Human sensitivity and adaptive capacity in NSW coastal erosion hotspots

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Abstract

This paper proposes a methodology to evaluate potential human sensitivity and adaptive capacity along the New South Wales coast using open data. The paper identifies potential analytical frameworks and proposes a methodology for a preliminary, first pass evaluation of human sensitivity and adaptive capacity including an identification of relevant data metrics. The collation of data on coastal erosion hotspots shows some key demographic and built form trends relevant to human sensitivity and adaptive capacity. The paper indicates that further datasets and data collection is required to improve the validity of the methodology and deliver more reliable results.

Introduction

The ultimate objective of integrated coastal management is to concurrently manage the biophysical and built environment and encourage resilient, sustainable and functional co-existence. In New South Wales (NSW), local governments rely on risk assessments and complex engineering and environmental studies to prepare coastal zone management plans.

Coastal zone management planning requires councils, communities, land owners and planners to contend with varied planning timelines, diverse methodologies and uncertain coastal futures to imagine what their community might look like in 30, 40, 100 years and beyond. This involves consideration of different community values, expectations, ideology, lifestyle choices, socio-economic status and human needs.

In a confrontational and politicised environment stakeholders may focus attention on coastal management strategies that are the most consistent with their worldview and interests and neglect strategic evaluation or long term assessment (Haasnoot et al:2013). Human vulnerability, habitation, livelihood needs and adaptive capacity of resident populations can be pushed to the periphery. Collectively self-reflection on human capacity, existential questioning of development futures and dispassionate examination of environmental, economic and social vulnerability is a challenge for most communities.

Limited data for sophisticated human sensitivity and adaptive capacity analysis is a further constraint. The investigation of human vulnerability and adaptive capacity requires amalgamation of ‘top down’ public data such as Australian Bureau of Statistics with ‘bottom up’ local knowledge (Prior and Herriman:2010) across multiple data indicators at different spatial scales and with varying levels of reliability.

Despite these barriers, the imperative for including human sensitivity, vulnerability and adaptive capacity in coastal risk assessments is strong. Without this dimension, coastal planning cannot truly embrace a ‘systems analysis’ approach, thereby limiting a community’s opportunity to understand coastal settlement function, metabolism and management pathways (Broto et al:2012, Wolman: 1965 and Kilcullen:2013). Communities may make more informed decisions through improved understanding of coastal settlement metabolism, social terrain and the urban/marine interface.

Human and built environment attributes such as socio-economic status, urban intensification, personal mobility, transportation, age, lifestyle preferences, critical infrastructure reliance, population density, housing type and physical capabilities can provide

critical insight into coastal management options (Clark et al:1998). The social terrain is as important as ocean geomorphology and biophysical systems.

This is evident in the increasing application of cost benefit analyses to coastal hazard management. Complex economic appraisal requires spatial and socio-economic data to characterise built form development options, evaluate coastal management pathways and undertake scenario planning. For example, estimations of future urban development and intensification can alter the economies of scale for hard infrastructure protection works. Urban housing intensification needs to be 'ground-truthed' in existing demographics, land availability and economic realities.

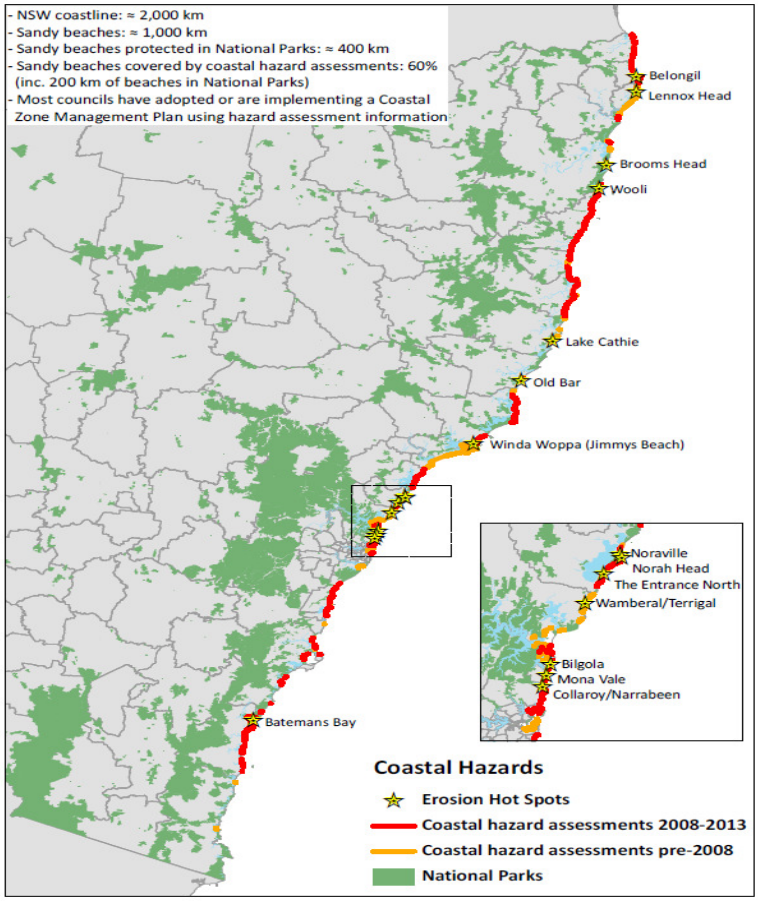
This paper proposes a methodology to evaluate potential human sensitivity and adaptive capacity using open data. The paper identifies potential analytical frameworks to aid characterisation of human sensitivity and adaptive capacity and proposes a methodology for a preliminary, first pass evaluation including an identification of relevant datasets.

The paper reveals that there are significant data gaps preventing a comprehensive representation of human sensitivity, vulnerability and adaptive capacity. The data presented should not be used for a determinative characterisation of human vulnerability in NSW coastal communities and is only used to illustrate the utility and potential of the methodology.

Scope for human vulnerability and adaptive capacity assessment in coastal management planning

The NSW Government has identified fifteen locations in eleven council areas susceptible to coastal hazards. These areas have been identified as 'coastal erosion hotspots' and are areas where five or more houses and/or a public road are located in an immediate coastal hazard area. There are other locations along the coastline where either a smaller number of houses or only residential land (i.e. no houses) is in a coastal hazard area (OEH:2014). In 2011, the Minister for the Environment directed councils to prepare coastal zone management plans for the fifteen coastal erosion hotspots.

FIGURE 1: NSW COASTAL EROSION HOTSPOTS (OEH:2013)



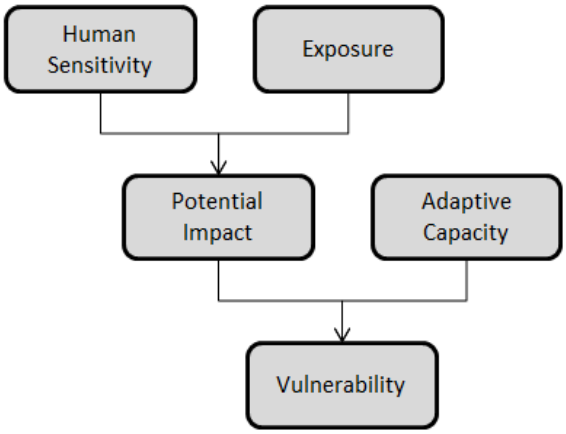
Coastal zone management plans (CZMPs) - prepared under the *Coastal Protection Act 1979* - outline risks coastal risk management activities and coastal management strategies. Once certified by the Minister for Environment, CZMPs are considered in development applications requiring consent. To be eligible for certification, plans must be prepared in accordance with provisions of the *Coastal Protection Act 1979* and the *Guidelines for preparing coastal zone management plans* published by the NSW Office of the Environment and Heritage (OEH).

The guidelines identify issues that councils should address when developing and reviewing CZMPs. While the current guidance provides a reasonable foundation for supporting councils, it does not include advice on how to assess levels of human vulnerability and adaptive capacity.

It should be noted that although human vulnerability and adaptive capacity are not formally part of CZMPs, state emergency service (SES) local disaster planning and 'disaster (flood) intelligence collection' systems may provide some coverage and planning around human vulnerability. Utilities providers may also undertake planning activities or manage operations to ensure reliable service for vulnerable communities.

The vulnerability of a system, such as an urban coastal settlement, is a function of sensitivity, exposure and adaptive capacity. Figure 2 illustrates the relationship of vulnerability to sensitivity, exposure and adaptive capacity.

FIGURE 2: RELATIONSHIPS BETWEEN KEY CONCEPTS (Adelphi & Eurac Research:2014, CSIRO 2009 and Allen Consulting:2005)



Human Sensitivity

Sensitivity can be conceptualised in multiple dimensions; human, biophysical, built form or institutional. This paper is predominately focused on human sensitivity Social or human sensitivity can be based on the social, cultural, and economic factors that shape capacity to cope with the impacts of a natural hazard (BMZ:2014 and CSIRO:2009). Physical capacities, economic resources, habitation requirements and personal preferences may all influence human sensitivity.

Exposure

Exposure to coastal hazards in NSW is generally associated with damage to property. Coastal erosion and inundation risk along the NSW coast has been documented and there is a general awareness of the potential extent of impact. The nature and timing of coastal erosion, which generally provides significant lead time for emergency response, means exposure may be limited to a particular magnitude, not beyond immediate foreshore properties. While the hazard impact area may represent a relatively small geographic area – over the medium term – the loss of property, services and infrastructure in coastal communities have broad impacts on the functionality of the affected area (Kinsela and Hanslow:2013).

Adaptive Capacity

The Intergovernmental Panel on Climate Change (IPCC) Assessment Report 4 (AR4) defines adaptive capacity as 'the ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences' (Parry et al: 2007). Adaptive capacity can be built from or reside within social agents or networks, natural or ecological systems, organisational flexibility or economic resources.

Human Vulnerability

Human vulnerability to natural hazards is a measure of both *exposure* to the actual physical event and underlying *human sensitivity* offset by *adaptive capacity*.

Analytical frameworks to assess human sensitivity and adaptive capacity

The basic vulnerability formula only provides a starting point. Analytical frameworks and human-environment system theories are required to identify relevant data metrics and understand relationships between multiple sensitivity indicators. These frameworks also assist in interrogating built environment and biophysical system performance and human interaction with these systems.

