Climate Change & Solent Coastal Vulnerability: Mapping Impacts on at-risk Assets and Vulnerable Sectors of Society

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Summary: Climate change is expected to increase the frequency and magnitude of flood events. Society's vulnerability to flooding has increased, due to urbanisation, extension of infrastructure and other land-use changes in flood-prone areas. This project will concentrate on coastal flood vulnerability, and aims to produce an integrated GIS database that will facilitate the modeling of coastal flood vulnerability maps, which will identify at-risk assets and vulnerable sectors of society. The Solent region will be used to test this methodology, particularly the island city of Portsmouth and the Havant coastal district.

KEYWORDS: Vulnerability, Assets, Flooding, Mapping, Solent

1. Introduction

Coastal zones have social, economic and environmental importance: they attract settlements and economic activity. Coastal activities are vulnerable to climate changes. Sea-level rise and more intense storms could raise flood risk, increase coastal erosion and adversely affect ecosystem structure and functioning, especially on low-lying coasts (Nicholls et al, 2008). Coupled with natural risks, the problems associated with our ever changing human environment on the coastline have increased the risk of coastal flooding. According to the Environment Agency (2011), there are around 490,000 properties today in England that face a 1 in 75 chance, in a given year, of flooding from rivers and the sea. The Environment Agency have also predicted within their Investing for the Future Report (2009) that if overall investment remains at 2009 levels and if there is no additional development in the areas at risk, by 2035 there will be an additional 350,000 properties (280,000 residential) in areas with a 1 in 75 or greater annual chance of being flooded. The expected annual damages to residential and non-residential properties in England at risk of flooding from rivers and the sea is estimated at more than £1 billion. Floods can also cause serious indirect impacts, including damage to important energy, water, communications and transport infrastructure. They can also interfere with basic public services such as schools and hospitals (Environment Agency, 2009). According to the latest Environment Agency reports (2011), 55% of water and sewage pumping stations/treatment works, 20% of railways, 10% of major roads, 14% of electricity and 28% of gas infrastructure are located in areas at risk from flooding.

Population change, development and land management, will also affect risk to coastal flooding. For example, in England the population is predicted to increase by 10 million by 2030 (Hughes, 2009), which will increase the need for homes and infrastructure. Planning must be carried out correctly, otherwise more people and properties could be placed in areas at risk from flooding. Land cover type and land management can also have significant effects on the movement of surface water, with a likely increase in impacts from fluvial flooding and urban flash-floods (The Environment Agency, 2011). Sea level rise and regional subsidence will also affect water tables, with a probable increase in groundwater flooding.

This study examines the effects of climate change on coastal businesses and communities in the Solent (Figure 1), focusing on the island city of Portsmouth and the coastal zone of Havant Borough (highlighted in Figure 1). The main research questions are:

- How can at-risk social, environmental and economic assets be classified and analysed?
- Can socio-economic vulnerability analysis be interlinked with land cover/ land use analysis?
- Can improvements be made to frameworks for coastal flood vulnerability analysis?

