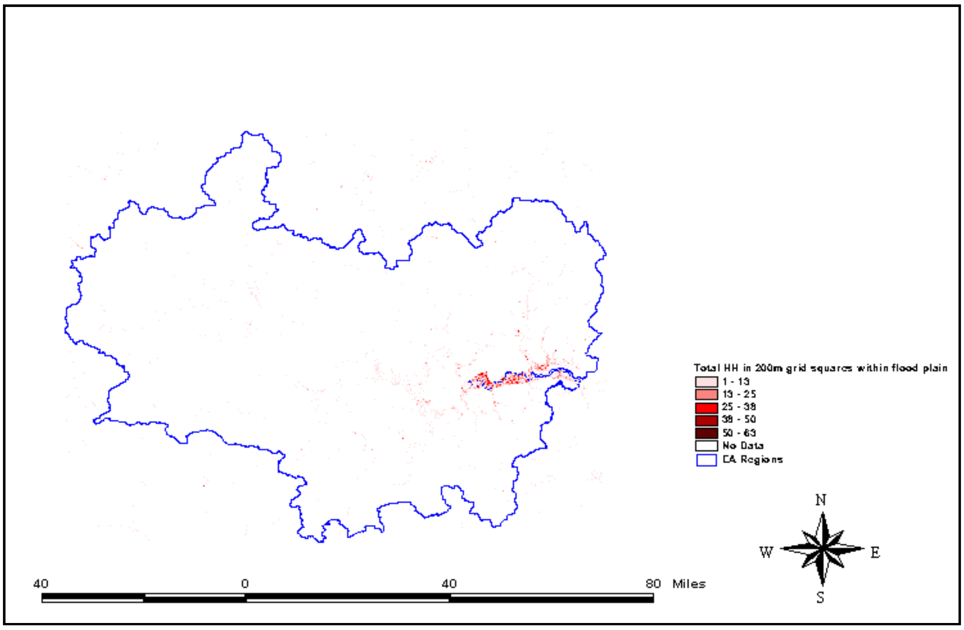
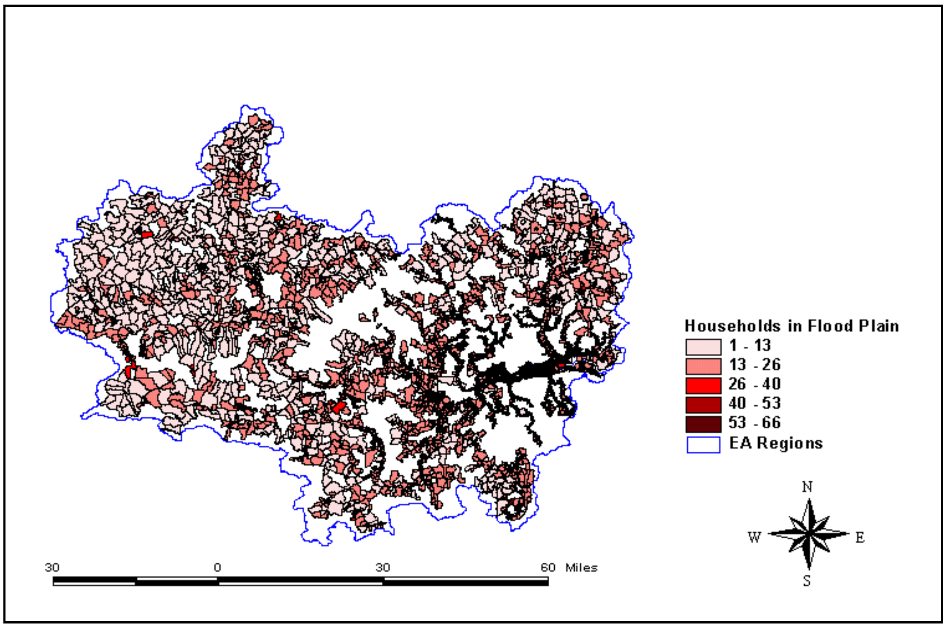


