SECCCA Enhancing Community Resilience to Climate Change

Methods and Application

Paper 3

Final

8th December 2023

About this document

Company	Spatial Vision
Purpose	Methods and Application
Document File Name	SECCCA Enhancing Community Resilience_Paper 3 Methods and Applications_FINAL_8_Dec_23.docx
Project Client	South East Councils Climate Change Alliance (SECCCA)
Date of Issue	8th December 2023
Project Number	SV006177
Version Number	4.0
Document Type	Project Paper
Document Status	FINAL
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Cover photo: Inundation at Mornington Pier

SECCCA and Spatial Vision respectfully acknowledge the Traditional Owners of the lands on which we work, and pay respect to their Elders, past, present and future. We appreciate and acknowledge the advice and guidance of the Bunurong Land Council in assisting with the consideration of potential climate change impacts on First Nations communities, which for this study began with a focus on the Frankston Local Government Area.

Thanks to the Minderoo Foundation for supporting this project.

Contents

1 Document purpose

This document outlines the proposed process by which a vulnerability rating is assigned to groups in the community of concern, and to areas of interest where these groups reside.

This document, referenced as Paper 3, should be read in conjunction with the SECCCA-wide outputs that are provided in the form of Microsoft (MS) Excel tables, PDF maps, and spatial data, as well as the additional papers developed as part of this project to gain deeper understandings of the various components of the project:

Paper 1 – *Definitions and Approaches*: Outlines and introduces the key terms and definitions, and proposed conceptual framework by which community vulnerability and resilience to climate change is to be assessed.

Paper 2 – *Vulnerable Populations*: Describes the vulnerable groups within the community, identified by SECCCA councils, to be of concern in relation to the likely impacts of climate change.

Paper 4 – *SECCCA-wide Outputs: Findings and Guidance*: Provides an overview of the outputs prepared and findings drawn from the SECCCA-wide evaluation. This report includes high-level guidance on how the outputs can be used to identify where there are likely to be groups or sub-populations in the community that are more vulnerable to climate-related events.

Paper 5 – *Case Studies*: Presents the findings of four case studies that apply the SECCCA-wide information for four separate geographic areas, where each case study considers a different climate-change-related event.

2 Project background

Climate change is significantly increasing risks such as fires, floods, coastal erosion and heatwaves to local communities throughout Australia. Preparing communities for current and future changes to the climate is a critical task and requires protection of life, property and wellbeing. Proactively preparing communities to act prior to, during and after disasters builds community resilience to future impacts and minimises risks and their consequences.

The Enhancing Community Resilience Project will help prepare communities in the SECCCA region for current and future changes to the climate by improving community preparedness through practical actions, tools, and resources. Project participants will be empowered with information and access to new or improved services, enabling them to make individual decisions to prepare for climate change.

Leveraging the outputs of the SECCCA Asset Vulnerability Assessment (AVA) project, the project will also assess the vulnerability of the SECCCA region's community to climate change.

Working with SECCCA council members and climate science experts, the project will identify and visualise the community services, demographics, locations, and communities that are exposed to the impacts of climate change. Councils' community planners are integral in understanding vulnerability across communities, including cohorts such as aged care, disability, those with non-English speaking backgrounds (NESB) and youth.

A further stage of the project will develop, deliver and evaluate interventions to build community resilience to climate risk by working with expert community development practitioners, councils, emergency services, and communities.

The project outcomes and approach will be converted into a practical Toolkit for councils and communities that can be applied in other regions throughout Australia to build community resilience to climate change in these areas. This Toolkit will be developed using a parallel evaluation and collation of lessons learned throughout the project.

For further background information on this project, refer to Paper 1 – *Definitions and approaches*: Appendix A.

3 Key definitions

3.1. Resilience

In the past few years, resilience has had significant attention in the context of climate change adaptation, disaster risk reduction and development cooperation in general.

Resilience is applied very differently in various disciplines. From a climate change perspective, an integrated social-ecological understanding of resilience is most appropriate. Following this line of thought, our environment is constituted by social-ecological systems (SES), which encompass five main dimensions: social, ecological, economic, physical and institutional. The concept of resilience considers systems on various levels (e.g. households, communities, countries) as well as the interdependencies between these systems. Moreover, it regards risk, uncertainty and change as normal features of every SES.

In the broadest sense, resilience can be understood as the ability of an SES to deal with shocks and stresses. This ability depends on its capacity to absorb, adapt and transform in the face of stressors threatening the system. Hence, it does not only include the responsive capacity to already known threats but also considers innovation, learning and anticipation to be prepared for projected impacts of a changing climate. Resilience possesses many commonalities with the concept of vulnerability. However, there is no consensus yet on the exact relationship between the two terms.

In order to assess and monitor climate resilience in practice, a better understanding and clear definition of the term is needed. However, due to the complexity and multiple interpretations of resilience theory, there is still no consensus on factors leading to climate resilience. Similarly, there is no consensus on the variables that should be used to assess and quantify progress in becoming more resilient. Against this backdrop, a practice-oriented explanation of central pillars of resilience is provided below. These pillars constitute the basis for assessing and monitoring climate resilience.

Building on the general considerations stated above, climate resilience is defined as the ability of social-ecological systems to absorb and recover from climatic shocks and stresses, whilst positively adapting and transforming their structures and means for living in the face of long-term change and uncertainty.

Key definitions

For the purposes of this project, the following definitions are proposed. These will form a common understanding of how the project will define and measure concepts of resilience and vulnerability as they relate back to climate change and stressors.

Vulnerability:

‘The degree to which a system is susceptible to or unable to cope with shocks and stresses. Vulnerability is a function of the character and magnitude of shocks and stresses to which a system is exposed, its sensitivity, and its adaptive capacity.’

Resilience:

‘The ability of a system to deal with shocks and stresses while retaining the same basic structure and functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.’

Climate resilience:

'The ability of a system to absorb and recover from climatic shocks and stresses, whilst positively adapting and transforming their structures and means for living in the face of long-term change and uncertainty.'

Additional terms that build on and relate back to the vulnerability or resilience of a system link back to concepts of the capacity of a system to deal with climatic shocks and stressors. These have been used in many various forms across a multitude of papers and projects. Here we broadly apply three definitions for these capacities.

Mitigation/Absorptive capacity:

'The ability of a system to prepare for, mitigate or recover from the impacts of negative events using predetermined responses in order to preserve and restore essential basic structures and functions.'

Adaptation/Adaptive capacity:

'The ability of a system to adjust, modify or change its characteristics and actions in order to better respond to existing and anticipated future climatic shocks and stresses and to take advantage of opportunities.'

Transformation/Transformative capacity:

'The ability of a system to fundamentally change its characteristics and actions when the existing conditions become untenable in the face of climatic shocks and stresses.'

These three definitions on capacity broadly cover and join concepts on the ability of a system to prepare for, respond to and recover from climatic shocks and stressors. These three factors, individually or together, are important aspects to quantify or understand how resilient, or vulnerable, a system is.

3.2. Community and community types

This project aims to identify those in the community most vulnerable to climate change and, in the follow-up subsequent stages of the project, to work with these vulnerable groups to build resilience to this change and associated impacts (see Paper 1, section 9.5 for the proposed approach). The project sought to identify these vulnerable communities in the following ways

- Identify the sub-populations in the community that are of greatest concern, and those within this group that are likely to be most vulnerable based on inherent sensitivity factors and capacity considerations (such as LGA and non-government organisation services).
- Consider areas of interest, or 'geographic areas of concern', in relation to climate change impacts; identify the vulnerable groups within these areas; and consider broader ecological, physical and institutional factors (such as existing plans) that impact on vulnerability.

In the context of this project and in consideration of those assessed to be the most vulnerable to climate change, it is proposed that the sensitivity of any sub-population of concern be initially undertaken, and that the services on offer to that group and other capacity considerations that may mitigate its vulnerability then be considered.

Key definitions

Key definitions adopted for use in this project relating to community:

'Sub-populations in the community' are groups defined by common socio-economic demographic parameters, e.g. those over the age of 65 and living alone.

'Geographic community', or 'area of interest', refers to a defined geographic location or extent – typically a rural town, e.g. township of Cockatoo.

3.3. Weather and climate change

Key definitions

'Weather' is day-to-day information of the changes in the atmospheric condition in any area. It refers to short-term conditions or events. However, in relation to climate change, this can relate more so to an abrupt shock or event. This is often referred to as an 'extreme weather' event.

'Climate' is statistical weather information that provides information about the average weather condition of a particular place over a long period. Changes in the weather condition can be observed very frequently.

'Climate change' refers to long-term changes in regional climate patterns as influenced by anthropogenic impacts such as increased fossil fuel usage and input of greenhouse gases that alter atmospheric conditions.

'Climate history' builds on the insights of paleoclimatology (the reconstruction of past climates from the archives of nature) and historical climatology (the reconstruction of past climates and weather from the archives of societies), as well as the methods of conventional history.

'Extreme weather' refers to weather phenomena that are at the extremes of the historical distribution and are rare for a particular place and/or time, especially severe or unseasonal weather. An extreme weather event is significantly different from the average or usual weather pattern. This may take place over one day or a longer period of time. A flash flood and a heatwave are two examples of extreme weather events.

4 Vulnerability assessment framework

4.1. Vulnerability Assessment Framework overview

Underpinning the broader concepts of an overall vulnerability assessment method are the approaches developed by the Intergovernmental Panel on Climate Change (Quin, 2007). These methods describe how likely exposure to climate scenarios, and sensitivity and adaptive capacity of assets and systems to these scenarios, are used to assess the likely impact and vulnerability of assets and systems to these changes (see Paper 1, section 5.1).

The broader conceptual framework on which these vulnerability assessment approaches are based is presented in Figure 1.

Solid lines indicate direct affective relationships between biophysical components (such as the impact of climate change on direct climate variables, or of non-climate variables on exposure to climate variables). Dashed lines indicate the effects of human activity, including the impacts of climate change, and adaptation and mitigation activities.