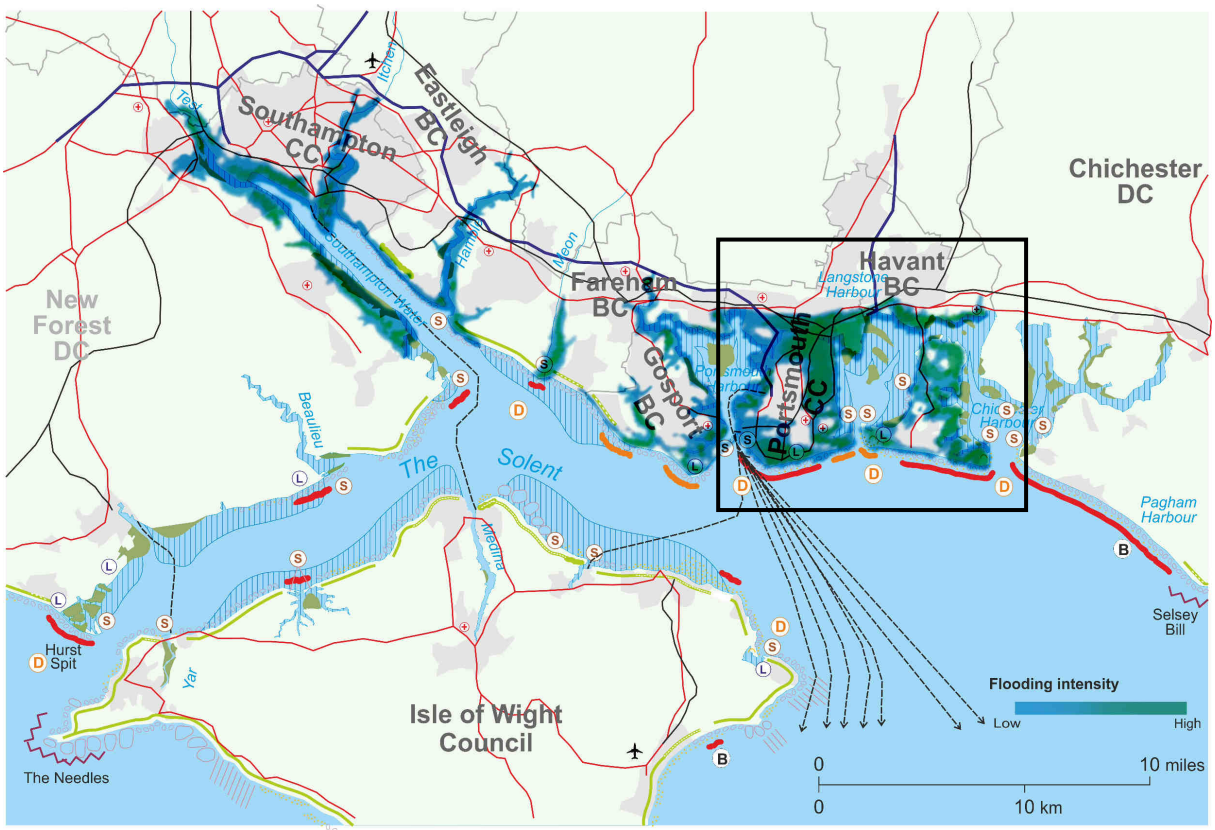

Figure 1. This map incorporates data from Standing Conference on problems associated with the Coastline (SCOPAC), The Solent Forum and Google Maps, it includes coastal landforms, urban distribution, important points of infrastructure and expected flooding for 2115 (based upon the Partnership for Urban South Hampshire (PUSH) Strategic Flood Risk Assessment)

1.1 Case Study areas – The Solent, Portsmouth and Havant Borough

The Solent is the body of water that lies between the central south coast of England and the Isle of Wight (Figure 1). It is a low energy, sediment dominated estuarine complex, consisting of 12 separately defined estuaries and harbours, draining a catchment of approximately 3000 km^2 (Fletcher et al., 2007). Expected predictive flooding from the PUSH analysis, indicated that the city of Portsmouth and Havant Borough, had the greatest risk to future high intensity coastal flooding (see figure 1). These two areas are also socio-economically different, one being a major city, the other more rural and suburban. Therefore, analysing coastal vulnerability in different socio-economic settings, but under the same environmental conditions.

The city of Portsmouth (Figure 1) is a low-lying maritime island city and one of the most densely populated areas in Britain (Portsmouth City Council, 2009). It is also of major economic importance for industry, commerce and, tourism, as well as being the primary naval port of Britain. The area of Portsmouth is approximately 40 km^2, split between Portsea Island and the mainland. The city has 45 km of open coastal frontage. At present, the Strategic Flood Risk Assessment (SFRA) for Portsmouth

has shown that the primary source of flood risk is from the sea: approximately 47% of the city's land area is designated as within the Environment Agency's Flood Zones 2 and 3. The SFRA has predicted that the areas most vulnerable to rising sea levels, are Southsea and Eastney (Atkins, 2007). Portsmouth has a mix of average and high social vulnerability to flooding. However, Flood zones 2 and 3generally have a high social vulnerability to flooding on the east of Portsea Island and the north-eastern part of the mainland, while the remaining areas mostly have an average social vulnerability to flooding (Atkins, 2007).

The Borough of Havant has a coastline of 48 km, mostly around Hayling Island (Figure 1). Havant Borough Council maintain the coastline, with the assistance of land owners whose land adjoins the shoreline (Havant Borough Council, 2008). Hayling Island has an area around 30km^2, and is a low lying coastal plain island, separated from the mainland by shallow tidal harbours. The maximum height is about 5 m Above Ordnance Datum (Hampshire County Council, 2010). At present, approximately 22% of the Borough's land area is within the Environment Agency's Flood Zones 2 and 3. The primary source of flood risk to Havant is from the sea (Atkins, 2007), with Hayling Island the most sensitive area to sea level rise, particularly the southern half of the island. Havant Borough has a mix of average and high social vulnerability to flooding. However, within flood zones 2 and 3 there is a high social vulnerability to flooding on the mainland and average social vulnerability to flooding on Hayling Island Atkins (2007).

2. Preliminary Findings

This study has utilised maps from the Ordnance Survey, historical flood data from the British Geological Survey, and data on expected flooding to 2115 from the SRFA. Combining these datasets identified 'assets' that were affected by past flooding and the areas for potential future flooding. Coastal flood risk maps for the Solent lack detail with regard to socio-economic and asset data. For instance, Figure 2 is the most detailed Environment Agency map, in which, 'asset' and land use data have been identified. Furthermore, the National Flood Risk Assessment shows areas at risk of land flooding, but does not show which specific properties are at risk. This project will produce an integrated GIS database based on Ordnance Survey data sets (Mastermap, Integrated Transport Network, Points of Interest, Address layers 1 & 2, and a Digital Surface Model), Environment Agency Flood Hazard Zones (2 &3) and socio-economic data (UK national census (2001) and economic). These datasets will be used to develop a methodology for a vulnerability and resilience analysis which will facilitate the production of flood vulnerability maps for the UK coastal zone.