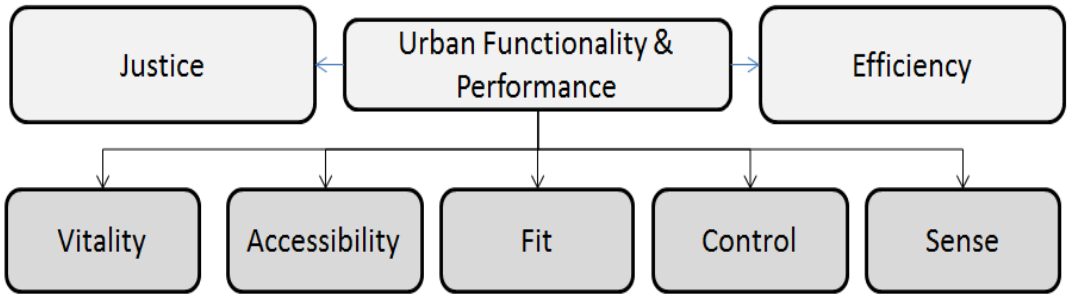
A range of social vulnerability profiling and human vulnerability analysis methodologies are used in natural disaster risk assessments for events such as earthquakes, landslides, floods, coastal hazards, hurricanes and extreme heat events (Yung-Jaan:2014, Willroth et al: 2012, Uitto:1998, Clark et al:1998, AECOM:2010: NSW Planning and Infrastructure:2013).

The paper highlights three analytical frameworks that may assist in identifying relevant vulnerability and adaptive capacity data and provides foundational conceptualisation of coastal settlement functionality. These frameworks include urban form theories of Kevin Lynch (Lynch:1981), critical infrastructure interdependency literature (Graham: 2010) and emerging urban climate resilience planning frameworks (Tyler: 2012).

Urban Functionality

Urban planner and theorist Kevin Lynch (Lynch:1981) developed a theoretical framework to evaluate good built environment form in his seminal work 'Good City Form'. Lynch provides a means of systematically evaluating urban form and functionality. The evaluation criteria outlined in Figure 3 touches on multiple aspects of coastal settlement metabolism – population movement, safety and shelter, landscape control, environmental outputs. It also helps identify interrelationships between demographics and built form of relevance to human sensitivity.

FIGURE 3: KEVIN LYNCH'S 'GOOD URBAN FORM' FRAMEWORK



Vitality refers to a built environment supporting and sustaining biological performance of human beings and includes concepts of built form enabling sustenance and safety.

Accessibility refers to multidimensional notions of access and mobility including accessibility of resources, people, places, activities and information.

Fit is the compatibility of cultural requirements with the built environment or in other words "how well the spatial and temporal pattern of a settlement matches the customary behaviour of its inhabitants".

Control is the spatial equivalent of ownership or custodianship with a focus on use, modification, appropriation, exploitation and exclusion.

Sense is the degree to which the urban form is legible, structured and provides an inhabitant with a sense of place and location.

The meta-criteria of justice and efficiency are used to help ensure outcomes on the five key elements meet equity and cost-efficiency measures.

A broad range of open data can be used to apply Lynch's built form evaluation to coastal settlements, however resident surveys and other qualitative assessment may also be necessary.

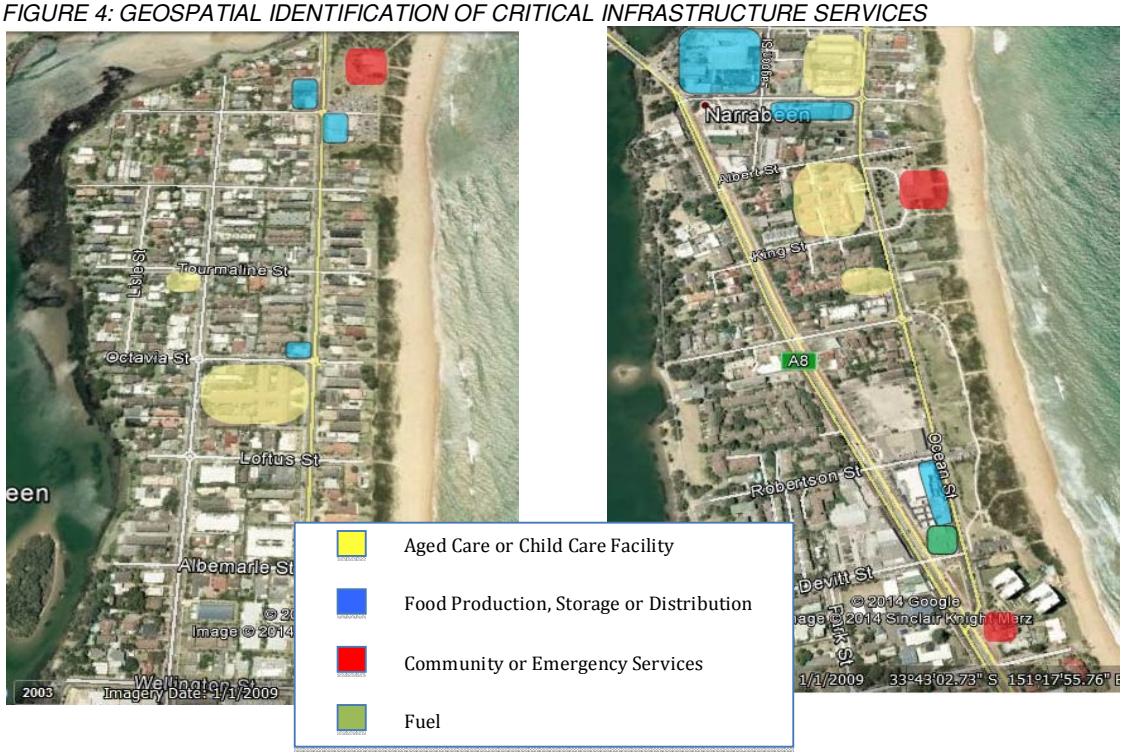
Critical Infrastructure Resilience

While critical infrastructure and service provision can be considered within Lynch's framework, a more tailored approach may be required to understand proximity of interdependent and highly connected infrastructure systems. Critical infrastructure resilience (Graham: 2010) focuses on key sectors that provide essential services to residents.

In many jurisdictions critical infrastructure protection authorities (Hickie: 2013) attempt to manage the interdependency of critical infrastructure and services such as water supply and sanitation, energy and fuel, health, community services, information and communications technology (ICT), banking and finance, food distribution and transport. Interdependency and 'anchoring' critical infrastructure in a highly connected urban environment adds a complex dimension to achieving resiliency. It is also a key component of coastal settlement functionality and metabolism.

A number of organisations undertake geospatially-based scenario planning of climatic events or security emergency to evaluate the impact of cascading infrastructure failure across multiple networks. Figure 4 is a basic example of geo-locating critical infrastructure service sectors across North Narrabeen, Sydney for the purpose of understanding potential cascading system failure.

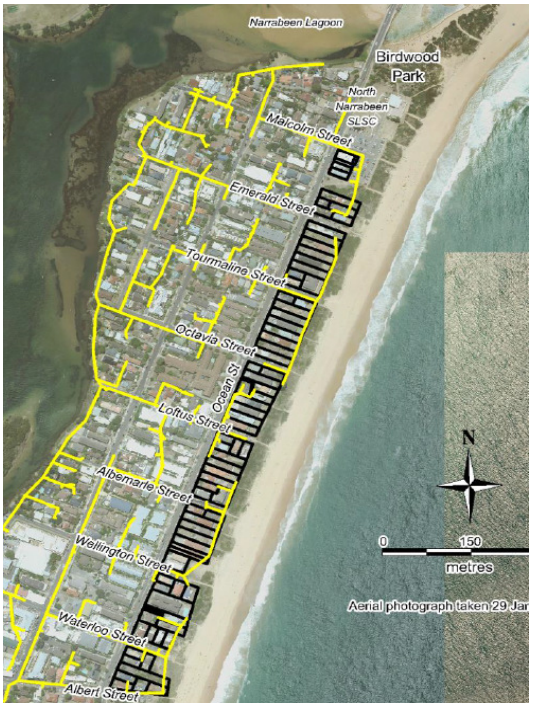
FIGURE 4: GEOSPATIAL IDENTIFICATION OF CRITICAL INFRASTRUCTURE SERVICES



This map does not show critical subterranean water, sanitation, gas, ICT or electricity networks. Disruption to critical infrastructure may impact habitation and key service delivery. Data on installation of rainwater tanks and rooftop solar photovoltaic (PV) installations[1] may be used to indicate some level of decentralised resilience to network disruption, however greater data on the reliability and security of critical infrastructure networks is required for human vulnerability analysis. The mapping of sewer mains in the draft Warringah Coastal Zone Management Plan for Collaroy-Narrabeen Beach illustrates the type of critical infrastructure analysis required (Figure 5).

[1] There are a number of caveats on the ability of these to provide resilience from network disruption. Different solar PV system

FIGURE 5: DRAFT WARRINGAH CZMP (COLLAROY-NARRABEEN) (ROYAL HASKONING DHV: 2014)

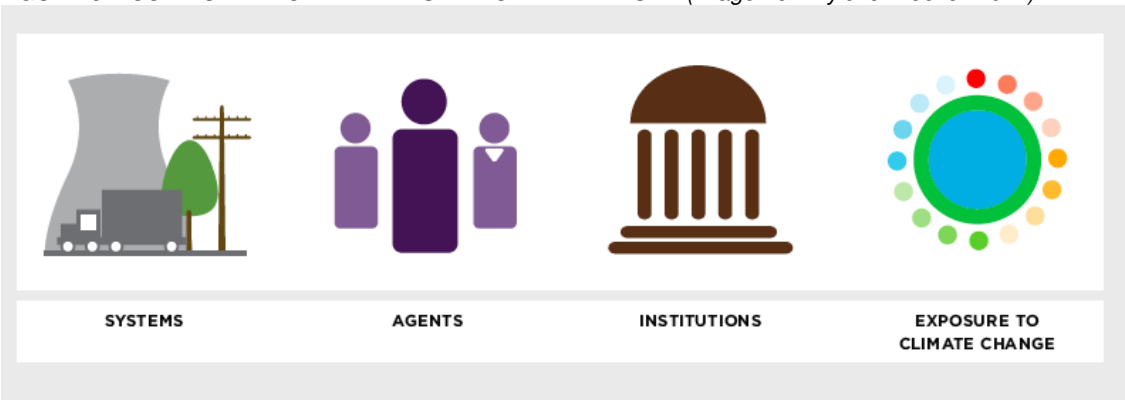


Urban climate resilience

The urban climate resilience framework developed by the Asian Cities Climate Change Resilience Network (ACCRN) (Tyler & Moench:2012) can be used to holistically understand the connection between infrastructure, urban systems, human groups and organisations. Developed through resilience planning activities in ten Asian cities, the framework advocates assessing climate and natural disaster vulnerability through *systems, agents and institutions (*Figure 6*)*.

The conceptual focus on 'agents' and 'institutions' encourages the interrogation of 'difficult to measure' aspects of human sensitivity. Social network connectivity, behavioural patterns, cultural norms and governance arrangements become relevant.

FIGURE 6: ACCRN URBAN CLIMATE RESILIENCE FRAMEWORK (image from Tyler & Moench:2012)



In this framework vulnerability and resilience is assessed across:

- infrastructure systems (transport, energy, sanitation, food distribution) and ecosystems (water, land, air).
- social agents who depend upon urban systems such as individuals, households, public and private organisations and civil society

- Institutions that comprise of governance systems, norms, rules and regulation.