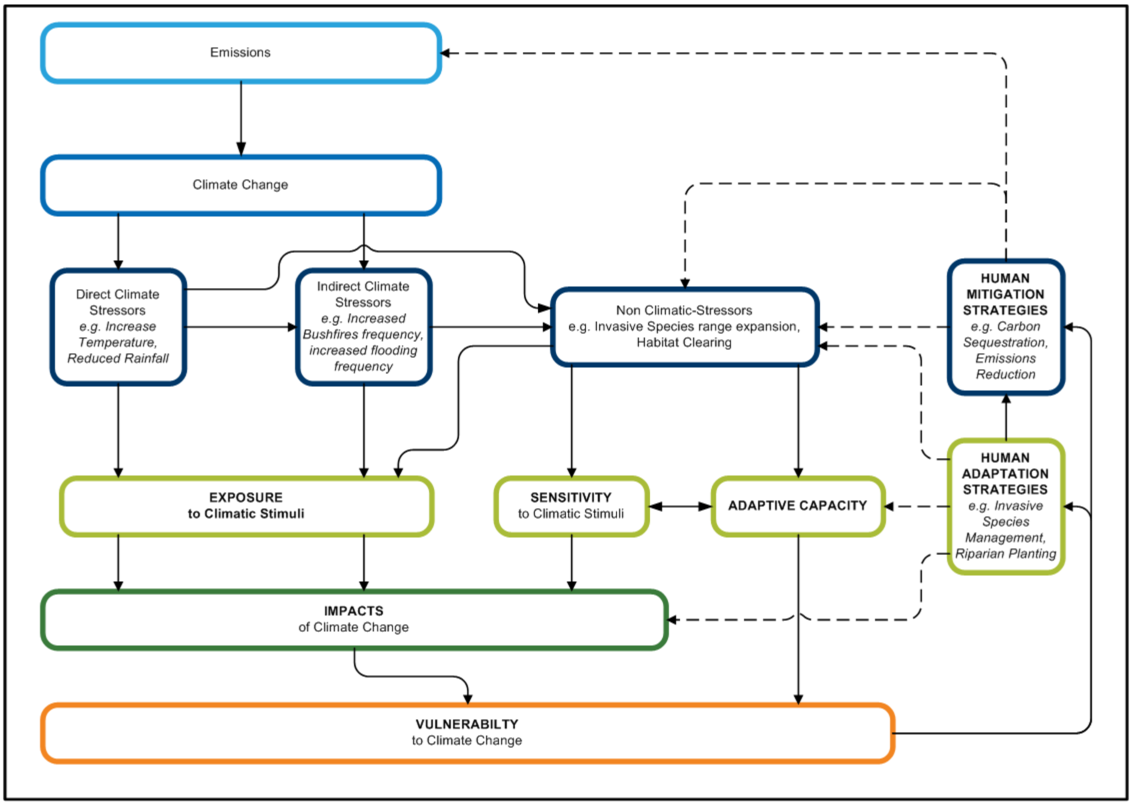

Figure 1. High-level conceptual framework for assessing vulnerability to climate change, showing relationships between exposure, sensitivity, impacts, adaptive capacity and vulnerability (Source: Copan 2014).

This approach generates an impact rating based on assessed asset sensitivity to different climate change exposure scenarios. The adaptive capacity of assets in relation to impacts is also assessed and used to assign asset vulnerability, where adaptive capacity relates to asset condition and context.

The first pass asset vulnerability assessment approach previously applied to SECCCA-built assets involved using individual asset characteristics to assign a likely estimate of an asset's sensitivity to particular climate change variables and the features of an asset impacting its adaptive capacity to such change. Suitable asset attribute information was required to support this assessment.

A review of how individual asset attributes were used to support this assessment was undertaken and agreed with council staff.

4.2. Vulnerability Assessment Framework applied in SECCCA AVA

The vulnerability assessment framework was applied in the SECCCA Asset Vulnerability Assessment (AVA) project (see Paper 1, section 5.2).

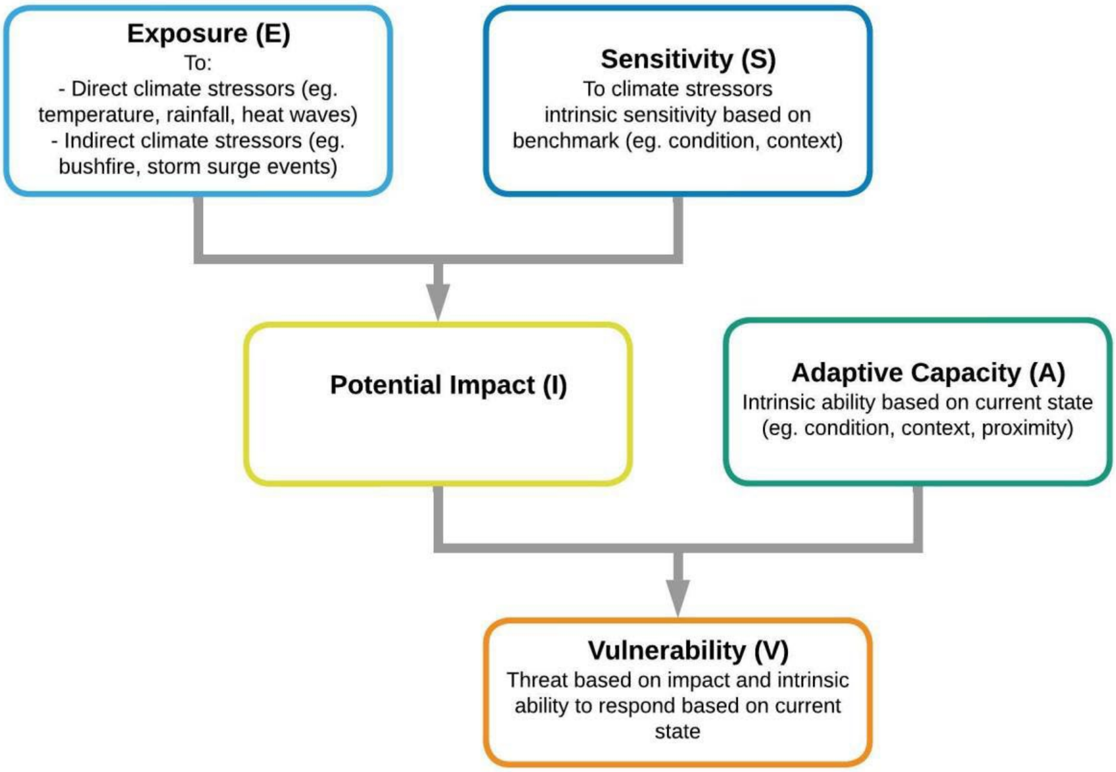

Figure 2. High-level conceptual framework applied in the SECCCA AVA project to assess vulnerability to climate change.

Key definitions

Key definitions relating to this framework, building on the definition of vulnerability introduced above:

'Exposure' relates to the influences or stimuli that impact on a system. Exposure is a measure of the predicted changes in the climate for the future scenario assessed. It includes both direct variables (such as increased temperature), and indirect variables or related events.

'Hazard' refers to a process, natural or otherwise, that has the potential to impact on a given area to a degree that assets associated with that location may be at risk. In the context of coastal areas, these hazards are primarily naturally driven and can include processes such as storms and sea-level rise. However, anthropogenic influences on these processes are indirectly increasing the impact of the hazards.

'Impact' refers to the effect of particular hazards – including extreme events such as storms and other climate events – on the natural or built environment. It relates to the exposure of an asset to a particular hazard and the sensitivity of that asset to that exposure.

'Sensitivity' reflects the responsiveness of a system to climatic variables, and the degree to which changes in climate might affect that system in its current form. Sensitive systems are highly responsive to climate and can be significantly affected by small climate changes. This term is often used interchangeably with the term 'susceptibility'.

'Adaptive capacity' in this framework aligns with the previously introduced definition on adaptive capacity. Within this framework, it broadly relates to intrinsic or inherent factors to adjust to climate change (including climate variability and extremes) in order to moderate potential damages, take advantage of opportunities, or cope with consequences.

4.3. Building on the AVA Framework

The AVA framework has been employed in many applications, but it can be altered to adapt to new understandings within applied climate studies. This variation on the AVA approach centres on risk as a central concept and separates 'hazard' from 'exposure' to focus on what the hazard (or shock) is and where and how severe the exposure (or stressor) is.

An assessment of risk in relation to climate change should not only concentrate on factors that relate directly to climate change, as has been the approach with the AVA framework, but should also incorporate other pathways and options that a system may take. According to the IPCC, severity of a disaster depends not only on climate events, but also on exposure and vulnerability which arise from non-climatic factors.

Key definitions

The vulnerability framework approach applied in this and earlier SECCCA projects can be varied to incorporate risk, or potential impact, as the key output (see Paper 1, section 5.3).

Figure 4 summarises how the AVA framework may be transformed by separating the hazard (or threat) from the exposure (or event), and having the threat inform the likely vulnerability of an asset or system based on its sensitivity and capacity to respond in relation to the hazard. The potential impact or risk therefore results from the combination of the vulnerability of an asset or systems and the actual exposure (or event) it experiences in terms of its severity, duration and spatial extent. It is proposed that this model be adopted for this project, with further details presented later in this document.

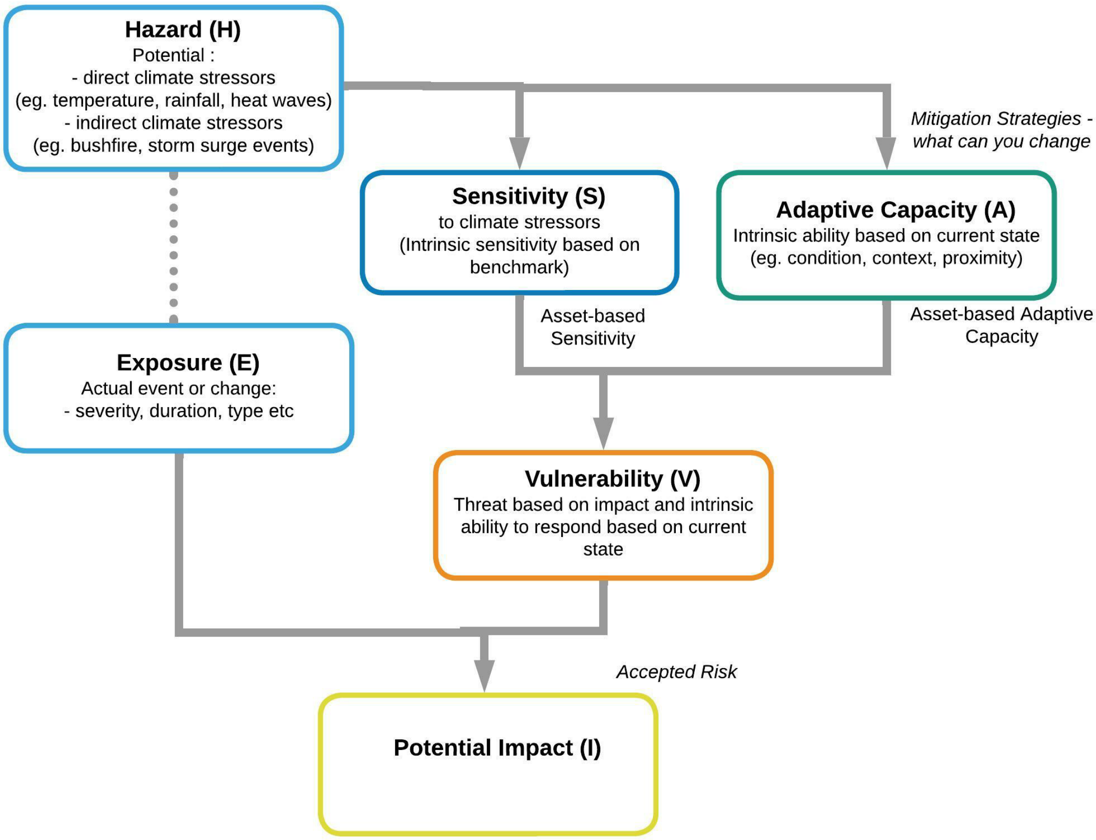

Figure 4. Proposed high-level conceptual framework to be adopted in this study building on the earlier AVA work.