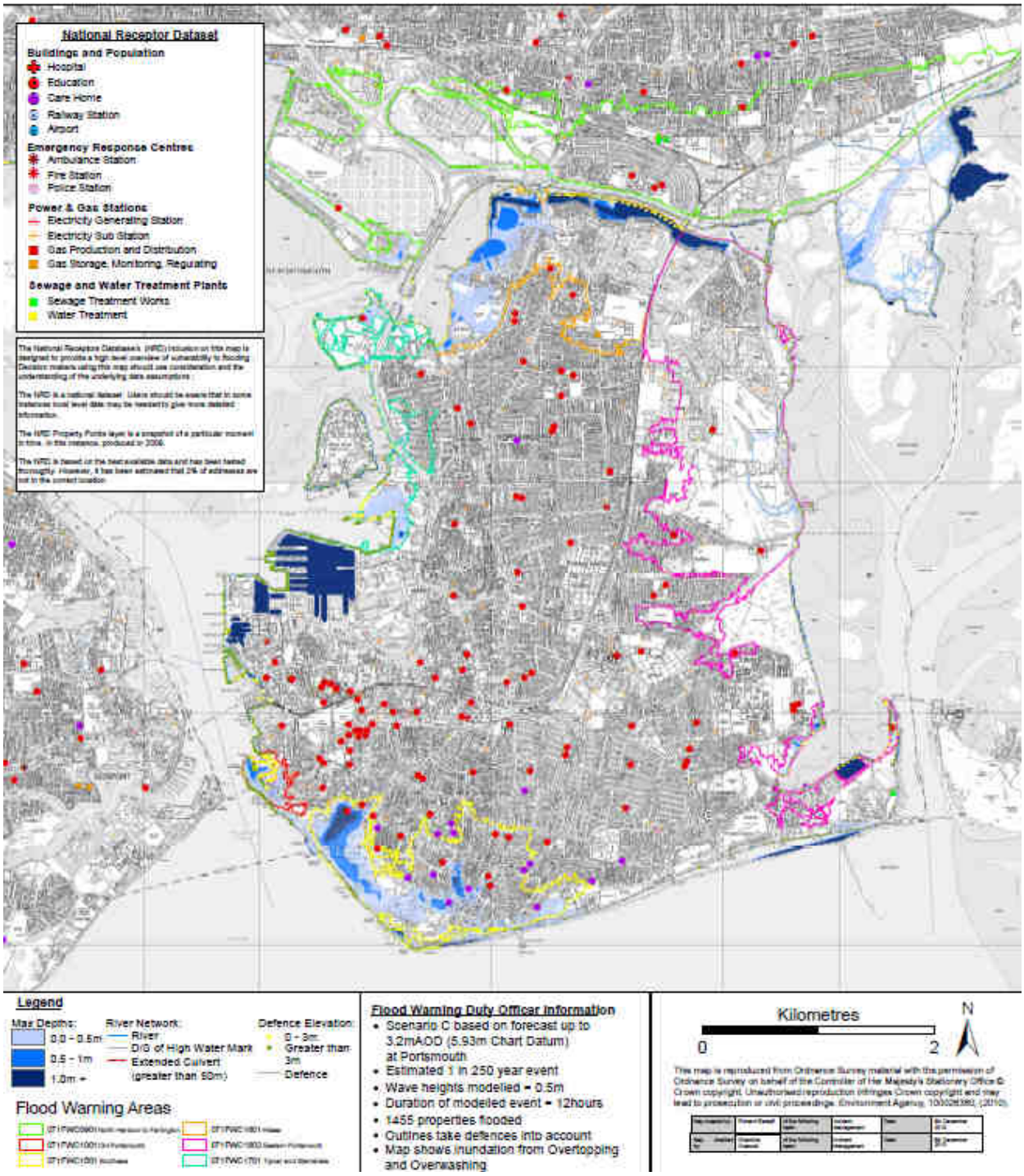

Figure 2. Portsea Island – Flood Inundation Scenario C (Environment Agency, 2010)

3. Methodology

The methodology follows six stages to produce Coastal Flood Vulnerability maps (Figure 3). They include different social, environmental and economic 'asset' datasets, which have been split into three stages within the methodology, and are explained in more detail in sections 3.1, 3.2 and 3.3. This mapping methodology can be re-applied around the UK coastline and will result in a social, economic and environmental vulnerability analysis for coastal flood hazards that can be used by local authorities, private organisations, government agencies, developers and emergency planners.