Deriving data metrics on these dimensions requires labour intensive and multi-disciplinary analysis. The ACCRN framework is the closest of the frameworks to a dynamic, full scale systems analysis. It requires the concurrent examination of laws, governance, anthropology, demographics, economic coping capacity, social networks, built environment and infrastructure with a range of qualitative and quantitative tools. There are clear data gaps that make the full application of the ACCRN approach challenging.

Methodology for preliminary human sensitivity and adaptive capacity evaluation

Data collection

Multiple data sets are available to examine human sensitivity and adaptive capacity

TABLE 1: DATA SOURCES

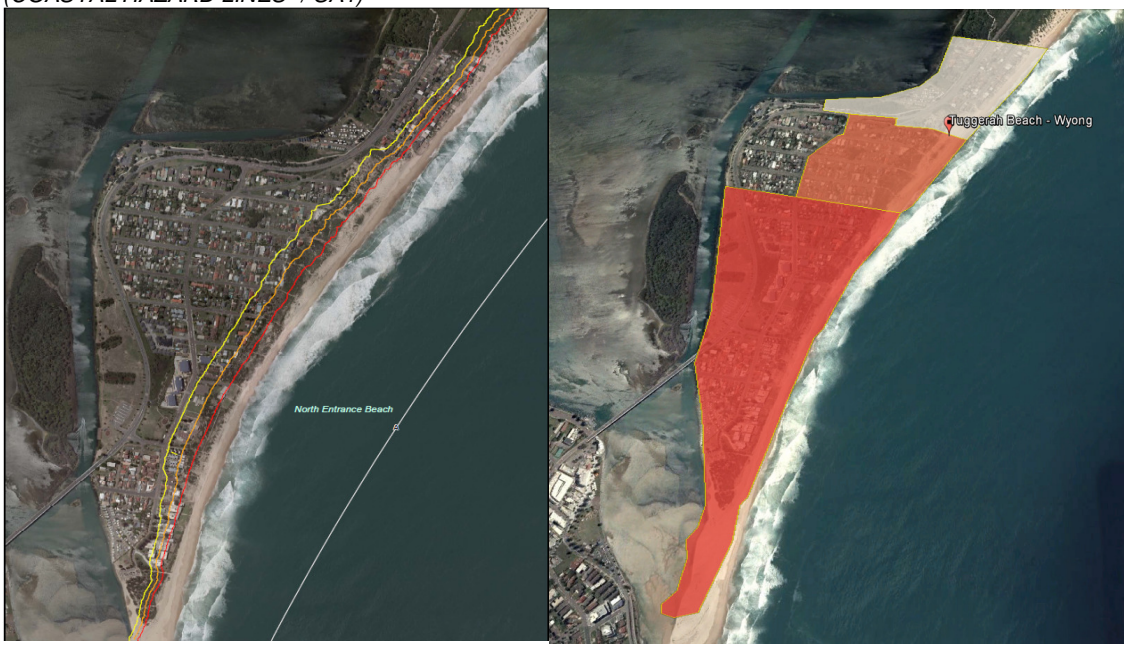
Data	Organisation
2011 and 2006 Census Data (Housing, Population, Income, Population Estimates)	Australian Bureau of Statistics (accessed using ABS Tablebuilder)
National Exposure Information System (NEXIS)	Geoscience Australia
Local Environment Plans and ePlanning Maps	NSW Department of Planning and Environment (DPE)
NSW Population and Dwelling Growth Projections	NSW Department of Planning and Environment (DPE)
Solar PV Installation	Clean Energy Regulator and NSW Department of Trade and Investment
Rainwater Tank Installation	Office of Environment NSW Home Saver Rebates Program data
Adult Population Health Surveys	NSW Ministry of Health (Centre for Epidemiology and Evidence)
Integrated Planning and Reporting (IPR) information	Individual councils
Tourism visitation figures	Destinations NSW and Tourism Research Australia

Taken collectively the data sets may provide a high level, though not determinative snapshot of potential human vulnerability and adaptive capacity. 'Value add' analysis may improve the relevance of data collected. Selection of data metrics are based upon a literature review of social vulnerability indicators and Geoscience Australia recommendations (Dwyer et al:2004).

It is important to note that data is not collected at a universal scale or spatial boundaries. These spatial boundaries include Local Health Areas (LHA), postcodes, local government areas (LGA), ABS Statistical Areas 1(SA1) and 2 (SA2), coastal zones and beaches. Local Health Areas are the largest spatial unit and as such are limited in any representativeness of a particular coastal place or locality. Data may require a degree of reliability discounting depending on representativeness when applied to a locality.

The aim is to spatially match data boundaries to the section of the coastal zone in which NSW coastal erosion hotspots are located. However, even the most disaggregated datasets from the 2011 ABS Census (Statistical Area 1) do not precisely match the boundaries of hazard planning lines or hotspots. For example, Figure 7 shows a comparison between the coastal hazards lines mapped at North Entrance / Tuggerah Beach (Wyong Shire) and the three SA1 spatial boundaries used to analyse this particular coastal erosion hotspot. The implication is that the data is only indicative and higher resolution qualitative surveys are required to improve the reliability of data.

FIGURE 7: COMPARISON OF SPATIAL BOUNDARIES AT NORTH ENTRANCE / TUGGERAH BEACH (COASTAL HAZARD LINES[2] / SA1)

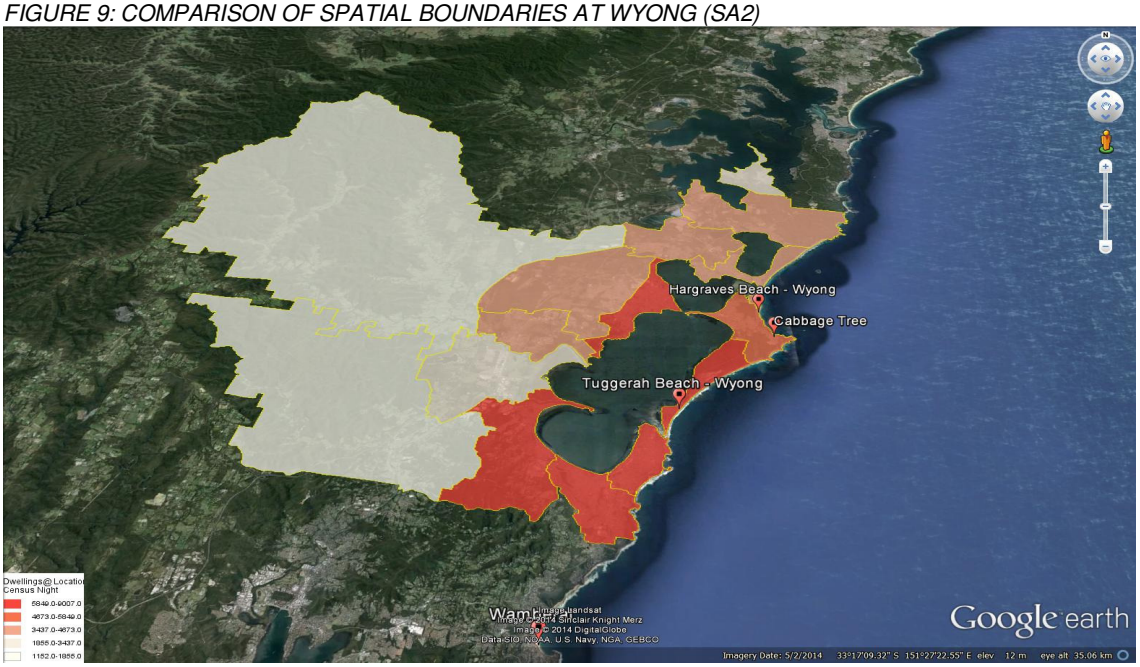


As Figure 7 shows, the SA1 areas (right) are larger than land and properties falling within the deterministic 2100 coastal planning hazard lines taken from work on the draft Wyong Shire CZMP (left). The result is that the SA1 areas are not precisely representative of individuals or properties within coastal hazard planning lines despite being the most disaggregated data collection set publicly available from the ABS. These SA1 and SA2 areas are identified with seven and nine digit numbers respectively. These numbers represent a spatial area as highlighted in Figure 8

FIGURE 8: TUGGERAH WITH SA1 IDENTIFIERS

[2] Map reproduced from a draft Wyong Shire Coastal Zone Management Plan. Umwelt (Australia) Pty Ltd (2011) – Figure 3.8.

FIGURE 9: COMPARISON OF SPATIAL BOUNDARIES AT WYONG (SA2)



Representativeness of data is further reduced where the spatial boundaries of the dataset are even larger. Statistical Area 2 (SA2) (Figure 9), postcodes, local government areas are larger than the coastal hazard planning lines. This reduces the accuracy of analysis drawn from the data.

Table 2 shows the relationship between the five main spatial boundaries used across all data sets and the coastal erosion hotspots.

TABLE 2: LISTING OF CORRESPONDING SPATIAL BOUNDARIES

Largest area		**SCALE**			**Smallest area**
Local Health Area	**Local Government Area**	**Statistical Area 2 (SA2)**	**Postcodes**	**Statistical Area 1 (SA1)**	**Coastal Hotspot Beach**
Northern NSW	Byron Shire	112011240 (Byron Bay)	2481	1124021	Belongil Beach
				1124022	
				1124001	
				1124002	
	Ballina Shire	112011242 (*Lennox Head - Skennars Head*)	2478	1124219	Lennox Head & Seven Mile Beach
				1124202	
				1124203	
				1124205	
	Clarence Valley	104011082 (*Maclean - Yamba – Iluka*) - Brooms 104011081 (*Grafton Region*) - Wooli	2463 (Brooms Head) 2462 (Wooli)	1108147	Brooms Beach, Wooli Beach & Main Beach
				1108148	
				1108209	
Mid-North Coast	Port Macquarie-Hastings	108041162 (*Laurieton - Bonny Hills*)	2445	1116223	Lake Cathie Beach
				1116234	
				1116207	
Hunter New England	Greater Taree	108051168 (*Old Bar - Manning Point - Red Head*)	2430	1116808	Old Bar Beach
				1116827	
	Great Lakes	106031124 (*Tea Gardens - Hawks Nest*)	2324	1112411	Winda Woppa & Jimmy's Beach
Central Coast	Wyong	102021053 (The Entrance) 102021054 (Toukley - Norah Head)	2263 (Hargraves and Cabbage Tree) 2261 (Tuggerah)	1105411	Hargraves Beach, Cabbage Tree Harbour & Tuggerah Beach
				1105319	
				1105320	
				1105321	
				1105414	
				1105413	
	Gosford	102011039 (*Terrigal - North Avoca*) 102011041 (*Wamberal - Forresters Beach*)	2260	1103920	Wamberal & Terrigal Beach
				1103910	
				1104109	
Northern Sydney	Pittwater	122021422 (*Newport – Bilgola)* 122021423 (*Warriewood - Mona Vale*)	2107 (Bilgola) 2103 (Mona Vale)	1142345	Mona Vale & Bilgola Beach
				1142344	
				1142342	
				1142210	
	Warringah	122031431 (*Narrabeen – Collaroy*)	2101 (Narrabeen) 2097 (Collaroy)	1143132	Collaroy-Narrabeen Beach
				1143142	
				1143116	
				1143104	
				1143153	
				1143151	
				1143109	
Southern NSW	Eurobodalla	101041017 (*Batemans Bay*)	2536	1101713	Wharf Road, Batemans Bay
				1101717	

Data Limitations

Verification and ground-truthing of the data with local surveys and knowledge is required. ABS data published at SA1 is randomly adjusted to avoid the release of confidential data and in some data sets the numbers are very low. This means a margin of error of at least 5% should be universally applied to SA1 data.