Exhibit 26 Total household populations within 200m Grid squares in the floodplain in the Thames Environment Agency Region
Source: 1991 Census 10% sample



4.3 Creation of grid data from the Census

Data on social class of head of household was downloaded for enumeration districts in England and Wales from the 1991 census (SAS90 table: social class of head of household for a 10% sample of the 1991 census). For the surface models, comma delimited csv files, one for each social class of investigation, were then imported into SurfaceBuilder in order to generate social class population grids. These population grids are then introduced as real data files into ArcView 3.3 where the proportion of those 'at risk' from flood was determined using the fluvial and tidal indicative floodplain maps as an analysis grid mask. Total households 'at risk' and not at-risk were then determined by summarising the household count within the total area.. In addition to an analysis of the whole of England and Wales, those ED's which are i) totally within and ii) intersect the Thames Environment Agency Region were also identified. This data was then exported into a statistical package (SPSS) for further analysis to determine spatial inequality based on social class.

4.4 Comparison of spatial method

In order to illustrate the difference between the two methods of capturing the 'at-risk' population, Exhibits 27 and 28 depicts a very much enlarged view of a small section of Exhibits 25 and 26 respectively. Exhibit 27 shows the household density in those EDs which intersect with the floodplain layer and Exhibit 28 shows the 200m grid squares which intersect the floodplain grid. Only those EDs or grid squares within the floodplain are shaded according to the number of households they contain in the 10% sample of the 1991 Census. Thus in Exhibit 27, ED 47SCFX01 contains 9 households and ED 47SCFX14 contains 22 households. To obtain a final count of all households within the floodplain within a defined area, a simple sum of all the households is calculated. This sum can then be compared with a similar simple sum of all the households in EDs outside the floodplain. Thus the total sum of households in the labelled EDs in Exhibit 27 is 159. Use of the grid square method gives a very different result however. Exhibit 28 shows that only 36 households were identified in the seven, pink-shaded and numbered grid squares. Clearly, these are big differences in this very small area and when this difference is explored for the whole of the Thames Environment Agency region we see very large differences overall.