5 Climate data inputs and assumptions

5.1. Climate hazard and exposure data

In assessing the likely impacts of climate change on the SECCCA region, flooding extent, extreme heat, extreme fire risk and increased coastal inundation have been identified by councils to be of particular concern (see Paper 1, section 7.2).

Flooding and inundation

Flooding and inundation impacts were considered in the SECCCA AVA project, but were not directly incorporated or assigned to likely climate futures. Inundation data that was available for use in this project includes modelled flood extent information. This flood extent data identifies the likely area flooded for a number of recurrence intervals, such as 1-in-100-year recurrences or 1% Annual Exceedance Probabilities (AEP). This data was sourced from state government, water authorities and councils.

The overall assessment will include consideration of the following three inundation events:

- Coastal inundation
    - Sea-level rise at 20 cm, 47 cm and 82 cm
    - Sea-level rise of 20 cm, 47 cm and 82 cm with 1% AEP storm surge event
- Overland flooding
    - 1-in-100-year flood event extent based on historical data

Future climate projections of flooding extent and depth can be problematic to model. Factors such as river flow velocities; local terrain and flow restriction points; localised landscape weak points and landslip areas prone to increase flow velocity; and other hydrological factors need to be accounted for if modelling future scenarios.

Melbourne Water has begun creating flood depth analysis using a climate forcing for their jurisdictional boundaries, but currently this is only for a limited number of creeks and basins and is only for the year 2100.

Using current recurrence intervals and AEP levels, a basic understanding of future scenario points can be gained. It is accepted that under likely future scenarios, flooding and inundation will become more frequent due to increased sea levels and changed climate rainfall patterns.

However, the application of historical recurrence intervals in combination with future climate projections requires expert guidance.

Bushfire

A fire risk index, as a single variable measure, will not be included in the vulnerability analysis.

In the initial SECCCA AVA project it was proposed that bushfire risk factors be included as a single variable in the assessment. Through subsequent discussions with the SECCCA Technical Reference Group, in particular Ramona Dalla Pozza (DELWP) and Dr Roger Bodman (CSIRO), who was undertaking fire variable analysis for DELWP as part of the Victorian Climate Projections 2019 (VCP19) program, it was understood that a single index would not provide an accurate indication of fire change and risk into the future.

Therefore, a range of other key variables were adopted and assessed. These included dryness, rainfall trends and temperature increases, which were used in combination to indicate areas likely to experience an increase in fire danger.

Secondary data layers, such as bushfire management overlays, and fuel load information may also be considered. Tom Davies (Insurance Council of Australia) has advised that the ICA primarily makes use of Bushfire Management Overlays in its assessments.

Figure 5 presents a conceptual framework that identifies four factors that influence fire regimes or risks in a landscape. The figure indicates that, while fuel load is influenced by climate or growing conditions, climate also impacts the other elements of the framework – including fuel dryness (and hence flammability), fire weather, and likelihood of an ignition source (particularly lightning).

As indicated in the figure, climate variables such as seasonal rainfall distribution or deficiencies, temperature changes, dryness indexes and extreme days in relation to rain or temperature can be used to provide context for fuel dryness and fire weather.

This framework supports the adoption of key variables such as changes in seasonal rainfall, monthly temperature and dryness to assess likely fire regime impacts.

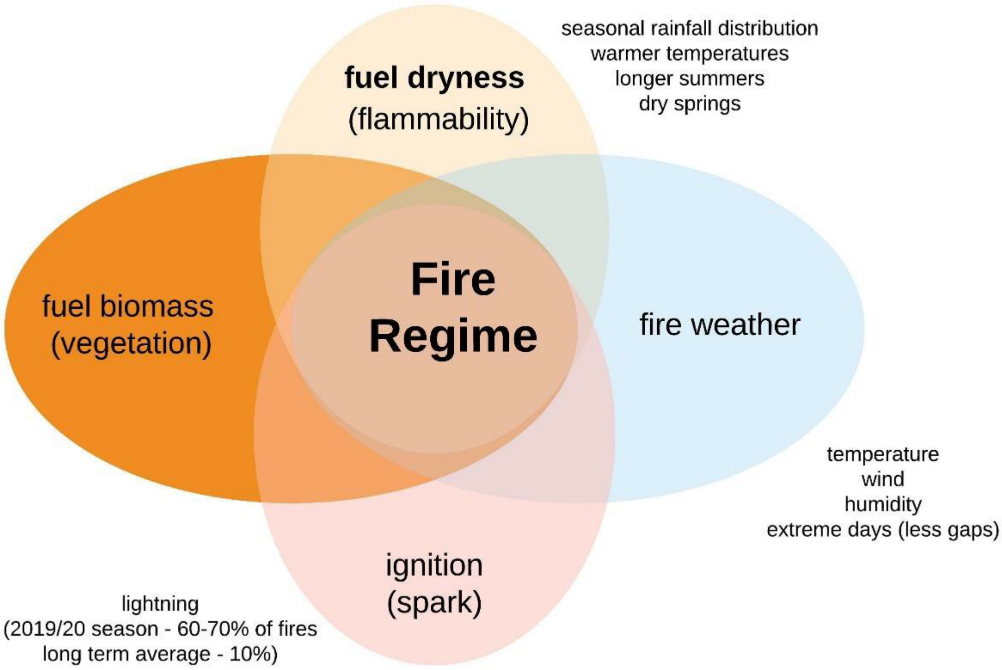

Figure 5. Relationship between climatic variables and landscape factors associated with increased fire risk (Source: Figure adapted from University of Melbourne, 2020).

Wind

Other variables explored by the project team for inclusion in the project included current observations of and future climate change data projections for wind factors. The VCP19 database includes wind speed as part of its suite of variables. However, readings and projections are monthly and not available as daily data (as provided for other climatic variables), resulting in a comparatively coarse dataset.

Additionally, the available data only presents average projected wind speed over a given month, and not details on wind direction or wind gust speeds. Furthermore, the available data does not show any significant variation in monthly wind speed for any of the climate scenarios.

As such, the data is more generalised than what is required for a vulnerability assessment and will not be used.

Similarly, there is limited information on storm event frequency.

Heat and extreme temperatures

Exposure to heat-related events can be explored through the use of the original SECCCA climate data leveraged for the AVA. This can either be as heatwave events for the region or as extreme summer temperatures above a certain threshold. Any variable can be explored in a current baseline and into likely future scenarios.

Excessive periods of dryness due to low rainfall and heat are also included in the consideration of likely climate change. Changes in dryness are expressed in terms of changes in the standard precipitation index measure.

Climate change projections

To explore exposure and likely impacts of heat-related events (either heatwaves or extreme temperatures) on vulnerable communities, the project team proposes using the most recent climate modelling prepared by CSIRO as an outcome to the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5). This application-ready data has been made available as part of the VCP19 program.

The VCP19 updated modelling includes downscaled modelling to a resolution of 5 km^2 Victoria-wide, within the Coupled Model Inter-comparison Project Phase 5 (CMIP5) suite of projections initially made available through CSIRO at a coarse resolution in 2015. These have been updated based on new understandings and modelling techniques and are available for all of Victoria.

Up to six General Circulation Models (GCMs) for the projected years of 2030, 2050, 2070 and 2090 can be found in the VCP19 database, and are available at two differing Representative Concentration Pathway (RCP) emissions scenarios of 4.5 and 8.5. Use of these six models will provide a range of projected climate changes and impact assessments ranging from a warmer and more minimal rainfall change to a hotter and drier projected future.

From these six available climate models, three will form key points of information. This includes models that present for Victoria a 'hotter and drier' future, a 'comparatively warmer and wetter' future and a 'middle ground' maximum consensus future. These will, respectively, represent a maximum, minimum and median climate future projection.

Each climate model and point in this envelope of projected futures can be treated as a climate scenario. They will also be treated as independent of one another. They are seen to represent a possible future and each is as likely as one another. Therefore, creation of a multi-model output that combines all available climate models is not recommended.

All future projected climate and downscaled outputs are similarly based on a thirty-year baseline period. Under the VCP19 database, this is based on historical observed climate records from 1981 to 2010. Other climate databases are known to have differing baselines, but the principles of downscaling from coarse to higher resolution are largely similar.

Extreme weather events

While extreme weather events are not readily modelled in the latest climate science, and downscaled modelling is available through the CSIRO, the latest modelling outcomes will be used to help contextualise key trends in the climate data that directly influence likely extreme weather events for the region. For example, the locations where daily rainfall is anticipated to exceed a particular threshold at a future date and under a particular scenario will be identified.

Climate change events that refer to climate exposures or variables that have a short time frame and sharp response can relate more to extremes in climate or flooding/storm events, the extreme 1% AEP events, or 1-in-100-year events.

5.2. Available climate data

Climate models and climate scenarios

In line with the Climate Measurement Standards Initiative (CMSI) a range of General Circulation Models (GCM) will be selected, representing:

1. maximum consensus future climate (based on all six available VCP19 models (Clark et al. 2019))
2. hotter and drier future climate
3. warmer and wetter future climate.

This approach is also in line with climate change modelling advice provided directly by the project technical reference group, which has advised that futures represented by each GCM are equally possible and that, ideally, two or three different GCMs should be considered in any vulnerability evaluation. The proposed approach to incorporate a range of possible futures is presented in Section 6.