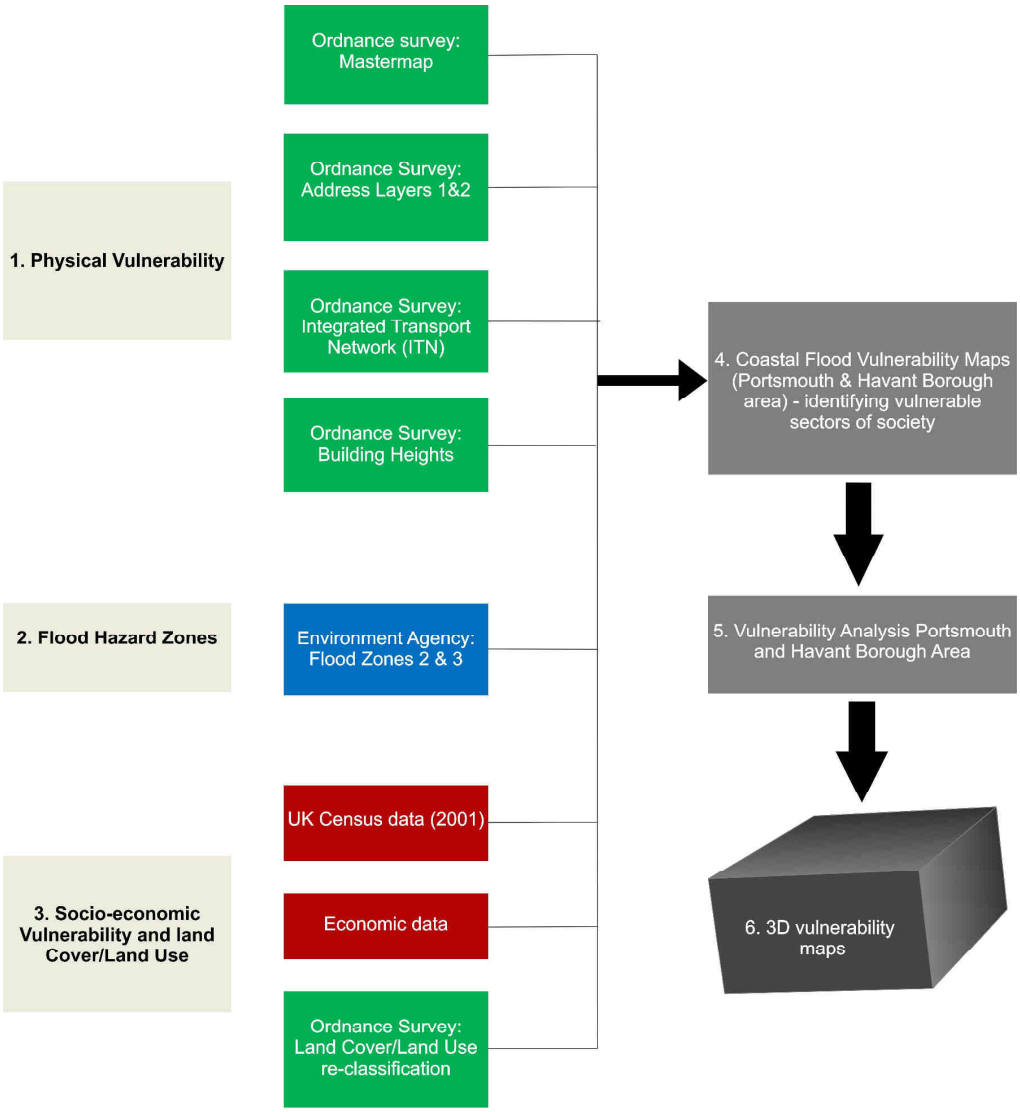

Figure 3. Mapping methodology

3.1 Stage 1 - Physical Vulnerability

Ordnance Survey data layers have been processed using ArcGIS. The O.S. datasets include; Mastermap, Address Layers (1 & 2), Integrated Transport Network, and building heights. The layers have been clipped and split into electoral ward size polygons. The Land cover/Land use data was separated using a classification system (ontology) already present within the O.S. Mastermap datasets. These steps have produced ward size maps that give a detailed, manageable view of the area, at a local scale (e.g. Figure 4).