Exhibit 27 Total households within the indicative floodplain: ED analysis

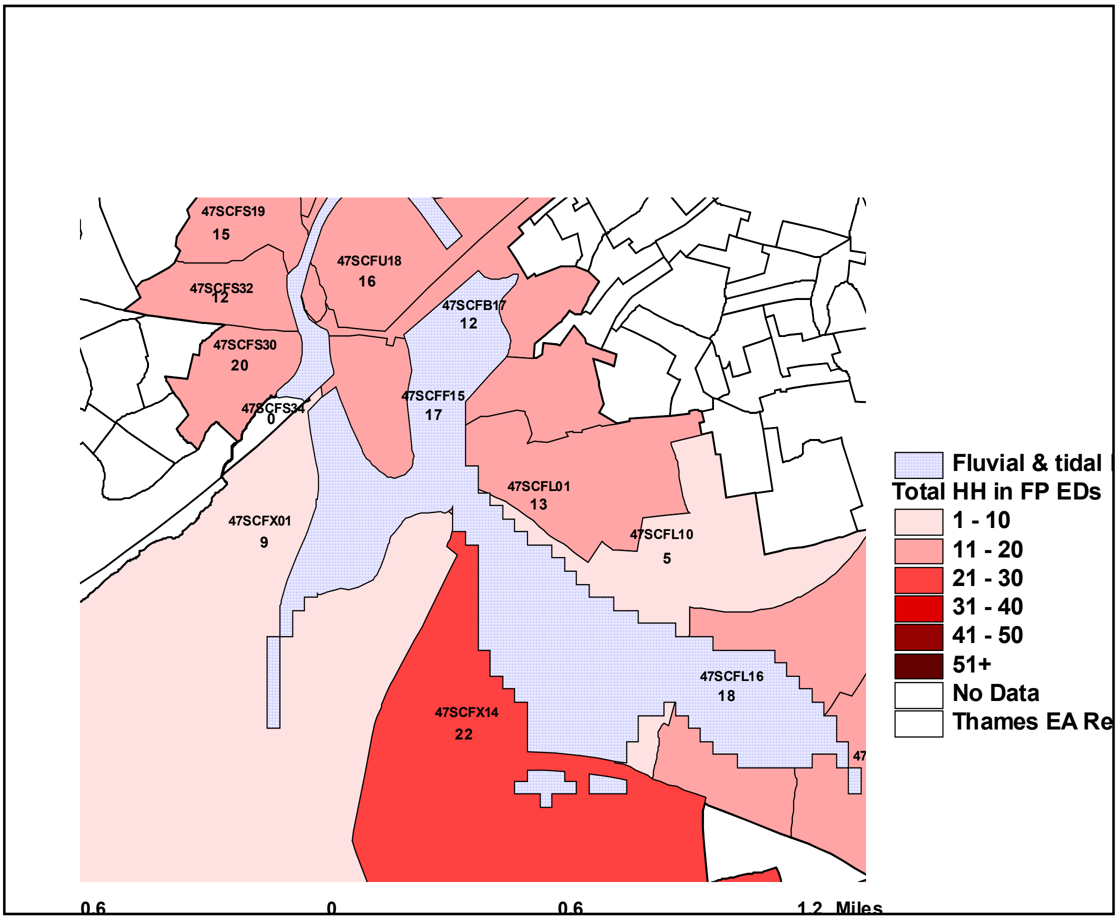
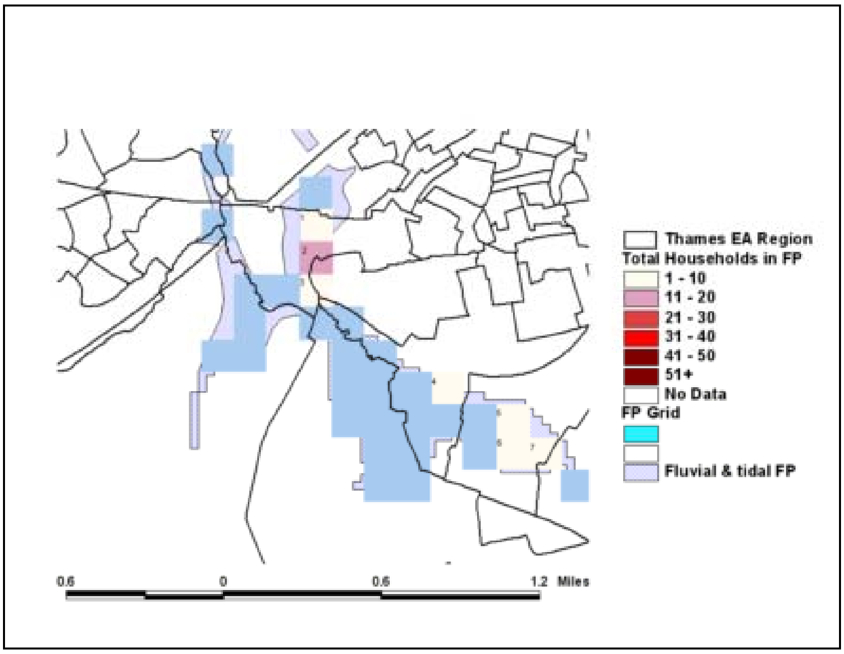


Exhibit 28 Total households within the indicative floodplain: grid analysis technique



Using the Enumeration District method, 30.4% of all households are intersect the indicative floodplain, compared to the 9% of households within the floodplain revealed by the grid technique (Exhibit 29). This latter figures compares well with the Environment Agency's own reporting of 1.9 million homes 'at risk' from flooding in England and Wales (Flood Facts Press Release 14th October 2003), which if taken as a percentage of the total number of households in the 2001 Census (21.66 Million) gives us 8.77% of households at risk. In the Thames Environment Agency region, this 'at risk' figure increases to 11.9% of households using the grid technique compared to 27.6% (EDs totally within the Thames Environment Agency Region) and 27.7% (EDs intersecting the Thames Environment Agency Region) when using the ED technique.