The three models selected to represent the range of likely futures for both temperature and rainfall projections are the NorESM1-M, HadGEM2-CC and ACCESS 1.0 GCMs, where these models have been developed by:

1. ACCESS 1.0 CSIRO and BoM – representing a maximum consensus future
2. HadGEM2-CC Met Office Hadley Centre – representing a hotter and drier future
3. NorESM1-M Norwegian Climate Centre – representing a warmer and wetter future.

Carbon emission futures

In terms of climate projections based on carbon emission future scenarios, SECCCA have expressed interest in the Representative Concentration Pathway (RCP) emissions scenarios of 4.5 and 8.5 (RCP4.5 and RCP8.5).

The VCP19 projections are only available for an RCP4.5 and RCP8.5 carbon emission future.

Time frames

The VCP19 projections are available for 2030, 2050, 2070 and 2090.

This projection data is based on a baseline climate represented by the period from 1981 to 2010. It is proposed that, while the project will compile and review the projection data for all four future time periods, there will be a focus on presenting results and outputs for the period up to 2050. Inclusion of three models for two RCPs and four time points will result in a significantly large volume of data and outputs. Reporting and presentation are largely suggested to focus on one time point to present the context of the results. Other points can be brought in to further expand discussion.

For the period up to 2030, it is noted that changes in the projections between any GCM at both RCP 4.5 and 8.5 may be minimal, but periods after will have larger differences (see below Figure 6) (IPCC 2007).

We also propose investigating the use of existing climate observation data to see how some climate variables are already changing.

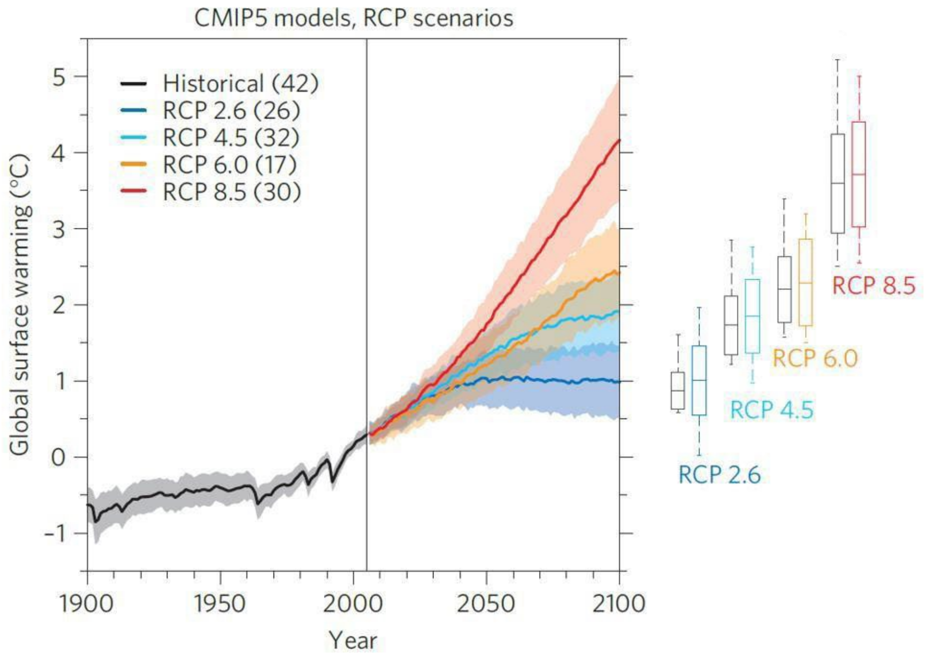

Figure 6. Relationship between four RCP scenarios, where RCPs provide standardised greenhouse gas concentration inputs for running climate models.

Application of the latest climate change data from CSIRO will involve evaluating relevant annual and monthly climate variable data for agreed carbon emissions scenarios (see Paper 1, section 7.3).

This information has been prepared for presentation in a spatial data viewer with a supporting graph-based view of these key climate variables. Evaluation of likely change for the periods of 2030, 2050, 2070 and 2090 and historical decadal information will be used to inform trends in key variables such as rainfall and daily maximum temperatures.

6 Assessing the vulnerability of sub-populations

6.1. Proposed approach to assessing the vulnerability of sub-populations

This figure incorporates aspects of the models presented previously in this document, based on the earlier AVA approach and its transformation to separate hazard from exposure, and applies these separately to sensitivity and capacity aspects of a community.

These aspects of a community sub-population are also viewed in the context of absorptive, adaptive and transformative factors of a group involving social, ecological, economic, physical and institutional aspects. This initial model, which is applied to an individual sub-population, is further developed in the next section. This further development involves expanding the sub-population assessment to multiple sub-populations, and then considering these sub-populations in the context of a geographic area or area of interest.

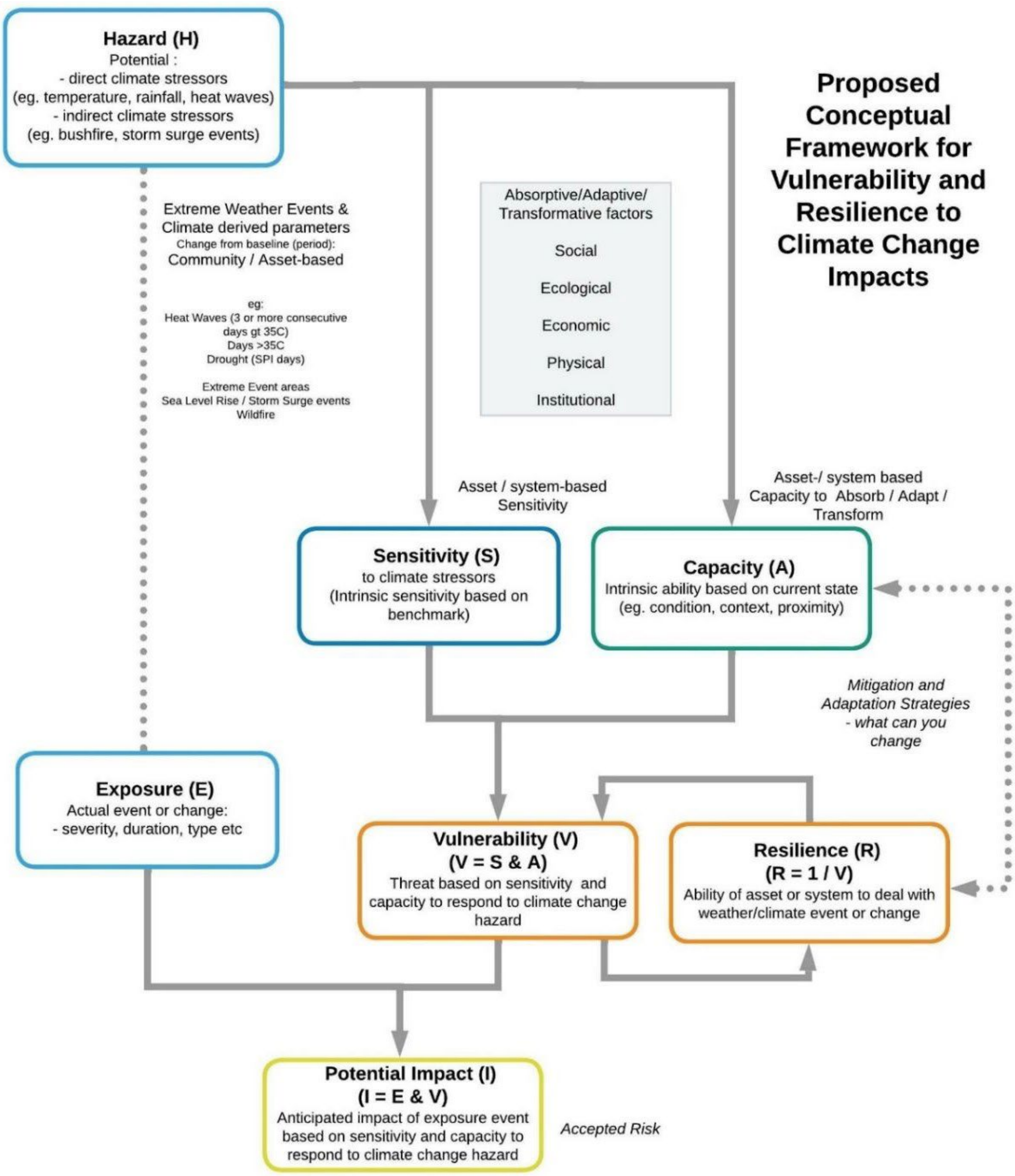

Figure 9. Proposed high-level framework to assess vulnerability and resilience of a community.

The proposed approach is based on social, ecological, economic, physical and institutional measures. It involves using a range of variables or indicators to assign a sensitivity and capacity rating to sections of a defined community relative to a particular climate hazard.

An example of these measures for a sub-population in the community defined as 'older people' (aged 65 years and over) in relation to a severe storm cell flooding event is provided below:

Table 1. Initial thoughts on key community-based variables to assess sensitivity and capacity to a climate change scenario.

Sensitivity variables (defined as those characteristics inherent with the individual or community) Sensitivity increases with:	Capacity variables (defined as those characteristics that can have a mitigating impact on the vulnerability of an individual or sub-population) Capacity increases with:
greater need for assistance	cohabitation with others (not living alone)
greater level of chronic health conditions	greater financial resources
better connections with local community	
proximity to public service node	
area covered by a flood response plan	
greater level of integrated water infrastructure (IWI) investment	
level of service by Council or other services	

Figure 10 builds on the earlier framework and incorporates aspects of consequence, and consequence of loss, of extreme weather events or climate change. These include:

- death (loss of human life)
- damage (asset or system replacement value)
- disruption (to asset or system service, whether economic, social or environmental)
- dispersal (in the short or long term, points to community structure and capacity changes).

6.2. Application of framework to an area of interest

For the vulnerability assessment approach to be scalable and nationally applicable, it needs to introduce a geographic area or area of interest component, and allow the vulnerable groups within that area to be assessed in relation to different climate events or changes of concern (see Paper 1, section 11).

In this project, four geographic case studies (or climate change event–based scenarios) were developed. Each of these geographic case studies focused on a different climate event of concern. For example, that for the area south of Mordialloc Creek (as suggested by Kingston Council) considered flooding from a storm cell event. For new estates, (as suggested by Cardinia Council) the case study considered a heatwave event.

Introducing this concept of an area of interest supports a more nuanced approach to the treatment of capacity factors in the proposed vulnerability assessment approach, especially in relation to the treatment of institutional, ecological, and physical assets.