Another limitation imposed on the analysis is the use of multi-factor attributes at the SA1 level. For example, we do not identify the number of residents in the 65-75 age bracket who also live in a separate house dwelling without a car. This means that the analysis is unable to pinpoint whether multi-factor vulnerability is concentrated in particular residents, such as low income earners, with no motor vehicle that are over 45 years old, thereby multiplying vulnerability. This avoids analysis based on very small percentages, privacy issues and data reliability problems.

These data limitations and other methodology challenges should be addressed by continued improvement in data resolution and collection to augment coastal zone management decision making. Otherwise the use of data in decision making will be unduly limited.

Relevant data and metrics for human sensitivity and adaptive capacity

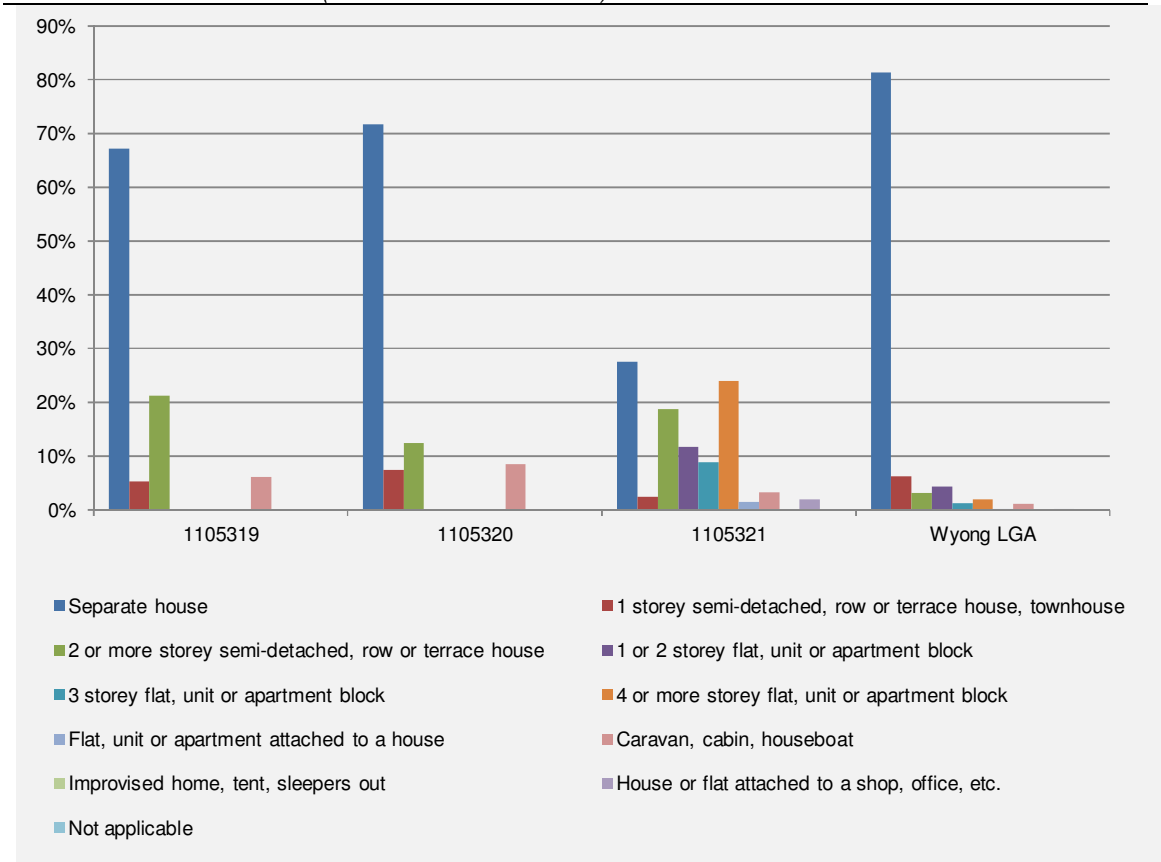
Assessment of potential human vulnerability and adaptive capacity can be based on extracting relevant data and building metrics. The metrics used are not exhaustive, but cover most key indicators. This section provides a justification on why certain metrics are used, what information can be elicited and assumptions relevant to the information.

1. Dwelling Type
Metrics *Urban Form Characterisation (1A)*[3] *Population Density (1B)*

The prevalence of particular building structures and dwelling format provides insight into potential density of the existing built form. A higher percentage of single story detached dwellings in most cases will indicate a lower level of urban consolidation whereas medium to high rise multi-unit apartments most likely indicate higher urban density. Dwelling type may also provide insight into capacity (universal design and accessibility), family structure and broad demographics.

Density also has some correlation to achieving 'economies of scale' for infrastructure development and funding of local council services and asset maintenance obligations. 2011 ABS Census data (Dwelling Characteristics – SA1) can be used to establish dwelling type (Figure 10).

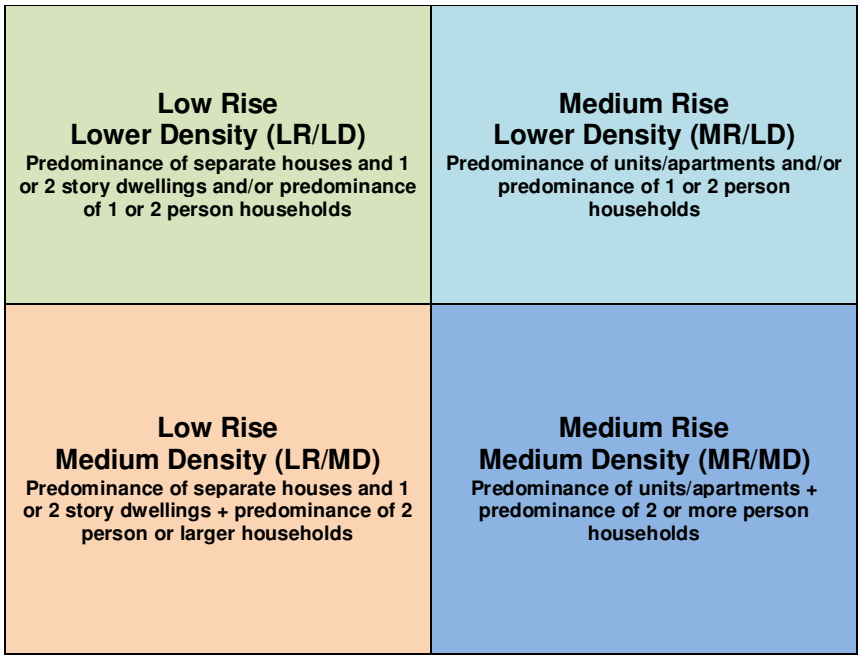
FIGURE 10: DWELLING TYPE (TUGGERAH BEACH SA1s)



When combined with occupation rates, dwelling type can provide a more complex picture of dwelling and population density (Figure 11) and enables a broad characterisation of urban form.

FIGURE 11: DWELLING TYPE AND OCCUPANCY CATEGORISATION[4]

[3] The numbering corresponds to the table at the end of the paper.



Population density can also be obtained through comparing SA1 m^2 data with ABS dwelling and population numbers. Population density data is also available at SA2 (Regional Growth Estimation dataset) and LGA levels. There are significant limitations on using ABS SA1 areas as spatial units to measure population or dwelling density as they have no relationship with land use planning activities and generally show overall higher density figures than those at broader spatial scales.

Comparatively lower dwelling and population density may indicate a narrow rate base from which council raises revenue. If this is coupled with depressed property asset values, local councils may face significant limitations in raising revenue. However, low dwelling density may indicate a capacity to grow and accommodate relocation within a locality (Young:2014)[5] which could be interpreted as a form of adaptive capacity. The average population density (person per km^2) across 152 LGAs is 781 residents (2013).[6]

FIGURE 12: POPULATION AND DWELLING DENSITY (WAMBERAL/TERRIGAL SA1s)

SA1	SA1 m^2	Number of Dwellings	Dwellings per km^2	Actual Population	Population density per km^2
1103920	523,923	463	884	699	1,334
1103910	351,882	509	1,447	714	2,029
1104109	268,766	269	1,001	386	1,436
Total	**1,144,571**	**1,241**	**1,084**	**1,799**	**1,572**

[4] Note that there is no reference to high-rise. While there are some SA1 areas with apartment blocks with 4 or more storeys (ABS definition of high rise), local government areas might characterise building as 'high-rise' based on different building heights. While most areas analysed in the article do not have high rise apartment buildings some areas such as Tuggerah, Wamberal, Collaroy-Narrabeen and Mona Vale have a number of apartment buildings that are 4 storeys or more.
[5] It is noted that biophysical limitations or national park tenure may suppress dwelling density also leave little room to grow or relocate away from coastal hazards locally.
[6] Note the NSW total population density is 9.3 residents per km^2. This is much lower than the Greater Sydney figure of 374 residents per km^2. Even within the Greater Sydney region there is a significant diversity of population densities. The approach used here is to add the total population density figures of all 152 LGAs and divide it by 152. This ignores the fact that LGA vary significantly in geographic size. However, this does provide an average of population densities that local councils need to cater for across NSW or raise rates from.

2. Historical and Projected Population and Dwelling Growth
Metrics
SA2 Historical Population Growth Rate % 2001-2011 (ABS) (2A)
LGA Historical Population Growth Rate % 2003-2013 (ABS) (2B)
LGA Projected Population Growth Rate % 2011-2031 (DPE) (2C)

Historical and projected population and dwelling growth may provide a speculative insight into the future development pressures. If a coastal settlement is earmarked for increased population growth and urban development due to proximity to key infrastructure (ports, transport hubs), employment opportunities or natural resources, vulnerabilities might be ameliorated by greater economies of scale and urban consolidation. Alternatively, without appropriate planning, urban development growth could increase risk exposure.

The Victorian Coastal Spaces Study (2006) attempted to strategically identify places for urban growth within biophysical limits (Department of Sustainability and Environment: 2006), and is incorporated into the Victoria Coastal Strategy 2014 (Victorian Coastal Council: 2014).