Exhibit 29 A comparison of methods exploring total households within the floodplain in England and Wales and in the Thames Environment Agency region.

	England and Wales			Thames Environment Agency Region		
Method of analysis	**EDs***	**Population Grids ****	**ED analysis****	**Population Grids****	**ED analysis** (within Thames Region)**	**ED analysis** (intersecting Thames Region)**
Base	**EDs**	**Sum of households within 200m sq grid cells**	**Sum of Households within EDs**	**Sum of households within 200m sq grid cells**	**Sum of Households within EDs**	**Sum of Households within EDs**
If in Floodplain	33.5%	9.0%	30.4%	11.9%	27.6%	27.7%
Not in Floodplain	66.5%	91.0%	69.6%	88.1%	72.4%	72.3%
TOTAL[2]	109518	1919004	1921759	426868	422465	431712

Source: *1991 Census; **10% sample of 1991 Census

[2] There is a 0.1% discrepancy in households totals in England and Wales between the two methods which rises to a 1% discrepancy in total household numbers in EDs when the analysis is confined to the Thames region. The former discrepancy represents the expected error between the techniques and the latter, larger error, is mainly due to the geographical techniques used to select 'at risk' EDs. For instance, when only enumeration districts *totally within* the region were selected, there are 1% fewer households compared to the grid technique. This difference, however, is seen to be in the reverse direction when the EDs selection technique includes not only those EDs *totally within* the Thames Region but also those that *intersect* the Region.

Exhibit 30 demonstrates however, that the distribution of social class in the Thames Environment Agency region is virtually identical for the two method ED methods (within and intersecting) and the grid method. Thus, despite the different bases (N=1,919,004 or 1,921,759 for England and Wales for the grid and ED method respectively) overall the distribution of social class is not affected by the method employed.

Exhibit 30 Distribution of social class: a comparison of methods.

	England and Wales		Thames Environment Agency Region		
Social Class	**Grid analysis %**	**ED analysis %**	**Grid analysis %**	**ED analysis (within) %**	**ED analysis (intersecting) %**
Class1/2	23.52	23.5	29.8	29.7	29.8
Class 3	25.10	25.09	24.8	24.8	24.8
Class 4/5	11.32	11.32	9.8	9.8	9.8
Emp: Other class	1.58	1.58	1.6	1.6	1.6
Retired	26.29	26.33	23.3	23.3	23.4
Other inactive	12.19	12.19	10.7	10.7	10.7
Total	1919004	1921759	426868	422465	431712

Source: 10% sample of 1991 Census

4.5 Distribution of social classes within the floodplain

In order to compare social classes in 'at risk' and not 'at risk' populations and to evaluate the two methods, we adopted a measure called the comparative environmental risk index (CERI) (Harner, Warner et al. 2002). This measure involves the calculation of a ratio of the population 'at-risk' as a proportion of the total population for any particular characteristic (class in this case) over the ratio of the rest of the population 'at-risk' as a proportion of the total rest of the population. In terms of social class, this ratio of ratios (a quotient) can be represented by the following equation, where X is any particular social class:

$$\frac{ClassX^{at-risk} / ClassX}{Not-in-ClassX^{at-risk} / Not-in-ClassX}$$

This simple calculation was used by Harner to show how much more likely any particular group (racial minority or low income households in US census blocks in his Colorado city analysis) was to be 'at risk' compared to the rest of the population within each city.