It is proposed that this approach provides additional value for the building of resilience phase.

The approach by which an area of interest, such as a township, can be assessed in terms of vulnerability to climate change is summarised in Figure 10.

6.3. Role of community assets in assessing vulnerability

For the purposes of this project, community assets are identified in relation to their role in providing sub-population services and broad support to the general community (see Paper 1, section 11).

Sub-population services are provided to mitigate the vulnerability of the community (or sub-populations within the community) to the impacts of climate change. In many instances, these same services and related assets will provide support services and functions that assist with a broad range of social, economic and economic stresses and shocks. An example is the role that schools, child care centres, non-government community service centres or places of worship play in supporting or offering a service to the community. In this regard, community assets are considered in relation to capacity factors and are used in combination with sensitivity factors to assess those of most concern within any vulnerable sub-population.

Broad support to the general community is provided as an indicator of broader community resilience or vulnerability across a larger geographic area. Examples of community assets in this category include proximity to public transport, local shops, hospitals, or open space, or the number of certain assets within a given distance.

Key definitions

Key definitions adopted for use in this project relating to community assets:

Community assets are identified as physical assets that:

- provide services to selected sub-populations to mitigate the vulnerability of the community (or sub-populations within the community) to the impacts of climate change
- provide broad support to the general community as an indicator of broader community resilience or vulnerability across a larger geographic area.

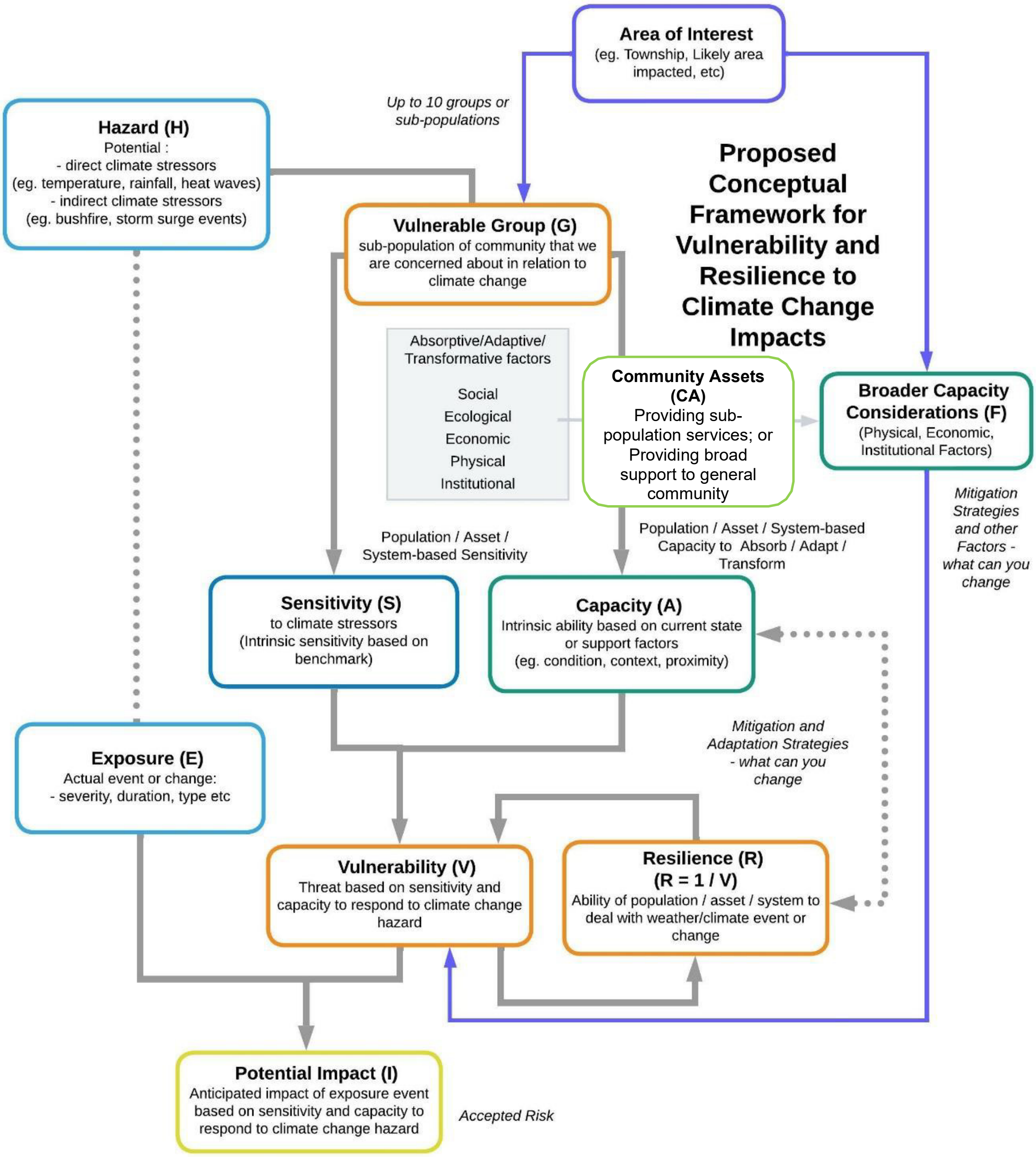

Figure 10. High-level framework to assess vulnerability of a community and consequence of loss dimension.

6.4. Bringing it all together – analysis workflow

In relation to the application of the climate vulnerability assessment process proposed in this paper, the suggested steps to undertake an assessment of community vulnerability to climate change (and hence their current level of resilience) are as follows:

1. select a community (as identified by SECCCA councils and confirmed as a priority for assessment)
2. select a climate change event of concern
3. identify key parameters that are likely to demonstrate variability in relation to vulnerability or

resilience of that community to the climate change event of concern. This may include:

- socio-economic parameters
- assets and associated services provided
- other planning and institutional considerations

A checklist may include:

  - social: *primarily refers to characteristics such as health, education and food security*
  - ecological: *particularly addresses the diversity and state of the natural environment*
  - economic: *comprises the economic activities within a system as well as the availability and distribution of financial assets and other endowments, which may fulfil a variety of purposes*
  - physical: *mainly focuses on physical infrastructure such as housing, transport infrastructure, communication networks or health facilities*
  - institutional: *focuses on effective governance and institutions as well as participation on various levels*

4. assign a level of importance to each parameter
5. leverage available data and expert opinion to apply a rating or measure to each parameter based on the climate change event of concern in relation to the identified community
6. apply in the proposed framework to assess vulnerability of the identified community to the climate change event of concern.

7 Approach to assign sensitivity and capacity ratings

From the workflow outlined above, the following section will provide examples of the application to a sub-population in the community defined as 'older people' in relation to a severe storm cell flooding.

7.1. Community selection

1. List all identified vulnerable populations.
2. Cross-link populations to climate hazards of concern.
3. Prioritise those in list that are most vulnerable to hazard of concern.

The first stage in the analysis workflow is the identification and selection of a vulnerable sub-population or community of concern. This requires a considerable consultation process with council and external stakeholders who can aid in this process.

This process and the outcomes of that consultation are discussed in detail in Paper 2 – *Vulnerable Communities*.

Outcomes of this process have led to identification of the 10 vulnerable sub-populations listed below:

- Older people
- Non-English-speaking backgrounds – recent arrivals
- Non-English-speaking backgrounds – established communities
- High level of care individuals
- Single mothers
- Homeless/insecure housing
- Youth
- Low income
- First Nations
- Geographic communities.

This list of 10 vulnerable sub-populations includes geographic communities that comprise a collection of all other sub-communities within an area, as well as other, broader considerations. The application to a geographic community approach is therefore viewed as a separate process. This will be outlined in the following chapter.

Part of the vulnerable sub-population selection process is the identification of which climate hazard is most likely to impact that population. Below in Table 2 is the hazard of concern that each contributing council member notes against each sub-population. This is by no means a complete cross-section, but is more a reflection on the shared concerns councils have within the SECCCA region. Each vulnerable group is expected to have an impact related to each hazard, but this table reflects council priorities.

Table 2. Council priority links of vulnerable sub-population to hazard of concern

Community	Flood/ Inundation	Fire	Storm	Heat
Older people	●	●	●	●
Non-English-speaking backgrounds – recent arrivals	●	●		●
Non-English-speaking backgrounds – established communities		●		●
High level of care individuals	●	●		●
Single mothers	●			●
Homeless/insecure housing	●		●	●
Youth		●		
Low income	●	●	●	●
First Nations	●	●	●	●
Geographic communities	●	●	●	●

7.2. Component identification and selection

1. For a given vulnerable population, list all component factors that may make them more or less vulnerable to a climate hazard.
2. Identify the components that are sensitivities in the population and those that are mitigating capacities.
3. If possible, assign to identified components a likely sector to which it belongs.
4. Determine data sources for each component to help spatially define location.
5. Determine physical assets that service the vulnerable population and detail the level of service provided.

Within a vulnerable sub-population of concern, a number of components may make an individual, or population as a whole, more vulnerable to a climate hazard. These components can be divided into the two broad categories of 'sensitivity components' and 'capacity components'.

Sensitivity components are factors that can make the group more vulnerable to a climate hazard. They cannot be readily changed by an individual or group. This can reflect the responsiveness of a sub-population to climatic variables, and the degree to which changes in climate might affect that system in its current form. Sensitive sub-populations are highly responsive to climate and can be significantly affected by small climate changes.

Capacity components are factors that mitigate climate hazards and sensitivities. They broadly relate to intrinsic components of a community to adjust to climate change to moderate potential damages, take advantage of opportunities, or cope with consequences.

Each component factor can also be assigned into one of five sector groups:

- social/health
- economic
- physical
- institutional
- environmental.

These groupings are a means of separating various aspects of a vulnerable population into key divisions that can be overlayed against one another or assessed individually.

Data sources

For any given vulnerable sub-population, the source of input data broadly shapes how each component is defined and hence is spatially represented.

Census data

The majority of data inputs for a given facet of the population base are sourced from the Australian Bureau of Statistics (ABS) 2021 census. This data is provided for a number of components relating to their General Community Profile (GCP) down to a Statistical Area level 1 (SA1) geography. Within the GCP is a range of census statistical outputs for various facets of the population. These outputs can range from simple population metrics to household composition to places of enumeration.

Using the example of older people, the ABS data allow for this group to be split by age cohort. Additionally, health metrics by condition type can be used as well, by age. For this analysis, the majority of inputs for older people that helped define vulnerabilities originated from the 2021 ABS census data packs.