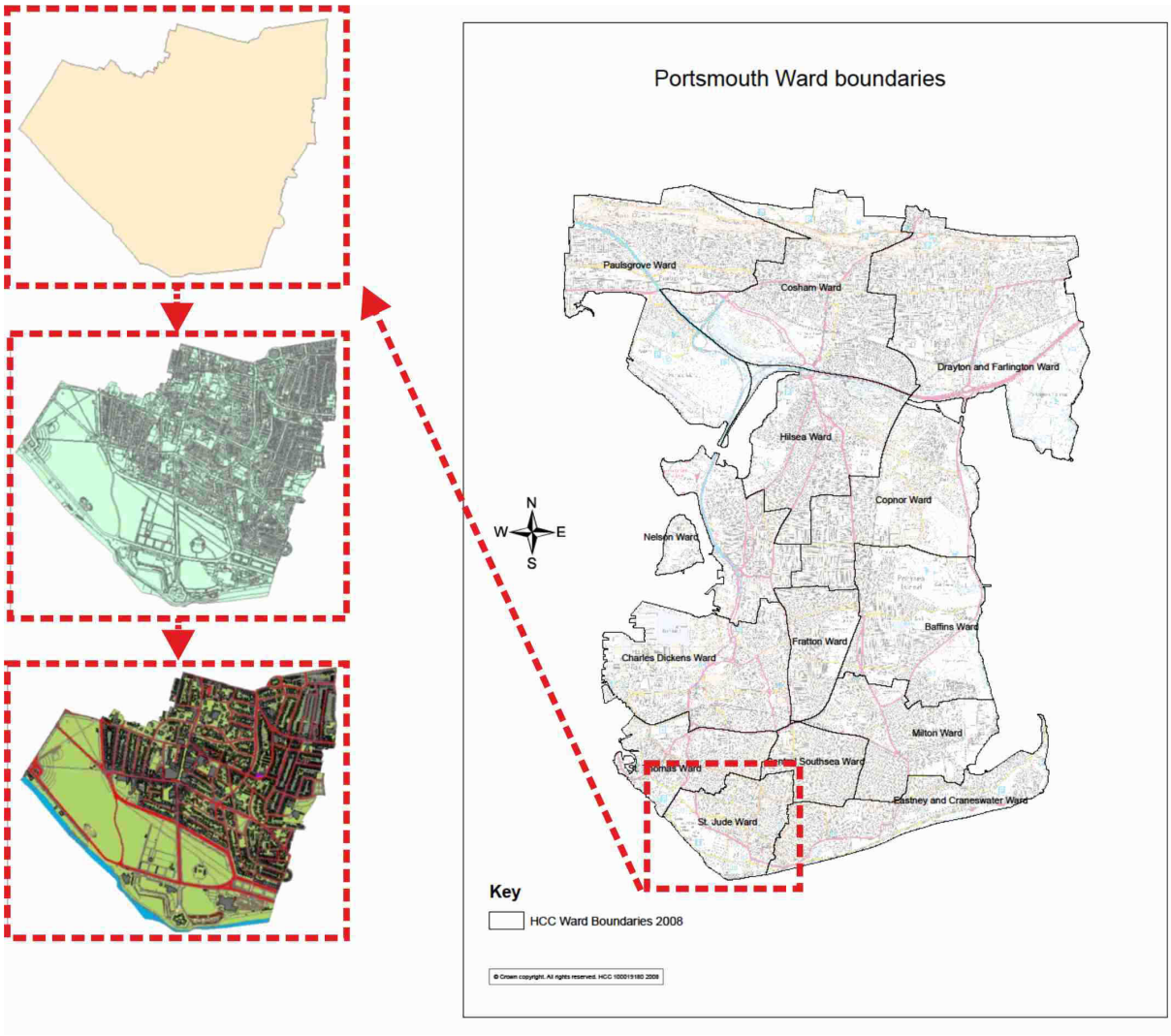

Figure 4. Adding all Ordnance Survey Mastermap data layers; split into electoral ward size polygons

3.2 Stage 2 - Flood Hazard Zones

The flood hazard zones used within this research are provided by the Environment Agency (Figure 5). The production of these flood hazard zones in England followed the publication of the Planning Policy Statement (PPS) 25 and pressure from the Government to provide Local Planning Authorities with quality-assured flood risk data. Combined with this, is the commitment the Environment Agency has given to improving information on flood risk (Environment Agency, 2011). The flood zones used within this research are:

Zone 2 - areas where the chance of flooding in any one year is between 0.1% and 0.5% (i.e. between a 1000 to 1 and a 200 to 1 chance). The outer edge of this zone is the 'Extreme Flood Outline' (EFO).

Zone 3 - areas with the highest probability of flooding. The chance of flooding in any one year is greater than or equal to 0.5% (i.e. a 200 to 1 chance).

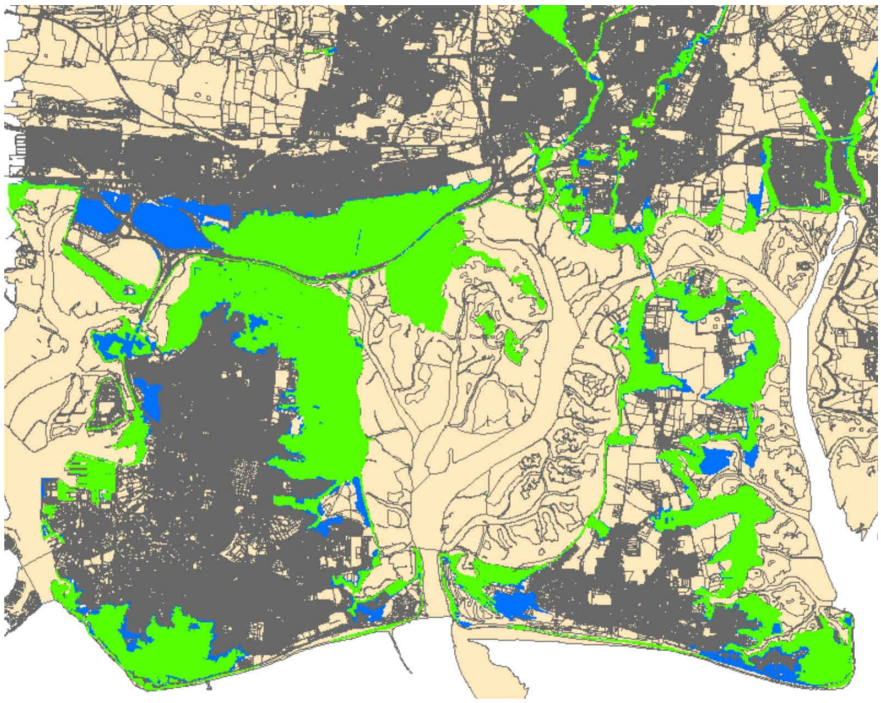

Figure 5. Environment Agency Flood Zones 2 (blue) and 3 (green) added over Ordnance Survey area polygons

The flood zone data has now been clipped to individual ward size (to continue with stage 1) and added to the physical vulnerability data layers (Figure 6). Orthorectified photography of the area has been used to provide a more easily recognisable background to the maps.