4.5.1 Distribution of social class within the floodplains of England and Wales

Initially, the distribution of social class within the whole of England and Wales was explored using both methods and the comparison of percentages within each class is seen in Exhibit 31. Looking at the differences between the percentages 'in' and 'not in' the floodplain, the ED method shows that those in class 1 / 2 have an increased likelihood of being 'at risk' (25.5% 'in' compared to 22.6% 'not in') while the grid technique shows the opposite effect (22.1% 'in' compared to 23.7% 'not in'). While differences seem very small it must be remembered that this data is a 10% sample of the census and small differences are often significant. These differences are more easily seen after calculating the comparative measure, the CERI index. Exhibit 32 displays the CERI measures for social class for England and Wales and is a measure of the increased or decreased risk of exposure for each class for each method of measurement.

It seems that using the ED as the spatial unit, those in classes 1 and 2 are the most likely to be exposed to flood hazard and have a 11% increased risk over the rest of the population. The only other class at increased risk (6% more likely than all other classes exposed to flood hazard) using this technique was those households whose head was classified as 'other employed'. These results are in sharp contrast to that seen when the grid analysis technique is used. Here those classes at increased risk are the lower social classes (Class 3 and 4 at 9% increased risk) and the unemployed (3% increased risk), and those in class 1 and 2 are at a lower risk of flooding (8% decreased risk). We argue that analysis conducted at the finer unit of measurement of 200m grid squares provides a more accurate picture of the 'at-risk' population than that conducted at the level of the administrative ED (although even with this technique assumptions and generalisations are being made).

Exhibit 31 Distribution of social class of households in the Floodplains of England and Wales

	Grid Analysis		ED analysis	
Social Class	**In FP %**	**Not in FP %**	**In FP %**	**Not in FP %**
Class1/2	22.1%	23.7%	25.5%	22.6%
Class 3	25.3%	25.1%	24.3%	25.4%
Class 4/5	12.1%	11.2%	11.1%	11.4%
Emp: Other class	1.6%	1.6%	1.7%	1.5%
Retired	26.4%	26.3%	26.2%	26.4%
Other inactive	12.5%	12.2%	11.3%	12.6%
Total	173021	1745983	583334	1338425

Source: 10% sample of 1991 Census

Exhibit 32 Comparative Environmental Risk Index for England and Wales

Social Class	Grid Method		Enumeration District Method	
	Quotient*	% likelihood at risk	Quotient*	% likelihood at risk
Class 1 / 2	0.92	-8%	1.11	11%
Class 3	1.01	1%	0.96	-4%
Class 4 / 5	1.09	9%	0.97	-3%
Other Employed	0.98	-2%	1.06	6%
Retired	1	0	0.99	-1%
Other inactive	1.03	3%	0.91	-9%

4.5.2 Distribution of social class within the floodplains of the Thames Environment Agency Region

Following this analysis at the gross scale of England and Wales, these same indices were calculated at the operational level of Environmental Agency region. Results from the Thames region is presented here. This region was chosen since it encloses the most populated and most diverse region, the London catchment basin. Exhibit 33 shows the percentages of households within classes, in EDs both within and intersecting the Thames Environment Agency Region, as well as a comparison with the grid analysis technique. This figure clearly shows differences between the grid and ED techniques, but no real differences between the different ED techniques. However, the picture in the Thames Environment Agency Region does not reflect that in England and Wales as a whole. Using the ED method, the differences in percentages 'in' and 'not in' the floodplain are minimal, the largest difference is seen in class 4 and 5 households with 0.4% increased likelihood of being within the floodplain. However, using the grid technique, those in class 1 and 2 are 3% less likely to be in the floodplain than not in the floodplain and those classified as 'inactive' have a 3% increased likelihood of being in the floodplain than not. These differences are made clearer by calculating the CERI measure (Exhibit 34), which (considering the minimal differences seen between the ED measures *within* or *intersecting* the Thames Region) has only been calculated for the EDs *within* the boundaries of the Thames Environment Agency Region for comparison with the grid method. This Exhibit clearly shows that using the ED method for the Thames Region no social class has an increased (or decreased) likelihood of exposure greater than ∀ 2.5%. In contrast, the grid method, shows clear inequality with classes 4 and 5 having a 12% increased likelihood and classes 1 and 2 a 12% decreased likelihood of exposure to flood hazard. The group that appears most disadvantaged however, in terms of increased likelihood of exposure (at 27% increased probability) compared to the rest of the population in the Thames Region, and probably least able to cope, are the inactive or unemployed.