Data on historical population growth at LGA level (2003-2013) and SA2 (2001-2011) is available from the ABS Regional Population Growth (Estimated Resident Population).[7] The total historical population growth rate for 2001 to 2011 is 9.7%. Projected population and dwelling growth produced by the NSW Department of Planning and Environment (DPE) can be used for analysis of potential future growth prospects. The average LGA population growth rate is 11.7%.

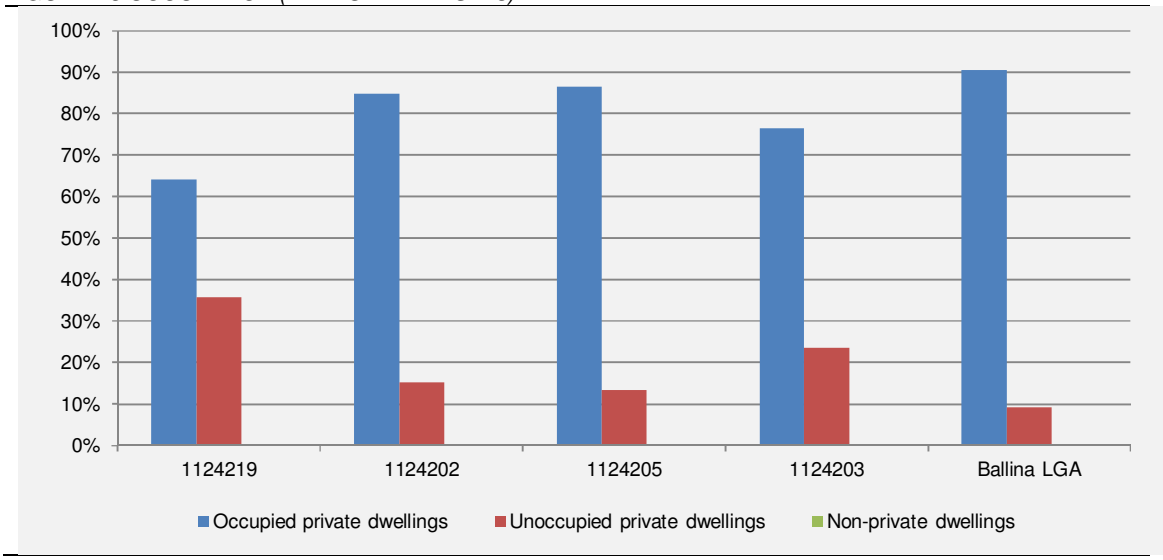
3. Dwelling Occupation
Metrics
% of potential temporary vacancy (3A)
% of dwellings rented (3B)
% of single person households (3C)

Dwelling occupancy relates to three key measures. The first is whether dwellings were occupied on the census night. While this indicator may simply show that occupants were not home on census night, the data can also be used as a tool to assess potential dwelling vacancy including seasonal occupation. There are reliability issue with using this data as an estimation of under-occupation and utility use data would be required to verify under-occupation (Soos & Egan: 2013). Sufficient discounting should be applied to allow for residents that were simply not home on census night.

Level of vacancy where a property may be under-occupied for significant periods of the year has implications for preparedness for coastal hazard events and adaptive capacity in terms of owner-occupiers in primary residences having less adaptive capacity than temporary. The average rate of census night dwelling non-occupation for NSW is 9.24%. Most coastal erosion hotspots will have above average dwelling vacancy compared to the NSW average due to tourism demands. This data set should be considered alongside visitor information from Destinations NSW.

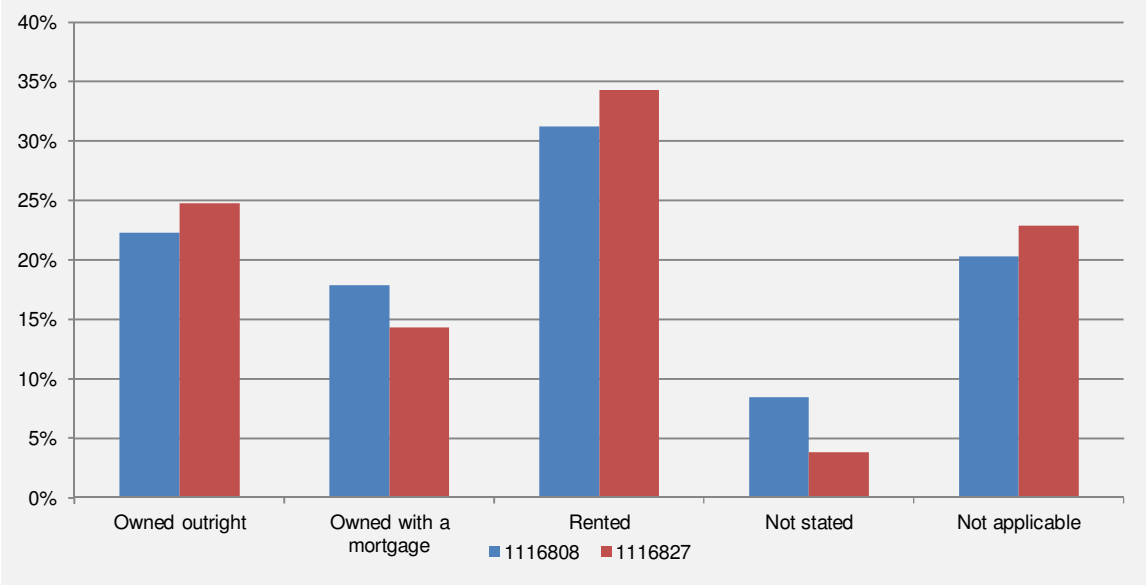
[7] It should be noted that 2013 figures are based on projections and that 2012 was the last year of reconciled population figures. 2013 is used to provide a 10 year growth period picture.

FIGURE 13 OCCUPANCY (LENNOX HEAD SA1s)



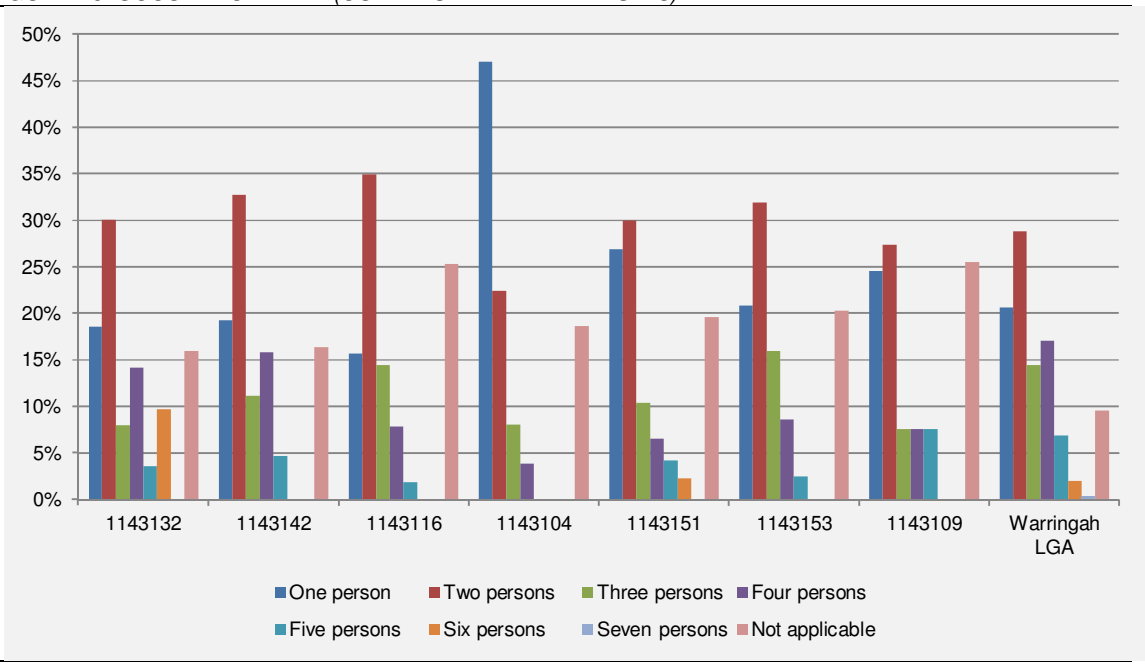
A secondary occupancy measure relates to the type of occupier: owner-occupier or tenant. The relationship of the occupant to the dwelling – tenant or owner – may influence continued occupation in the face of environmental risks or amenity impacts. For example, a tenant may have more flexibility to vacate a dwelling that reaches a particular risk threshold in comparison to the owner-occupier who is living in their primary residence. The average rate of dwelling rental is 25.4% in NSW.

FIGURE 14 RENTAL RATE (OLD BAR SA1s)



The third occupancy measure relates to the number of residents per dwelling. For example, a high number of occupants per each dwelling may indicate housing overcrowding or a generally higher population density. This data can also be used to measure the percentage of single person households, which may represent a measure of vulnerability depending on other social indicators such as age or gender (Figure 15). Approximately 20% of NSW dwellings are single person households.

FIGURE 15: OCCUPANCY RATE (COLLAROY NARRABEEN SA1s)



4. Tourism and Overnight Visitors
Metric % of total NSW visitors (day and overnight) per year received by the LGA

Destinations NSW reviews and collates tourism and accommodation data, primarily drawing from the survey of tourist accommodation complied by Tourism Research Australia. The data set provides total average yearly daytrip and overnight visitors for a number of non-metropolitan LGAs. Data is also available on the number of overnight stays and visitor expenditure.

The data provides insight into why there might be a high percentage of unoccupied dwellings, population numbers beyond the permanent residents (which impacts on infrastructure usage) and potential reliance on tourism income. Data on tourism industry prevalence can also be obtained through ABS census data on employment industry, particularly food and accommodation and arts and recreation industry sectors.

5. Land Use Zoning Configuration
Metrics *Predominant Land Use Zoning (within SA1s)* *Commercial Zone envelope* *Connectivity*

Land use zoning configuration provides a macro level insight into the spatial relationship between public and private areas, residential proximity to foreshore areas, commercial services proximity to residential areas, connectivity and urban structure (radial or grid formation). Local Environment Plan land use zoning maps and relevant overlay maps can enable qualitative analysis of:

- foreshore area zoning (environmental management, environmental conservation, public recreation and deferred matter) and presence of adaptable use hazard buffers.