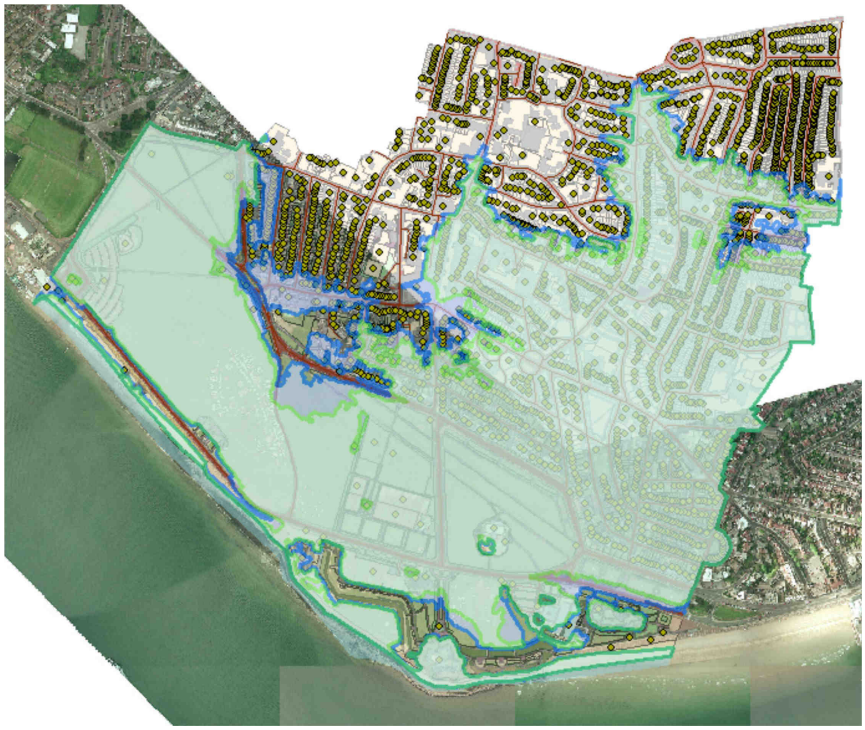

Figure 6. Environment Agency Flood zones 2 and 3 added to ward size physical vulnerability polygons.

3.3. Stage 3 and Beyond

The research is now at the beginning of Stage 3. Work has started for the last point (visualisation techniques) this can be seen in Figures 8a and b:

1. Frameworks will be established for (i) socio-economic vulnerability analysis and (ii) for land cover/use analysis; interactions between land use and socio-economic vulnerability will be examined (for instance, Figures 7a and 7b show examples of other studies and their results for land cover/use re-classification).
2. The end-product will be Coastal Flood Vulnerability Maps: identifying vulnerable infrastructure and sectors of society. The final stage of the project will investigate innovative visualisation techniques for flood risk mapping, as illustrated in Figures 8a and 8b which show preliminary results when combining ward coastal vulnerability maps in 3D.

Figure 7a. Re-classifying land cover and land use data sets and adding 3D structures (Kinley, 2010)

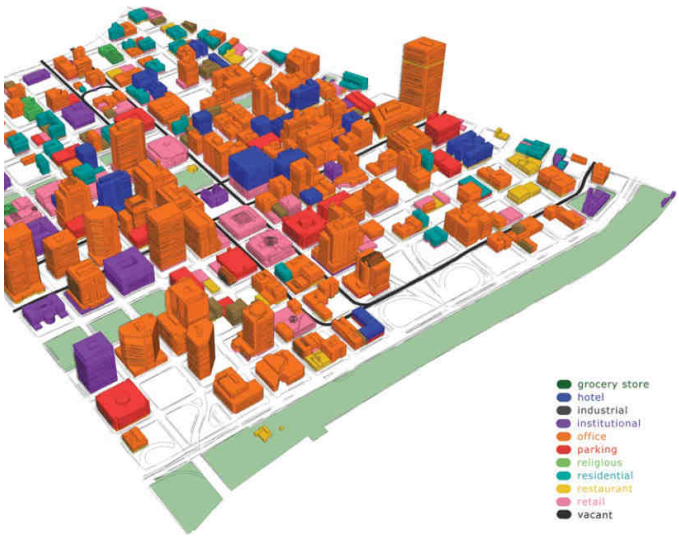

Figure 7b. More examples of a re-classified land cover and land use data set, with the addition of 3D structures, but for a section of the City of Portland (City of Portland Bureau, 2002)