Exhibit 33 Distribution of social class of households within the floodplain in the Thames Environment Agency Region

	Grid analysis		ED analysis (within Thames Region)		ED analysis (intersect Thames Region)	
Social Class	In FP %	Not in FP %	In FP %	Not in FP %	In FP %	Not in FP %
Class1/2	27.1%	30.1%	29.6%	29.8%	29.8%	29.8%
Class 3	24.2%	24.9%	24.6%	24.9%	24.5%	24.8%
Class 4/5	10.9%	9.7%	10.1%	9.7%	10.1%	9.7%
Emp: Other class	1.6%	1.6%	1.7%	1.6%	1.7%	1.6%
Retired	23.2%	23.3%	23.3%	23.4%	23.2%	23.4%
Other inactive	13.1%	10.3%	10.8%	10.7%	10.7%	10.6%
Total	51005 (11.9%)	375865	116746 (27.6%)	305719	119627	312085
	426870		422465		431712	

Source: 10% sample of 1991 Census

Exhibit 34 Comparative Environmental Risk Index :Thames Environment Agency Region

Social Class	Grid Method		Enumeration District Method (within Thames Region)	
	Quotient*	% likelihood at risk	Quotient*	% likelihood at risk
Class 1 / 2	0.879	- 12.1%	0.993	-0.7%
Class 3	0.975	-2.5%	0.989	-1.1%
Class 4 / 5	1.119	11.9%	1.025	2.5%
Other Employed	0.958	-4.2%	1.022	2.2%
Retired	0.991	-0.9%	0.996	-0.4%
Other inactive	1.267	26.7%	1.01	1%

5. CONCLUSIONS

Social vulnerability is a dynamic, multi-faceted concept and as such is not well represented by a single statistic. An understanding of who is 'at-risk' is clearly necessary for improving flood warning and post-flood recovery measures. Thus, an analysis of available data to characterise the 'at-risk' population is of vital importance but the need to subsume this under one measure seems of little value unless clear objectives are defined.

In the process of characterising the 'at risk' population, this report has illustrated the need to be cautious when considering spatial analysis of social characteristics. Clearly different results can be obtained depending on the areal unit of analysis and the approach adopted.

We argue that the use of grid analysis is a more valid representation of the data distributed over the whole surface area of interest, not least because of the gross overestimation of the household population estimated using the ED analysis. Thus the following three factors support this analytic technique:

- It is argued that the smaller aggregation of the data has resulted in a 'truer' view of the distribution of the characteristic.
- The finding that those in lower social classes are more likely to be 'at risk' from hazard is supported by a body of previous research.
- The percentage of 'at risk' population compares well with the Environment Agency's own calculations.

It should be remembered however, that the grid analysis is based on a mathematical algorithm to redistribute the population to population centroids and also ultimately comes down to an areal unit, albeit a much smaller unit, the grid square. However, it does have the advantage that unpopulated areas are taken in to account and mapped as such.

This report has taken just one Environment Agency area as an example to highlight the differences obtained in spatial analysis of the distribution of just one 1991 census characteristic. Further research would be needed to not only explore other characteristics in other areas but also to update and compare the analysis using the 2001 census data.