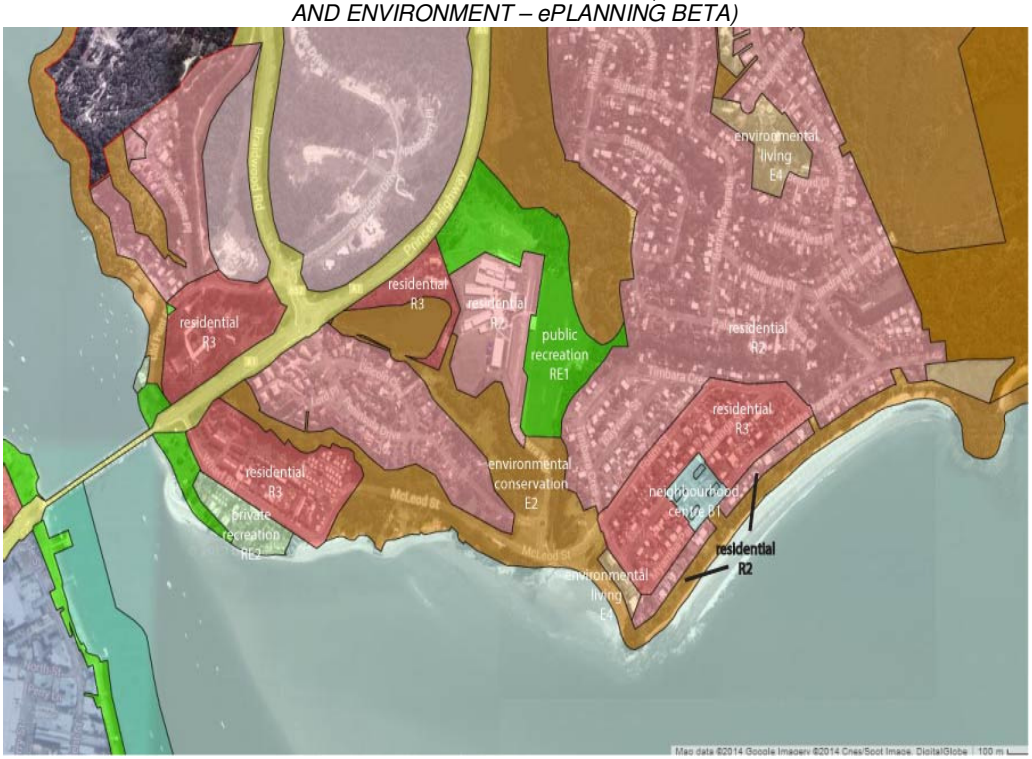
- critical infrastructure services or commercial areas within the built form structure relative to residential areas.

- relative zoning intensity (low density residential compared to medium density residential). For example, immediate foreshore residential properties may be zoned for

low densities while land set further back from the foreshore may have medium density residential zoning applied.

- presence of undeveloped urban land release areas.
- pathways and road network patterns (connectivity)

FIGURE16: EUROBODALLA LOCAL ENVIRONMENTAL PLAN 2012 *(NSW CROWN COPYRIGHT - PLANNING AND ENVIRONMENT – ePLANNING BETA)*



6. Residential Building Vintage and Construction Material
Metric % of residential building constructed before 1985

Building age can be used to make basic assumptions about structural features, as age will correlate with improvements in the Building Code of Australia. For example, in 1980 the Building Code introduced improved standards to make homes more resilient to high winds.

Building age and material can also be used as a high level indicator of potential remaining asset life. Together, these attributes may provide some insight into asset replacement, or renovation timelines. This is relevant to adaptive capacity as it may provide opportunity for consent authorities to revise building requirements in line with current building standards and risk exposure. Use of building construction material such as fibrous (or fibre) cement sheets – which were not used in residential dwellings beyond the mid-1980s - can also be an indicator of age.

Building age and construction data is accessible from the National Exposure Information System (NEXIS).[8] NEXIS provides data on residential, industrial and commercial building[9] exposure to natural hazards compiled at SA2. Extrapolating this data from the SA2 area may be less than reliable if there is a greater relative tendency for rebuilding newer homes in the immediate foreshore areas.

[8] Geoscience Australia National Exposure Information System (NEXIS) Accessed at http://www.ga.gov.au/scientific-topics/hazards/risk-impact/nexis

[9] Only 3 SA2 areas relevant to the hotspots have industrial building exposure. Due to the low sample rate of industrial buildings in hotspot areas and SA1s industrial buildings from NEXIS are not included

7. Decentralised Utilities – Rainwater Tanks and Rooftop Solar PV
Metrics *% of dwellings with connected rainwater tanks (postcode) (7A)* *% of buildings with rooftop solar PV installed (postcode) (7B)*

Most households and businesses rely on centralised services such as water treatment and electricity generation to deliver energy, sanitation and water through complex networks embedded across urban settlements (Graham:2010). Networks delivering centrally generated energy and resources may be susceptible to disruption or damage due to coastal hazards. Decentralised energy generation or water supply may provide a higher level of household resilience, although this will depend on specific system configuration. For example, on-grid solar PV systems in most instances will not function during a power outage whereas off grid can.

This metric seeks to evaluate the household resilience through the uptake of household rooftop solar PV systems and rainwater tanks by postcode. Data on solar PV installation is sourced from the Department of Trade and Industry and the former Clean Energy Regulator. Data on rainwater tank installation is sourced from OEH open source data. The data shows the number of households with rainwater tanks connected in a range of configurations to washing machines, toilets and mains. In most cases the primary rainwater tank use would be for non-potable purposes.[10]

8. Economic Resources
Metrics *Index of Relative Socio-Economic Advantage and Disadvantage (IRSAD) Score and Characterisation (SA1) (8A)* *% of population in low income bracket (SA1) (8B)* *Comparison of SA1 and LGA SEIFA scores (8C)* *T-Corp Financial Sustainability Rating and Outlook (LGA) (8D)*

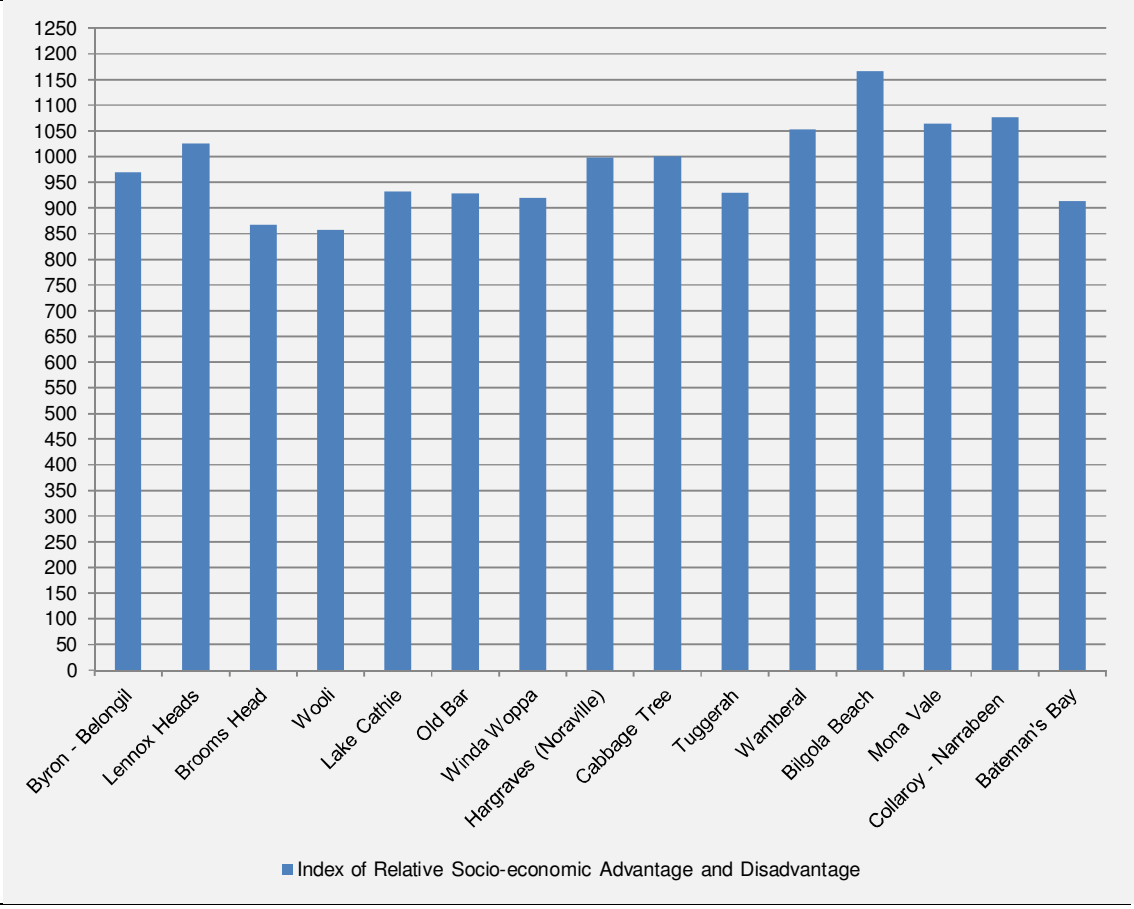
The Socio-Economic Indexes for Areas (SEIFA) data is measures relative socio-economic advantage and disadvantage (ABS:2011). SEIFA is made up of four key indexes; Index of Relative Socio-economic Disadvantage (IRSD), Index of Relative Socio-economic Advantage and Disadvantage (IRSAD), Index of Education and Occupation (IEO) and Index of Economic Resources (IER).

The ABS generally defines relative socio-economic advantage and disadvantage in terms of 'people's access to materials and social resources, and their ability to participate in society'. Each index is made up of relevant Census data set variables to provide a measurement of relative advantage or disadvantage.

The indexes are expressed as both a score and decile. The lower the score or decile, the higher the level of disadvantage. For example, Brooms Head has an IRSAD score of 867 and decile of 1 indicating significant socio-economic disadvantage whereas Bilgola Beach has a score of 1166 and decile of 10 indicating significant socio-economic advantage. Using the IRSAD deciles areas may be categorised into three relative categories: 1 to 3 (disadvantaged) 4 to 6 (advantaged) and 7 to 10 (most advantaged). Figure 17 shows the comparative IRSAD scores for the collective SA1s in each coastal erosion hotspot.

[10] These figures only represent the number of installations that were supported by Office of Environment and Heritage rebates (excluding Sydney Water rebates) resulting in underestimation of installations. The lack of Sydney Water information means that there is limited data for the two Sydney metropolitan LGAs Pittwater and Warringah.