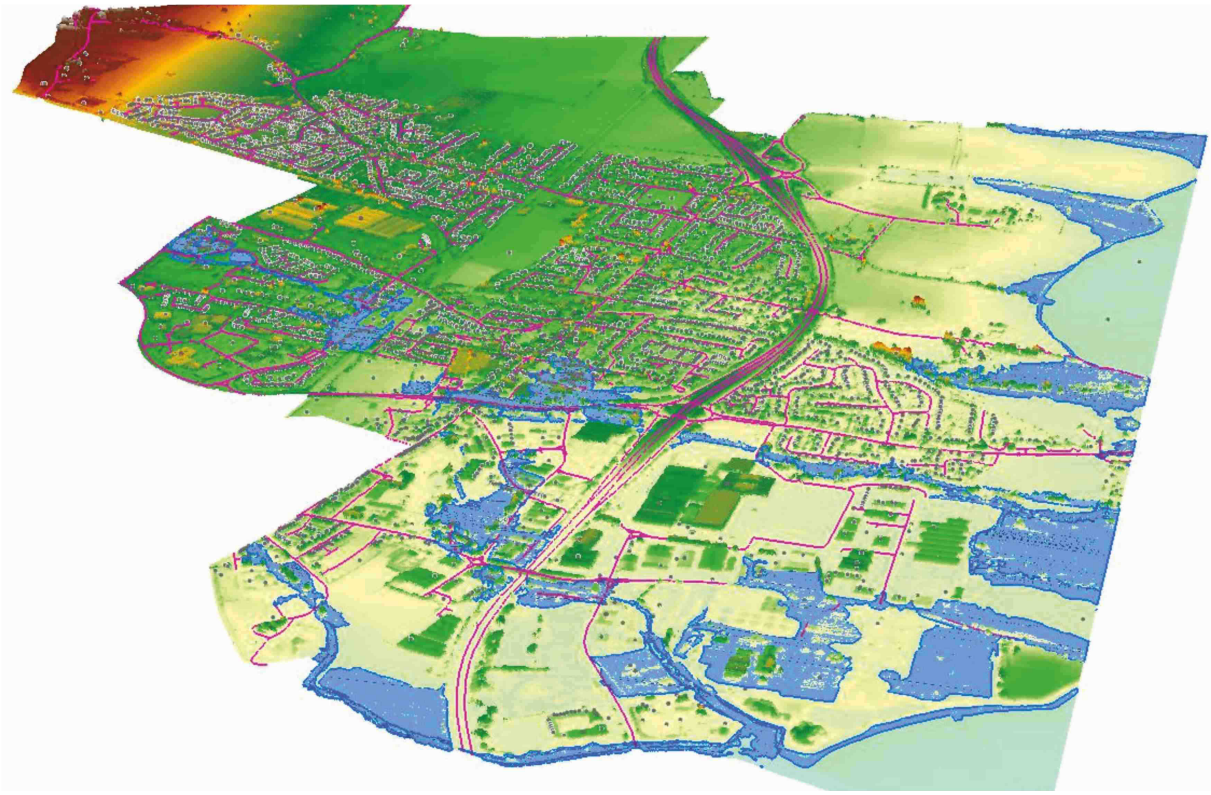

Figure 8a. 3D Coastal flood vulnerability maps at ward level. This map is clipped to an OS DEM and an OS digital boundary for St Faiths ward which is within the Havant Borough area. Within this clipped polygon are the OS Mastermap data layers; ITN and Address Layer. The final clipped layer, is the Environment Agency Flood Zone 2 layer.

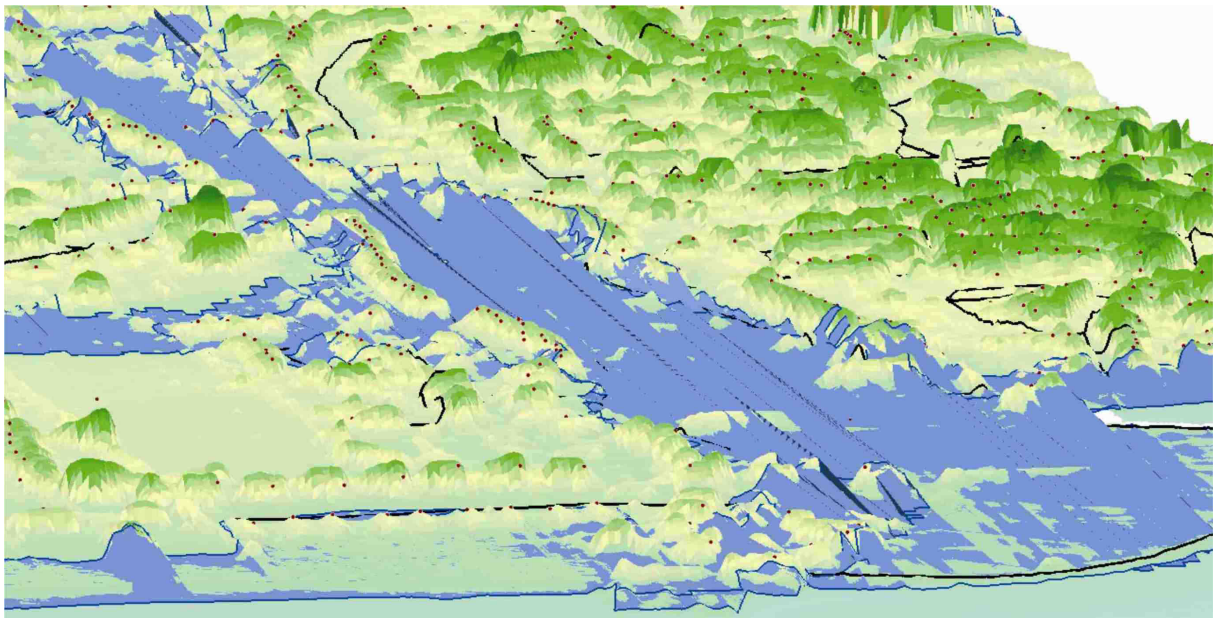

Figure 8b. Zoomed in section of St Faith's ward coastal vulnerability map.

4. Conclusion.

Coastal flood risk maps lack detail with regard to socio-economic and asset data. This research will produce coastal flooding vulnerability maps for Portsmouth and Havant Borough. These maps will incorporate new visuals and socio-economic and land cover/use analysis. These maps will be part of a social, economic and environmental vulnerability analysis for UK coastal flood hazard zones that can be used by local authorities, private organisations, government agencies, developers and emergency planners.