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APPENDIX 1

INDEX OF MULTIPLE DEPRIVATION 2000 (IMD2000)

Summary of Indicators Used
6 domains with multiple indicators:

Income Deprivation
- Adults in Income Support households (DSS) for 1998
- Children in Income Support households (DSS) for 1998
- Adults in Income Based Job Seekers Allowance households (DSS) for 1998
- Children in Income Based Job Seekers Allowance households (DSS) for 1998
- Adults in Family Credit households (DSS) for 1998
- Children in Family Credit households (DSS) for 1998
- Adults in Disability Working Allowance households (DSS) for 1998
- Children in Disability Working Allowance households (DSS) for 1998
- Non-earning, non-IS pensioner and disabled Council Tax Benefit recipients (DSS) for 1998 apportioned to wards

Employment Deprivation
- Unemployment claimant counts (JUVOS, NOS) average of May 1998, August 1998,November 1998 and February 1999
- People out of work but in TEC delivered government supported training (DfEE)
- People aged 18-24 on New Deal options (ES)
- Incapacity Benefit recipients aged 16-59 (DSS) for 1998
- Severe Disabement Allowance claimants aged 16-59 (DSS) for 1999

Health Deprivation and Disability
- Comparative Mortality Ratios for men and women at ages under 65. District level figures for 1997 and 1998 applied to constituent wards (ONS)
- People receiving Attendance Allowance or Disability Living Allowance (DSS) in 1998 as a proportion of all people
- Proportion of people of working age (16-59) receiving Incapacity Benefit or Severe Disablement Allowance (DSS) for 1998 and 1999 respectively
- Age and sex standardised ratio of limiting illness (1991 Census)
- Proportion of births of low birth weight (<2,500g) for 1993-97 (ONS)

Education, Skills and Training
- Working age adults with no qualifications (3 years aggregated LFS data at district level, modelled to ward level) for 1995-98
- Children aged 16 and over who are not in full-time education (Child Benefit data DSS) for 1999
- Proportions of 17-19 year old population who have not successfully applied for HE (UCAS data) for 1997 and 1998
- KS2 primary school performance data (DfEE, converted to ward level estimates) for 1998
- Primary school children with English as an additional language (DfEE) for 1998
- Absenteeism at primary level (all absences, not just unauthorised) (DfEE) for 1998

APPENDIX 2

INDEX OF MULTIPLE DEPRIVATION 2004 (IMD2004)

Summary of Indicators Used
7 domains with multiple indicators:

INCOME DOMAIN
Adults and children in IS households (A)
Adults and children in JSA-IB households (B)
Adults and children in certain WFTC households (C)
Adults and children in certain DPTC households (D)
National Asylum Support Service supported asylum seekers in receipt of subsistence only and accommodation support (E)

EMPLOYMENT DOMAIN
Average unemployment claimant count (A)
Incapacity Benefit (IB) claimants (B)
Severe Disablement (SDA) claimants (C)
Participants in New Deal for the under 25s (D)
Participants in New Deal for 25 + (E)
Participants in New Deal for Lone Parents (F)

HEALTH DEPRIVATION AND DISABILITY DOMAIN
Years of potential life lost (A)
Comparative Illness and Disability Ratio (B)
Adults under 60 suffering from mood or anxiety disorders (C)
Emergency admissions to hospital (D)

EDUCATION, SKILLS AND TRAINING DOMAIN
CHILDREN:
Average points score of children KS2 (A)
Average points score of children KS3 (B)
Average points score of children KS4 (C)
Not staying on at school (D)
Not entering Higher Education (E)
Absenteeism (F)
SKILLS:
No and low qualifications (G)

BARRIERS TO HOUSING AND SERVICES DOMAIN
GEOG. BARRIERS:
Road distance to a GP (A);
Supermarket or convenience store (B);
primary school (C);
Post Office (D)
WIDER BARRIERS:
Overcrowding (E)
Difficulty of access to owneroccupation at LA level (F)
Homelessness decisions at LA level (G)

CRIME DOMAIN

Recorded crime rates for the following composite indicators:
Burglary (A)
Violence (B)
Theft (C)
Criminal Damage (D)

LIVING ENVIRONMENT

THE INDOORS LIVING ENVIRONMENT:
Social and private housing in poor condition (A)
Houses without central heating (B)
THE OUTDOORS LIVING ENVIRONMENT:
Air Quality (C)
Road accidents involving injury to pedestrians and cyclists (D)