FIGURE 17:: IRSAD AT RELEVANT SA1s (2011) ABS (BY SCORE)



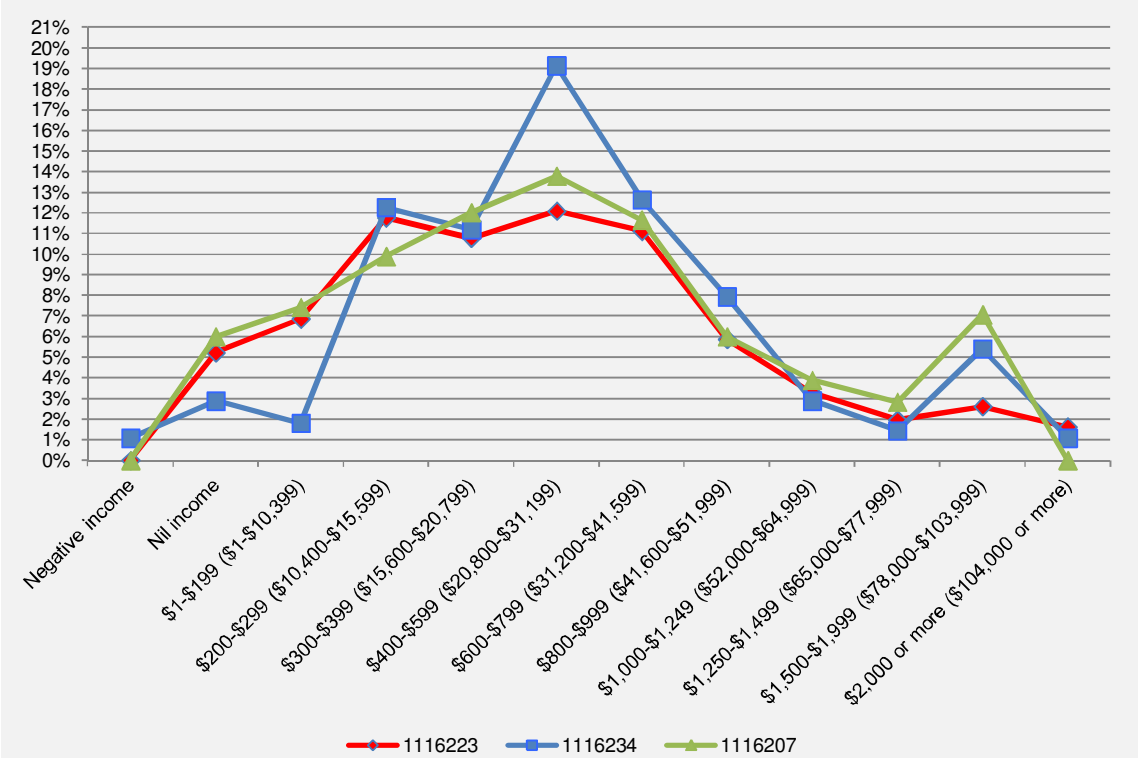
The SA1 to LGA comparison can be included to examine comparative socio-economically advantage between LGA and specific coastal areas.

FIGURE 18 SEIFA SCORE AND DECILE (NORAH HEAD/CABBAGE TREE HARBOUR SA1s)

SA1 / LGA	Index of Relative Socio-economic Advantage and Disadvantage		Index of Relative Socio-economic Disadvantage		Index of Economic Resources		Index of Education and Occupation	
	Score	Decile	Score	Decile	Score	Decile	Score	Decile
1105414	986	5	996	4	1010	6	962	4
1105413	1015	6	1005	5	1004	5	981	5
Wyong	942	4	952	4	973	5	916	2

Personal weekly income (Figure 19) can be used to provide additional insight into economic resources beyond SEIFA characterisation. To obtain a more accurate picture of economic resources weekly income should be evaluated in the context of expenses such as rent or mortgage repayments. Personal weekly income rates are commonly divided into three ranges: low ($1-$599), middle ($600-$1999) and high ($2000 or more). The NSW average ranges for personal income are low income (31.9%), middle income (30.1%) and high income (5.3%).

FIGURE 19: PERSONAL WEEKLY INCOME (LAKE CATHIE SA1s)



Economic resources are also considered at an institutional level. In 2013 NSW Treasury Corporation published a report on the financial sustainability of NSW local governments (NSW Treasury Corporation:2013). The report benchmarked the capacity of individual local councils to generate sufficient revenue to provide a level of service and infrastructure agreed to by the community. T-Corp benchmarking enables a degree of speculation on council capacity to meet needs of local communities, including coastal management.

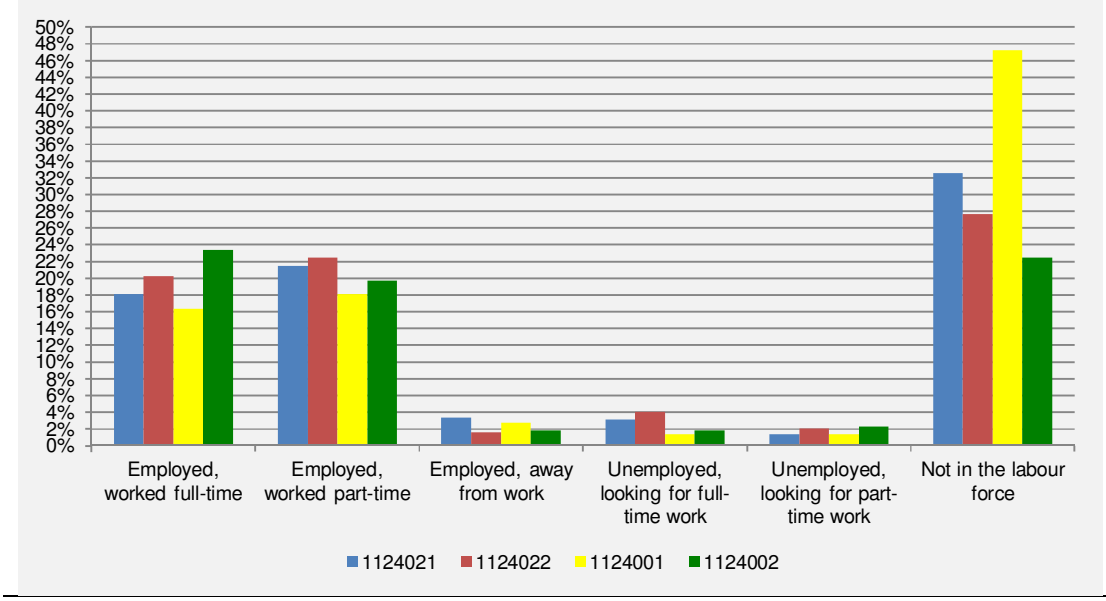
T-Corp uses a seven-band Financial Sustainability Rating (FSR) scale ranging from Very Strong to Distressed. T-Corp also provides an 'outlook indicator' ranging from positive, neutral and negative which indicates the likelihood in any change in a council's FSR in the next three years.

9. Labour Force Participation
Metrics *% of population not in the labour force* *% of population unemployed but seeking employment*

Labour force participation and unemployment levels are also important indicators of economic resources. Approximately 28% of the NSW population are not participating in the labour force. Non labour force participation is a potential vulnerability metric because it may represent a large pool of retirees (both older and younger than 65), people on disability support pension (but not categorised as requiring assistance with core needs), long term unemployed not looking for work or stay at home parents.

Secondly, the level of labour market participation may reflect on the intensity of local economic conditions and activities, notwithstanding that many workers may travel beyond local boundaries for employment. Unemployment is used as a measure of both local economic resilience and personal vulnerability due to lack of economic resources.

FIGURE 20: LABOUR FORCE PARTICIPATION (Byron Bay SA1s) (ABS Census 2011)



10. Age Composition

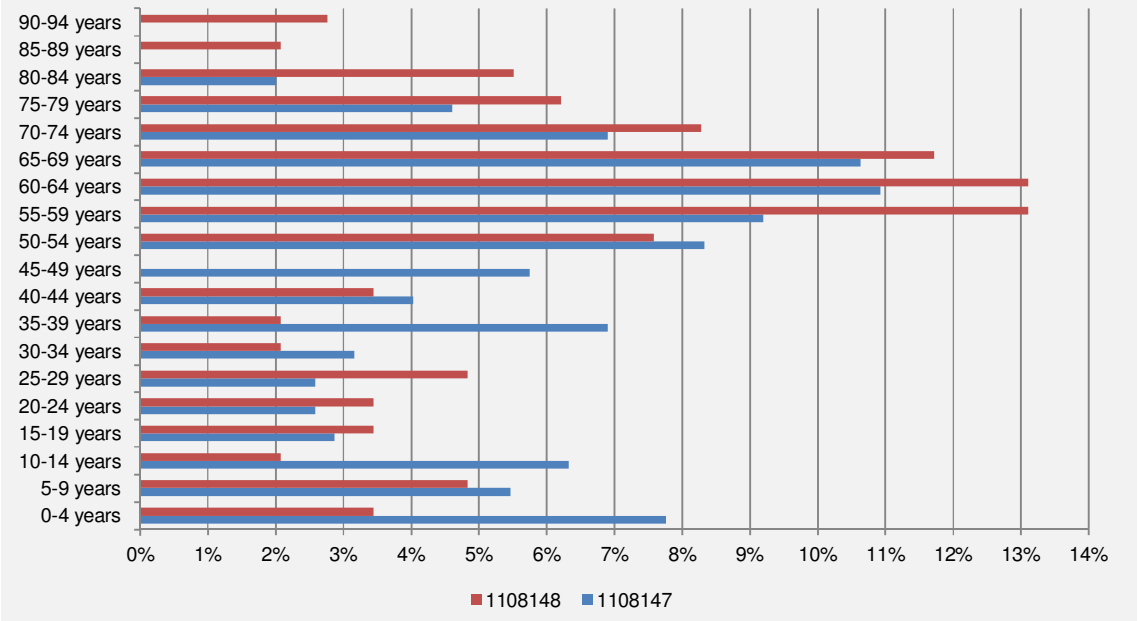
Metric

% of population in the 0-9 and 65> age brackets

Age is consistently used in social vulnerability profiling as an important variable, however its importance can vary depending on the natural environment threat. Extreme heat (Johnson et al:2012), strong winds or surface flooding may pose a greater risk to particular age cohorts than other threats such as slower moving storm surges or coastal erosion.

Age is used as a vulnerability indicator beyond physical capacity to manage biophysical hazards. Predominance of particular age cohorts influences labour force participation rates, local commercial and occupational structure, transport requirements and service demands. The metric of primary importance is the percentage of residents in the 0-9 and 65> age brackets as these age groups may have relatively higher vulnerability levels and dependency. Across NSW these age brackets equate to approximately 28% of the total NSW population.

FIGURE 21: AGE COMPOSITION (Wooli SA1s)



11. Disability

Metric

% of population requiring assistance with core activities and needs

The need for assistance with core activities is a variable introduced into the 2006 Census and is used to measure the number of people with a profound or severe disability. The key areas of core activity include self-care, mobility and communication. This group may have specific health service needs and modified homes reducing flexibility to move away from environmental hazards. Across NSW, approximately 4.9% of the population require assistance with core activities and needs.