5. Acknowledgements

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6. References

Atkins (2007) *'Partnership for Urban South Hampshire: Strategic Flood Risk Assessment – Final Report'*. [Online] Available at: http://www.push.gov.uk/work/sustainability-and-social-infrastructure/content-strategic-flood-risk-assessment.htm

City of Portland Bureau (2002) *'City of Portland 3D Land-Use Model'*. [Online] Available at: http://www.esri.com/mapmuseum/mapbook_gallery/volume24/pdf/mapbookv24_077.pdf

Cutter S, Boruff B and Shirley W (2003). Social vulnerability to Environmental Hazards. *Social Science Quarterly*, 84 (2), 242-261

DEFRA (2009). 'Shoreline Management Plans'. [Online] Available at: http://www.defra.gov.uk/environment/flooding/policy/guidance/smp.htm

Douben K-J (2006). Characteristics of river floods and flooding: A global overview, 1985-2003. *Irrigation and Drainage*, 55, S9-S21

Environment Agency (2009). 'Flooding in England: A national assessment of flood risk'. [Online] Available at: http://publications.environment-agency.gov.uk/pdf/GEHO0609BQDS-E-E.pdf

Environment Agency (2009). 'Investing for the future: flood and coastal risk management in England, a long-term investment strategy'. [Online] Available at: http://publications.environment-agency.gov.uk/PDF/GEHO0609BQDF-E-E.pdf

Environment Agency (2011). 'Understanding the risks, empowering communities, building resilience'. [Online] Available at: http://publications.environment-agency.gov.uk/PDF/GEHO0711BTZE-E-E.pdf

Few R, Brown K and Tompkins EL (2007). Climate Change and Coastal Management Decisions: Insights from Christchurch Bay, UK. *Coastal Management*, 35 (2), 255-270

Fletcher S, Johnson D and Hewett T (2007). Coastal Management in the Solent: An Introduction. *Marine Policy*, 31 (5), 585-590

Hampshire County Council (2010). 'Hayling Island Coastal Plain: Status Draft March 2010'. [Online] Available at: http://www3.hants.gov.uk/9h_hayling_island_coastal_plain.pdf

Havant Borough Council (2008). *'Coastal defence, land drainage and flooding'*. [Online] Available at: http://havant.gov.uk/havant-198

Haynes H, Haynes R and Pender G (2007). Integrating socio-economic analysis into decision-support methodology for flood risk management at the development scale (Scotland). *Water and Environment Journal*, 22 (2), 117-124

Hosking A and McInnes R (2002). Preparing for the Impacts of Climate Change on the Central South Coast of England: A Framework for Future Risk Management. *Journal of Coastal Research*, SI36, 381-389

Hughes M (ed) (2009). Social Trends. *Office of National Statistics*

IPCC (2007). Climate Change 2007: Impacts, adaptation and vulnerability: contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change, *Cambridge University Press*

Kinley L (2010). Land Use Data Capture Investigation . Ordnance Survey Internal Report

McInnes R (2006). Responding to the Risks from Climate Change in Coastal Zones - A good practice. *Centre for the Coastal Environment. Isle of Wight Council*, 1-12

McLaughlin S and Cooper J A G (2010). A multi-scale coastal vulnerability index: A tool for coastal managers? *Environmental Hazards*, 9, 233-248

Munich Re (1997). *'Flooding: Munich Re discusses loss potential and insurance solutions'*. [Online] Available at: http://munichre.com/en/media_relations/press_release/1997/1997_07_28_press_release.aspx

Nicholls R, Hanson S, Mokrech M, Stansby P, Chini N, Walkden M, Dawson R, Roche N, Hall J, Nicholson-Cole S, Watkinson A, Jude S, Lowe J, Wolf J, Leake J, Rounsevell M, Fontaine C and Acosta-Michlik L (2008). The Tyndall Coastal Simulator and Interface. *Proceedings of Coastal Dynamics*, 1-14

North Solent Shoreline Management Plan (2010). *'North Solent Shoreline Management Plan'*. [Online] Available at: http://www.northsolentsmp.co.uk/index.cfm?articleid=9907&articleaction=nthslnt&CFID=38693563&CFTOKEN=54654086

Pontee N I, and Parsons A (2010). A review of coastal risk management in the UK. *Maritime Engineering*, 163 (MAI), 31-42

Portsmouth City Council (2009). *'Flood Response Plan'*. [Online] Available at : http://www.portsmouth.gov.uk/living/5100.html

PUSH (Partnership for Urban South Hampshire) (2007) *'Strategic Flood Risk Assessment'*.

[Online] Available at: http:// push.atkinsgeospatial.com

North Solent Shoreline Management Plan (2010). *'North Solent Shoreline Management Plan'*. [Online] Available at: http://www.northsolentsmp.co.uk/index.cfm?articleid=9907&articleaction=nthslnt&CFID=38693563&CFTOKEN=54654086

Portsmouth City Council (2009). *'Coastal Protection'*. [Online] Available at: http://www.portsmouth.gov.uk/AtoZ/3726.html

PUSH (Partnership for Urban South Hampshire) *'Strategic Flood Risk Assessment'*. [Online] Available at: http:// push.atkinsgeospatial.com

SCOPAC (Standing Conference on Problems associated with the Coastline) (2001). Preparing for the Impacts of Climate Change: Summary Report. *Halcrow*

SCOPAC (Standing Conference on Problems associated with the Coastline). 2009. *'About SCOPAC'*.

[Online] Available at: http://www.scopac.org.uk

Southampton City Council (2010) *'Coastal Issues'*. [Online] Available at: http://www.southampton.gov.uk/s-environment/climatechange/coastal-issues.aspx

Vincent K (2004). Creating an Index of Social Vulnerability to climate change for Africa. *Tyndall Centre for Climate Change Research*, Working paper 56

7. Biography

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