Spatial data

The other primary source of data used for an evaluation of each sub-population included spatially referenced asset data or other derived spatial proximity analyses (for example, proximity to public transport). This is supported by the use of spatial data, such as key features of interest, to undertake analyses to derive service coverage areas. This will either detail areas that are within a distance of a given asset, or simple presence or absence of an asset in a geographic location.

This data is sourced from various resources, primarily public council asset data or state government asset data. For council data, each individual council has provided data regarding their managed assets, including attribution in relation to asset type or service function.

A differing set of asset data has been used for each vulnerable population, depending on the identified components. Broadly, these can relate to a number of physical asset data including:

- public transport
- open space
- medical facilities
- public housing
- retirement villages or aged care facilities
- child care and MCHC
- community centres and other council service assets
- housing type or condition.

This listing of physical assets is the beginning of a community asset register, as noted in Section 7.3. Together with service-level information, a more complete picture of services and assets is gained.

Consultation with First Nations people

In regard to the approach taken to the 'First Nations' sub-population, the Bunurong Land Council was consulted for guidance. Consultation discussions focused on considerations of vulnerability on First Nations communities to climate change impacts, and were based on a proposed approach to assess the Frankston City Council area. We appreciate and acknowledge the advice and guidance of the Bunurong Land Council.

Service data

The final aspect of data for any analysis is the consideration of services provided. This can cover the assets that deliver a service and its location as well as the service level provided within a location or to other locations. To provide a spatial assessment of service provision, council-held knowledge about these services, where they operate, and to what level they provide the identified service is identified for a suburb.

This can be detailed back to an asset that provides the service and the location in which it is located, or to the overall suburban boundary where the service is provided to. Regarding identification, a level of service (i.e. high to low) is assigned.

For example, for older people this can include council bus services, Meals on Wheels and other council services. Importantly, this is not a comprehensive list of services provided in each suburb, and does not cover services beyond those that the local council provides. However, it does provide insight into service provision.

Broadly, this service level and the potentially assigned assets form part of the community assets as outlined in Section 7.3. Together with the physical assets outlined above, a more holistic listing of community assets is gained.

Once created, this layer sits under a capacity component that can mitigate the sensitivity of a climate hazard within a vulnerable population.

7.3. Model creation and application

1. From the full component list, identify those principal components that are the most important in defining vulnerability.
2. Recognise sensitivity versus capacity components and then further divide into sectoral divisions.
3. Using expert decisions, rank the importance of each component on a high-to-low or one-to-five scale.
4. Use ranked importance to assign weights to components.
5. Assemble components into an assessment model.

The development and processing of any model for assessing climate impacts on vulnerable populations in the SECCCA region will combine multiple sources of numerical data inputs, subjective expert insights and various other data insights.

This combination of multiple data inputs from various sources is often referred to as a Multi-Criteria Analysis (MCA). This is a well-known suite of methodologies for dealing with complex decision problems, where several aspects of the problem in question have to be considered, or where several aspects of a problem have to be examined concurrently.

The distinguishing features of an MCA are that it can combine objective and subjective inputs as well as absolute or relative criteria, and it is flexible in terms of adjustment.

MCA techniques have been devised to investigate a number of alternatives in light of multiple objectives and conflicting preferences.

Framework development

As discussed in Section 8.1, the first stages of the analysis workflow begin with council and relevant expert discussion.

A key part of this discussion, aside from the identification of which populations within an area are vulnerable, is the identification of what makes these populations vulnerable to climatic impacts. These components, as initially outlined in Section 8.2, can form a long list of factors that are either sensitivity components or capacity components.

Table 3 provides a full component list considered for the older people vulnerable population assessment. This is separated into identified sensitivity and capacity components, which are then further defined into relevant sectors.

Table 3. Full listing of all components considered for vulnerable older people.

Component	Sector
Sensitivity	
Economic stress	Economic
Low income – $500 or less per week	
Income stress at 30 per cent rent/mortgage	
Insurance costs – home	
Need assistance for self-care activities	Health
Long-term health condition(s)	
Mental health condition – medically diagnosed	
CALD community – recent arrival	Social
CALD community – established community	
Capacity	
Heat island index and vulnerability	Environmental
Urban canopy and veg density	
Housing occupancy (renting)	Economic
Climate strategies	Institutional and Services
Council bus services	
Flood strategies	
Meals on Wheels	
Aged care facilities or residential care services	Physical
Building density	
Dwelling/housing structure	
Housing condition and/or age	
Population density	
Proximity to medical services	
Proximity to open space	
Proximity to other services	
Proximity to public transport	
Education level	Social
Employed	
Excluded populations	
Has a car (one, two or more)	

Component	Sector
Independent mobility (e.g. capable of taking transport independently)	
Level of social capital	
Level of trust	
Component	Sector
Live alone	
Marginalised, stigmatised	
English proficiency	
SEIFA – index of relative social advantage or disadvantage	
Social connections – internet access	
Social networks – levels of Inclusion	
Unpaid assistance	
Unpaid child care	

Part of the expert input process into the model and framework is for relevant Subject Matter Experts (SMEs) to identify the components in Table 3 that are the most relevant to the vulnerable population in question. Additionally, SMEs will provide a priority ranking for these components from very high to very low, using a one-to-five score. This component identification and ranking process is repeated individually by all SME participants for each relevant vulnerable population.

These individual SME assessments are collated into a summarisation process that removes components that are not seen as integral to the vulnerability of a population, and places a score against all ranked priorities. This score is combined and averaged within each component and then compared with all other ranked components.

This process also involves assigning a weight against each ranked component. For example, a component that is scored very high by all participants will be weighted higher than components ranked moderate, or mixed rankings by SMEs.

The output of this component identification and ranking process is provided in Table 4. From the extended list of older people vulnerability components presented in Table 3, this is an identification of those components that are seen are integral to assessing the vulnerability of older people. As before, these components are categorised as Sensitivity or Capacity components.

Capacity components are further split into social and economic capacities and physical and environmental capacities. Similar sectors within the capacity grouping can be arranged as a sub-group and treated separately.

Weights for each component are shown in the last column after each ranking was scored, combined and compared with one another. Weights within each grouping are relative within the group and always add to 1.0. This is to ensure that each component is compared and weighted within each relevant grouping and combined component scores are always processed back to a standardised range.

Using the Sensitivity components as an example, the most important component, as determined by SMEs, is economic stress related to a combination of low income and high rent or mortgage repayments. This is followed by needs assistance and long-term health conditions on equal weightings, and lastly by any medically diagnosed health conditions.

Table 4. Component identification and ranking output for the older people vulnerable population.

*Economic stress is an equal combination of low-income components and income stress.

Component	Sector	Weight
Sensitivity		
Economic stress*	0.32	
Low income – $500 or less per week	Economic	
Income stress at 30 per cent rent or mortgage		
Needs assistance for self-care activities		0.26
Long-term health condition(s)	Health	0.26
Mental health condition(s)		0.16
Capacity – social and economic		
Lives alone		0.23
Education level	Social	0.07
English proficiency		0.15
Level of social capital		0.29
Housing occupancy (renting)	Economic	0.26
Capacity – physical and environmental		
Aged care facilities or residential care services		0.33
Dwelling/housing structure		0.25
Housing condition and/or age	Physical	0.17
Proximity to other services		0.08
Proximity to medical services		0.17

From this output of the component identification and ranking process, each section can then be assembled into a framework to assist model processing.

To undertake this model creation and processing as an MCA approach, an Analytical Hierarchy Process (AHP) application, or part thereof, was used due to the consideration of multiple types and formats of spatial data, input of non-spatial data, incorporation of objective data and subjective input and inclusion of expert opinion.

AHP is a technique used for decision-making that uses a structured framework to break down complex problems into their base parts or components. It allows for a decision to be made to select a best outcome from a range of alternatives based on several decision criteria. AHP also provides a structured framework that can allow the incorporation of experts' knowledge.

In comparison to empirical-based models solely derived from experimental data and correlations, this type of modelling incorporates expert-based knowledge that understands the system of concern. In terms of examining the problem at hand, this expert's knowledge can fill the gap of incomplete empirically based data.

A process within the AHP is to undertake a pairwise weighting method to determine criterion weightings. This will not be done in this instance as weight setting has been covered by the component identification and ranking process.

The final model framework for assessing climate vulnerabilities in older people is demonstrated in Figure 11. Here the apex of the hierarchy is the vulnerability rating, which is a combination of sensitivity and capacity considerations. Under each of these branches are the individual components that were determined to be the most important factors in assessing vulnerability. As noted, capacity is split by sector into three sub-branches.

Note that the institutional branch is not populated, as this is covered directly by assessing service levels within an area in terms of services provided to and from that area. How this will be assessed is covered in the following sections.

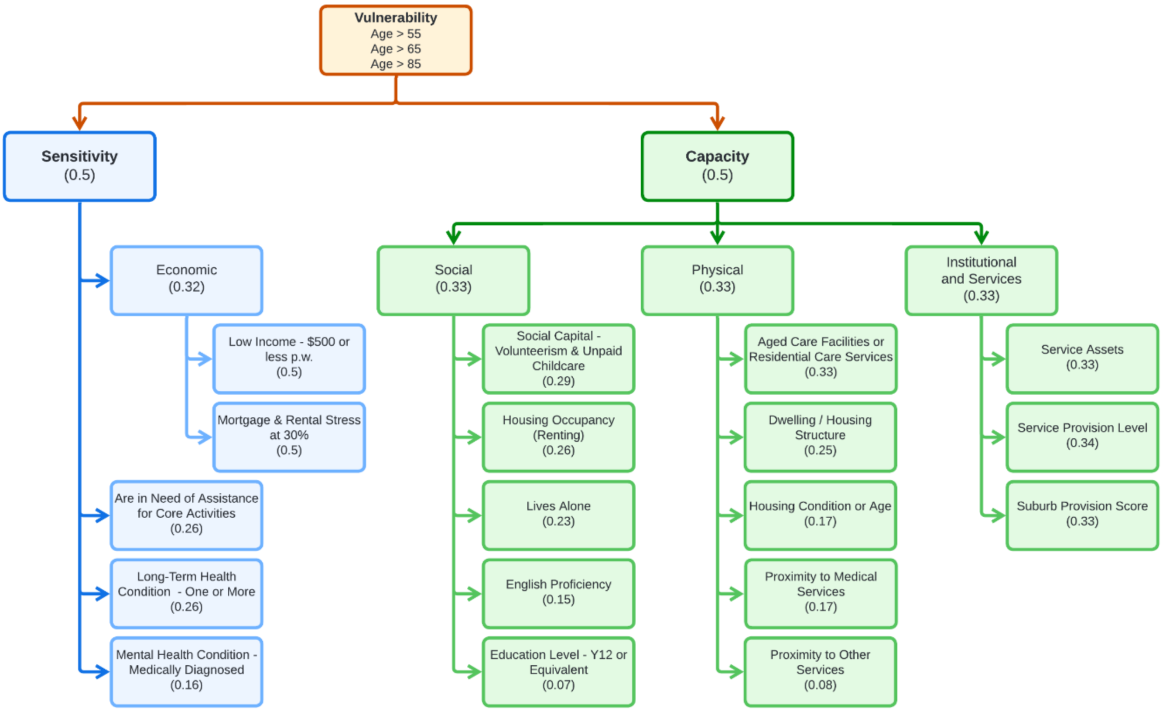

Figure 11. Older people vulnerability modelling framework.