12. Transportation and Mobility

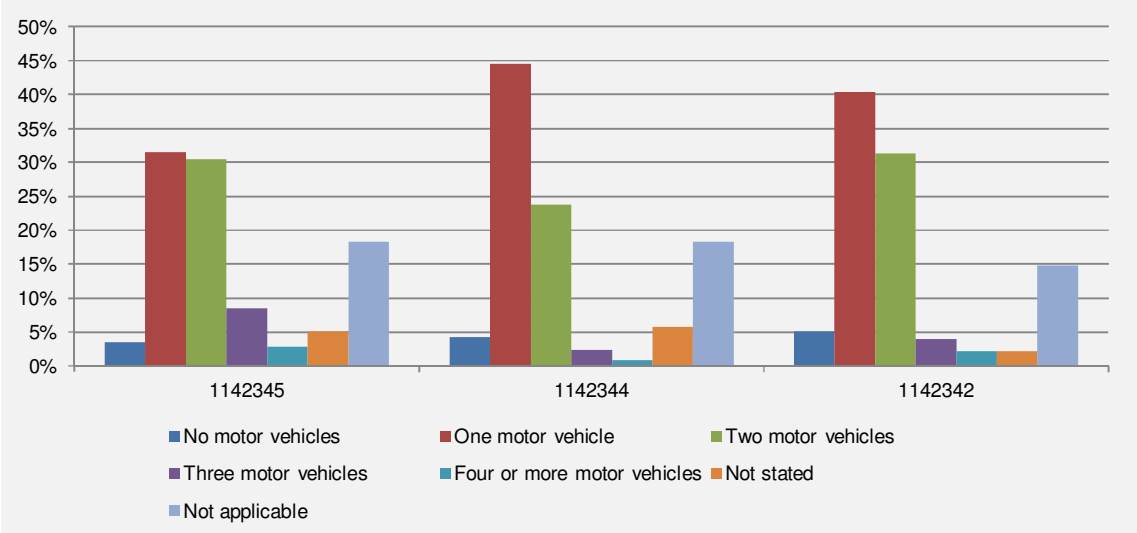
Metrics

% of dwellings or households with no motor vehicle (SA1) (12A)

Ratio of public transport to private transport used by usual residents travelling to work (SA1) (12B)

Movement of residents is a key function of urban settlements. Mobility and transportation allow residents to access critical services, employment opportunities, the natural environment and human interaction. Mobility also has implications for natural disaster evacuation, emergency response and reliance on local services. Without public transportation or private motor vehicles, residents are reliant on local services and commercial outlets. A lack of motor vehicle may also show a preference for active transportation such as walking and cycling or indicate the provision of accessible and convenient public transport.

FIGURE 22: MOTOR VEHCILE OWNERSHIP (Mona Vale SA1s)



Two ABS Census datasets are available to examine this measure including 'number of motor vehicles per dwelling' and 'means of transport to work'. In NSW, the percentage of dwellings with no motor vehicle ownership is 9.2%. The second metric is the ratio of public transport to private transport used by usual residents to travel to work, excluding multi-modal options that use both public and private transportation. The average ratio of private to public transportation for travel to work in NSW is 5.6:1

13. Language and Communication
Metrics *% of population with limited English language proficiency (SA1) (13A)* *% of dwellings with no internet access (SA1 average) (13B)*

Limited ability in English language skills may create an additional level of vulnerability in understanding and responding to extreme climatic events or states of emergency. This metric uses the percentage of the population with limited English Language proficiency as a potential indicator of vulnerability. Almost 4% of the NSW population do not speak English well or cannot speak English at all.

Household internet connections are the only information technology communication indicator. While households may rely on a number of devices (radios, television, telephone) or sources (neighbours) for homes without internet connection may have reduced capacity to actively 'search' for information. Approximately 17.6%% of NSW dwellings do not have internet access.

Conclusion: Human Sensitivity and Adaptive Capacity Data Summary

The table below summarises data collected as part of a preliminary, first pass process to examine the viability of the methodology. The table should be viewed in light of the spatial boundary information in Table 2. The table is produced to evaluate any conflicting or inconsistency in similar metrics rather than characterise vulnerability across the different hotspots. This said, the data can be used to initiate conversations about broad vulnerability issues and opportunities for adaptive capacity.

The table reveals key trends across the coastal erosion hotspots which should form part of community dialogue on coastal management. This is evident in a number of hotspots having similar data profiles across the same metrics. These trends or patterns should not be used as determinative indicators or characterisation but instead encourage and direct further analysis.

Table Key

Below Average

Above Average

No Public Transport: (NPT)

IRSAD

(D) Disadvantaged,

(A) Advantaged,

(MA) Most Advantaged

NSW Coastal Erosion Hotspots and Dataset Results															
	Belongil & Main Beach	**Lennox Head**	**Brooms Head**	**Wooli**	**Lake Cathie**	**Old Bar**	**Winda Woppa**	**Hargraves Beach (Noraville)**	**Cabbage Tree Harbour (Norah Head)**	**Tuggerah (The Entrance North)**	**Wamberal (Terrigal)**	**Bilgola Beach**	**Mona Vale**	**Collaroy Narrabeen**	**Batemans Bay**
1A. Urban Form Characterisation	Low Rise Lower Density	Low Rise Medium Density	Low Rise Lower Density	Low Rise Lower Density	Low Rise Lower Density	Low Rise Lower Density	Low Rise Lower Density	Low Rise Medium Density	Low Rise Medium Density	Low Rise Medium Density	Low Rise Medium Density	Low Rise Medium Density	Medium Rise Medium Density	Medium Rise Medium Density	Low Rise Lower Density
1B. Population Density (people per km^2) (SA1)	596	1591	420	261	405	284	268	1435	1433	1272	1572	992	4456	2780	773
2A. SA2 Historical Population Growth (2001-2011) (ABS)	-2.2%	20.4%	12.8%	3.4%	16.2%	26.3%	22.8%	2.5%		19.7%	2.4% to 8.7%	4.9%	19.1%	8.6%	18.4%
2B. LGA Historical population growth (2003-2013) (ABS)	5.5	5.9%	5.2%		12.6%	7.9%	10.4%	13.5%			6.2%	10%		12.4%	6.8%
2C. LGA Projected population growth (2011-2031) (DPE)	17.5%	9.9%	9.7%		20.7%	7.9%	7.7%	28.2%			17.1%	28.3%		21%	9.6%
3A. % potential temporary vacancy	28%	22%	44%	36%	23.4%	22%	72%	31%	19%	35%	42%	22%	16.2%	12.6%	29%
3B.% dwellings rented	22.5%	28.5%	12.5%	15.3%	27.2%	33.6%	10.2%	23.6%	20.3%	27.2%	25.8%	11.4%	38.2%	35.4%	24.7%
3C.% single person households	15%	16.9%	15.1%	23.9%	24.5%	17%	N/A	N/A	17%	15.5%	14.5%	9.4%	25.8%	24.7%	9.4%
4. % of total NSW visitors per year	1.7%	0.8%	1.2%		1.9%	0.8%	1.2%	2.2%			3.5%	N/A	N/A	N/A	1.5%
5. Land Use Zoning	Qual Analysis	Qual Analysis	Qual Analysis	Qual Analysis	Qual Analysis	Qual Analysis	Qual Analysis	Qual Analysis		Qual Analysis	Qual Analysis	Qual Analysis	Qual Analysis	Qual Analysis	Qual Analysis
6. % of residential buildings built before 1985	0%	40%	0%	23%	25%	25%	0%	22%		20%	11.9%	33.4%	23.6%	3.9%	28.2%

NSW Coastal Erosion Hotspots and Dataset Results															
	Belongil & Main Beach	**Lennox Head**	**Brooms Head**	**Wooli**	**Lake Cathie**	**Old Bar**	**Winda Woppa**	**Hargraves Beach (Noraville)**	**Cabbage Tree Harbour (Norah Head)**	**Tuggerah (The Entrance North)**	**Wamberal (Terrigal)**	**Bilgola Beach**	**Mona Vale**	**Collaroy Narrabeen**	**Batemans Bay**
7A. % of dwellings with connected rainwater tanks	1.4%	0.9%	2.7%	2.1%	2%	2.3%	1%	2.7%		1.9%	2.6%	N/A	N/A	N/A	0.6%
7B. % of buildings with rooftop solar PV installed	15.1%	18.4%	15%	12.1%	18.7%	14.1%	13.4%	9.5%		6.6%	7.7%	5.2%	5.8%	4.9-5.2%	8.2%
8A. IRSAD Score and Characterisation	970 (A)	1026 (A)	867 (D)	857 (D)	932 (D)	929 (D)	920 (D)	998 (A)	1000 (A)	930 (D)	1053 (A)	1166 (MA)	1065 (MA)	1076 (MA)	914 (D)
8B. % of population in low income bracket	43.1%	33.9%	62.5%	54.4%	44%	40.1%	46.9%	35%	42.3%	37.7%	27.4%	17.9%	25.3%	23.7%	50.7%
8C. SA1 SEIFA rankings higher than LGA	No	No	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No
8D. T-Corp (FSR) (LGA)	Weak	Moderate	Weak	Weak	Weak	Very Weak	Moderate	Moderate	Moderate	Moderate	Moderate	Sound	Sound	Sound	Moderate
8D. T-Corp (Outlook) (LGA)	Negative	Neutral	Negative	Negative	Negative	Negative	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Positive	Neutral
9A. % of population not in the labour force (SA1)	32.7%	25.1%	53.6%	51.4%	35.2%	30%	50.3%	33.8%	32%	27.5%	21.9%	26.4%	25.6%	25%	44.2%
9B. % of population unemployed (SA1)	4.1%	3.5%	1.6%	2.4%	3.3%	3.9%	3.4%	4.6%	3.5%	4.6%	3.8%	1.9%	2.1%	2%	2.2%
10. % of population between 0-9 years and 65 years & over	25%	26.6%	43%	39.6%	35.1%	27.9%	45.7%	27.8%	28%	23.5%	21.5%	28.7%	31.5%	26.9%	44.7%

NSW Coastal Erosion Hotspots and Dataset Results															
	Belongil & Main Beach	Lennox Head	Brooms Head	Wooli	Lake Cathie	Old Bar	Winda Woppa	Hargraves Beach (Noraville)	Cabbage Tree Harbour (Norah Head)	Tuggerah (The Entrance North)	Wamberal (Terrigal)	Bilgola Beach	Mona Vale	Collaroy Narrabeen	Batemans Bay
11. % of population requiring assistance with core activities	7.7%	3.3%	6.7%	9.3%	4.5%	6.9%	10%	3.5%	9.1%	4.7%	2%	0%	11.4%	3.5%	6.6%
12A. % of dwellings with no motor vehicle	5.7%	2.3%	3.2%	5%	5.5%	4.5%	3.2%	3.6%	2.7%	6%	2.3%	0%	4.1%	8.8%	7.2%
12B. Ratio of private to public transportation to work	98:1	161:1	NPT	NPT	NPT	NPT	NPT	NPT	28:1	19:1	18:1	9:1	8:1	5:1	NPT
13A. % of population with limited English language proficiency	0.5%	0.5%	0%	0%	0%	0.1%	0%	0%	0%	0.2%	0.2%	0.8%	1.3%	0.7%	0.5%
13B. % of dwellings with no internet access (SA1 average)	12.4%	14%	30%	26.6	22.1	18.7%	9.7%	15.9%	16.7%	14.9%	7.6%	3.2%	9.5%	11.9%	23.6%

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