Data processing

For each component there will be an underlying data input as discussed in Section 8.2. This is either as a direct numerical input or derived from a qualitative assessment from SME input.

Geographic boundaries

All data in the SECCCA region were processed to the ABS geographic SA1 boundary (ABS, 2022). This scale of analysis has been chosen because it is the smallest statistical area for which the ABS publicly provides most social/demographic statistics. This is inclusive of the ABS 2021 census, which is done to multiple scales and geographies.

On occasion, input data are presented at a non-SA1 scale. This can either be at larger statistical area scales, such as SA2 and above, which include a collection of SA1s within their boundaries. However, there are a number of non-ABS geographic structures, such as postcodes, suburbs and LCAs, that do not necessarily relate directly to SA1 boundaries. In these cases, there will be intersects between SA1 and non-aligned boundaries.

How these are treated will be assessed on an input-by-input basis. Mostly this will be by determining a scored value or percentage ranking, which can be easily applied back to intersecting geographies via spatial analysis techniques. Where appropriate, absolute values (such as total populations) will not be used due to this intersection issue. Proportions, densities or percentages are better suited in these cases.

Proximity and neighbourhood analysis

For a number of components, an assessment of coverage within a given SA1 boundary will be applicable. For example, coverage of accessible public transport within an SA1 was included in this report. To determine these levels of service coverage, a proximity analysis is undertaken based on the location of a given asset.

From the location of the asset, a coverage area is determined based on the neighbourhood concept with distances of 400 m, 800 m and 1600 m from an asset used to define neighbourhood or proximity measures. These distances are viewed to be roughly equivalent to a 10-, 20- and 40-minute neighbourhood distance. This concept is used to assess the accessibility of an asset to the surrounding neighbourhood.

This model relies on the assumption that residents' interaction with an asset depends solely on their proximity to it. In reality, factors such as the size, quality, type and other parameters of an asset may be more important to residents than proximity.

Council services application

To provide a spatial assessment of service provision, council-held knowledge about these services, where they operate, and to what level they provide service is detailed for a suburban boundary. Aside from input into the component identification and ranking process, questions were asked about these services as part of the initial set of workshops with councils and SMEs for each vulnerable population.

These questions regarding a vulnerable population included:

- What key assets are seen to provide a service?
- What locations do these assets provide a service to and how important is this service?
- What key service providers offer services from these, or other, assets?
- What locations do these service providers offer services to and how important is this service?

The first and third questions are related to an asset. With state government data and council-held asset data, an understanding of where these assets are was gained. Coupled with information about the level of service these assets provide, a ranking was assigned to a location.

The second and last questions related to where services were provided from a location. In particular, these questions sought to identify whether the service was having an impact beyond its immediate location. This can be a harder concept to define and map by expert input. Also, it may not be as comparable an output as the first and third questions. Where applicable and feasible, a ranking was provided to a suburban location and scored appropriately.

These two output layers were then combined into an institutional and services layer, which was then fed into the modelling framework.

The process used to assign these details included listing all building types (as classified by individual SECCCA councils) provided for assessment in the initial SECCCA AVA project and supplying these to councils to review. A table containing this list of council buildings was sent to all councils to populate in relation to a particular vulnerable sub-population. The table presented the likely candidate council buildings that may provide services to a relevant vulnerable sub-population. Councils were asked to examine the list of buildings (or physical community assets) presented.

Prior to sending each council the table, two additional fields were added:

- service asset within suburb, which the project team populated based on whether there was one or more of the buildings (or physical community assets) present in a particular suburb
- services provided to a suburb, which the project team initially populated based on the number of buildings (or physical community assets) present in the suburb.

Councils were requested to review what the project team provided and add additional material on the services and community assets available in each suburb in relation to the relevant sub-population.

Appendix B contains an example of this table for Bass Coast LGA. It shows how Bass Coast staff added significant detail that the project team then used to review and update the service/capacity ratings provided for the two key fields identified above.

This was undertaken on an individual LGA basis so that the list of each LGA was similar but different.

Model processing and application

For every SA1, or applicable geographic boundary, a score was calculated. This was done for every component that was used within the modelling framework.

The scoring system was used to assign a score between one and five for either sensitivity or capacity components. As per Table 5, for sensitivity a score of '1' indicates a component that makes it less sensitive (more resilient) to a hazard and '5' indicates a component with a particular characteristic that makes it more sensitive (or less resilient) to a hazard.

Conversely, for capacity components, a score of '1' indicates a component with a particular characteristic that makes it have a higher capacity (more resilient) to a hazard and '5' indicates a component with a particular characteristic that makes it have a low capacity (less resilient).

These one-to-five ratings are translated to a percentage score (or rating) as seen in Table 5.

Table 5. Sensitivity and adaptive capacity ratings and definitions

Score	Sensitivity	Capacity
1 – 20%	Very low sensitivity	Very high capacity
2 – 40%	Low	High
3 – 60%	Moderate	Moderate
4 – 80%	High	Low
5 – 100%	Very high sensitivity	Very low capacity

To determine a score for an SA1 or equivalent geography, the principal method is to undertake a proportional or density analysis. For example, using the older people example, it would be dividing the total number of people aged 65 and over by the total population in the area. An output would be the density, or the proportion, of people in the area. This is done for any boundary that has a subset population or number within a larger value group. The final value can be altered so it can be displayed as a percentage by multiplying the value by 100.

Some components will already have a percentage value assigned to them. There is no additional processing for these. These percentages will suffice for ranking and classification.

For those components that are subjectively based (i.e. non-numeric), the one-to-five ranking system will have to be assigned via expert input or subjective interpretation. This ranking will have to fit within the system outlined in Table 5.

Across the whole SECCCA boundary, using the range of values of this proportion for a component, a natural breaks assessment is done to determine class breaks in the one-to-five rankings, by dividing the range into five classes. A natural breaks classification is usually used on non-uniform distributions, giving a potentially unequal class width with varying frequencies of observations per class.

Once the five classes are determined, the appropriate scores are applied to the class. This is repeated for every component to be used within the modelling framework. An example output using population numbers of older people aged 65 years and over against total population is shown in Figure 12, where the five class breaks are shown.

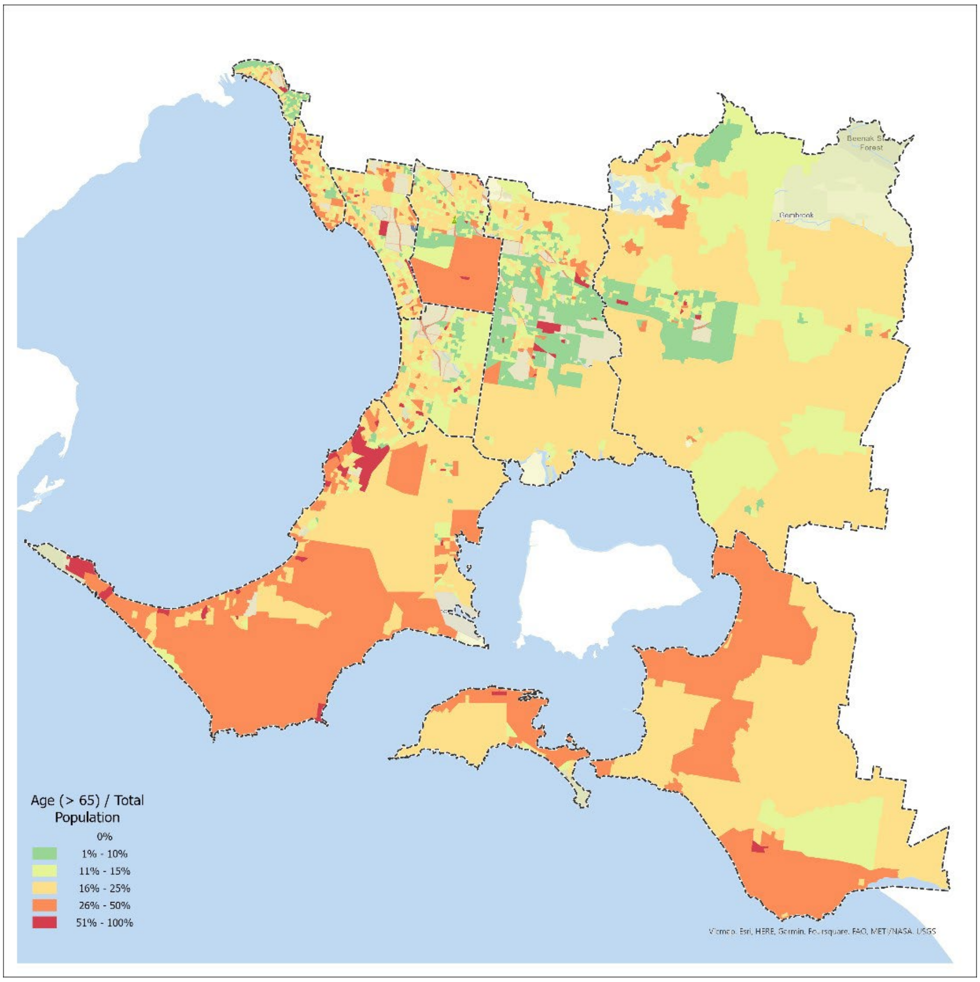

Figure 12. Older people class ranking example.

Once all components for the modelling framework are processed, they can then be combined into the respective branches in the hierarchy. As per Table 4 and Figure 11 for older people, there are three key branches in the modelling framework hierarchy. These can differ between models for vulnerable populations.

For every component within a vulnerable group's analysis framework (e.g. lives alone), there will be an associated data layer with an attribute that will have a finalised one-to-five score. This one-to-five score can then be translated to a percentage score as required.

Following the full scoring and attribution of every component data input, they can all be combined as per the framework seen in the example in Figure 11. For each component, there is an associated weight. This weight is multiplied by the score and then the components are summed within each branch. For example, in Figure 11 there are three main branches; only the components that relate to the branch in question are summed up.

Once summed, the capacity branches are combined and averaged and then the final capacity is combined with the sensitivity branch to produce a final vulnerability score for a given vulnerable sub-population.

Application to climate data

The final vulnerability score reflects all identified vulnerable populations in the SECCCA region. During the formulation and conception of each vulnerability model for each sub-population, a climate lens has been applied. This includes thinking how a population may be impacted during an extreme event, the services and assets that can aid in and around an extreme event, or key component factors that may relate to a climate event.

However, this lens is only for known and lived experience (i.e. for a current climate baseline). Future changes and likely projected impacts are not accounted for in this analysis in an adjusted scoring manner.

Within the framework shown in Figure 9, climate is separated into an immediate hazard and a likely exposure. A hazard is the climate variable or extreme event of concern. Exposure is the likely change of a hazard over time, expressed as a probability, percentage or absolute change.

For example, maximum temperature can increase from 38 °C to 40 °C in a future scenario. This is a 2 °C increase or about a 5 per cent increase over the base value. Alternately, a flood event could be modelled to occur once in 100 years (1/100 yr). This is a probability, or an Annual Exceedance Probability (AEP), that identifies this as an AEP 1 per cent event.

The indexing of climate change from a baseline into a very low to very high, or one-to-five, type classification is not undertaken in the analysis. A usual process would be to integrate this indexed class back to the vulnerability rating, either by adding or multiplying the ranks together.

For a direct climate event, such as temperature increase, this can be a relatively straightforward indexation and approach. However, for any probability type hazard (e.g. inundation, flooding, bushfire events) this index classification can become complex.

Furthermore, if an index approach is taken, a one-to-five score for heat events related to older people vulnerable populations may be completely different to a one-to-five score to single mother vulnerable populations. Additionally, there will be a lot of data created by all climate models, climate variables and all vulnerable populations. This can add additional complexity to the output.

The approach taken for this model is to keep vulnerability ranks separate from climate exposure changes and view this as an informal link. This will create a 'population profile' link between vulnerability, climate, and assets, where ranks can be viewed against the change from baseline. Using this approach, local and expert knowledge can be brought into this profile to more accurately interpret what is seen.

Although this is a subjective approach, it can avoid misinterpretation of data and it will add in subject matter expertise to the profile being viewed.

An example of this for older people vulnerable populations will be demonstrated in the following section.

7.4. Outputs and visualisation

1. Identify the main filters to create subsets of the vulnerable population.
2. Determine a class system for the vulnerable population, a high to low rank.
3. Spatially visualise vulnerable population.
4. Output into table format.

Identification of core vulnerable population

For each vulnerable population, there is an identified principal component list that is integral to score and rank vulnerability in the population of concern. However, within this process, a score can be placed onto every component that sits within the model. This can potentially assign a vulnerability to an entire population.

To further refine and focus on the vulnerable population of concern, a filter is placed on the overall model to limit results. This can move the analysis, for example, from looking at all older people in the study area to the subset that is most vulnerable to climate hazards.

An example is shown in Figure 13 where, for older people, the most integral components in the assembled model are outlined. Those who sit within the centre of the overlaps, or even within one of the primary spheres, are those who are most likely to be vulnerable to climate hazards, or even those who are vulnerable in general. Using the outlined older people population in Figure 13, those who are experiencing economic stress, medical conditions or health concerns, and those who require a high level of care, are those who are most vulnerable.

Those who sit outside these identified factors in the outer sphere are those who are less likely to be vulnerable. For example, this could be older people who are more financially stable, are able to care for themselves and/or those who do not have major health concerns.

Generally, for all vulnerable populations, it is identified that sensitivities in the population of concern constitute the core components. In the analysis, for each vulnerable population, those who are identified within these core filtering components are retained for final ranking and visualisations. Those who fall outside this core sphere are set aside for final analysis.

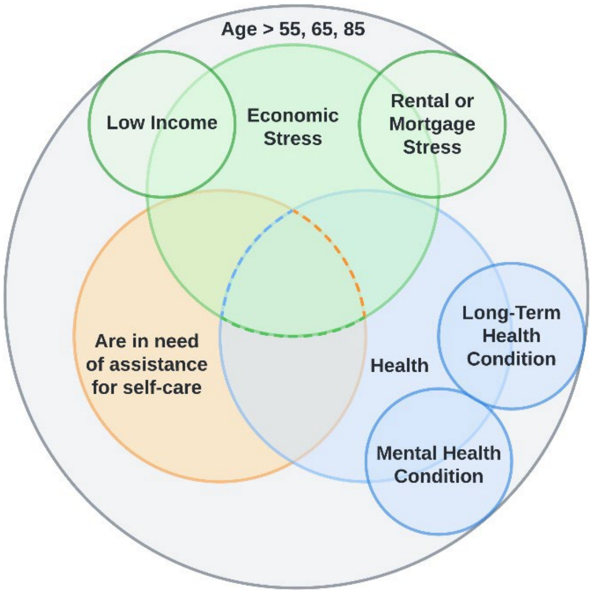

Figure 13. Vulnerability definition filtering diagram showing those in older populations who are most vulnerable.

A full outline of these filtering diagrams for each vulnerable population is provided in Appendix A.

Final ranking of vulnerability

From this core vulnerable sub-population, the final vulnerability scores are then ranked from low to high, or a one to 10 class system. As with scoring each individual component, a natural breaks assessment is done to determine class breaks in the one to 10 ranking system. A natural breaks classification is usually used on non-uniform distributions, giving a potentially unequal class width with varying frequencies of observations per class.

It is important to recognise that all people in a community are vulnerable to climate change to a certain degree. However, this ranking system aims to identify areas and populations of greater vulnerability in order to determine areas and populations in need of greater priority.

The final ranking is an indication of vulnerability of identified people in the population of concern. It is a score that shows there is at least one person identified in a location that is vulnerable. It is not adjusted in any form to account for higher populations in a region. However, this adjustment can be done separately from this analysis and adjusted to account for more vulnerable people in a given area.

Final mapping and outputs

This final ranking can then be visually represented and also exported into tabular format for analysis. Figure 14 shows this representation for older people aged 65 and over in the SECCCA region.

However, this static mapping output can be limiting when multiple factors or climate hazards are necessary to be shown overlaid on top of these higher-vulnerability populations. Particularly at this region-wide scale, some of the finer detail and smaller geographies can be missed or under represented.

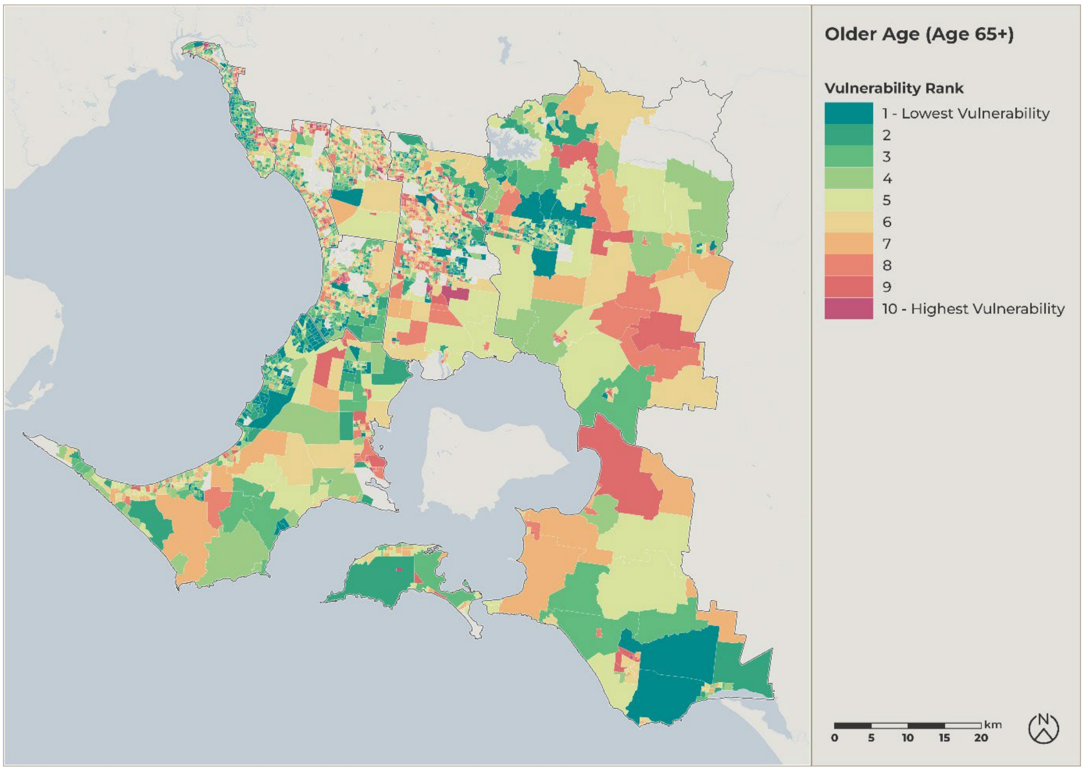

Figure 14. Final map output for older people vulnerability for those aged 65 and over.

To complement these cartographic outputs and bring in links to climate and community assets, all outputs are exported to tabular format. As noted in the previous section, this is referred to as a population profile and links vulnerability ranks, climate changes within an area, and assets that are located within, or service, the area.

This has been done for each SA1, and can link multiple populations together to a hazard of concern and key community assets. Within the analysis table, summations can be further undertaken to other geographies, such as suburbs or a council-wide view.

An example of a population profile output for older people in a selection of suburbs in Bayside is seen in Table 6. This view of the vulnerability rankings of older people by suburb also identifies a selection of community assets, including key services and emergency providers, and also several climate exposures. These climate exposures are described as changes under a likely future climate scenario.

Table 6. Cross-section of vulnerable older people presented against a selection of key community assets and climate exposures.

Values	Beaumaris	Black Rock	Brighton	Brighton East	Cheltenham	Hampton	Hampton East	Highett	Sandringham
Age 55 Over - Rank	4	5	3	4	7	4	7	6	3
Age 65 Over - Rank	4	5	3	3	7	3	5	6	3
Age 85 Over - Rank	5	5	3	3	5	4	5	5	4
Age 55 Over Population	5,225	2,748	10,834	6,131	1,725	4,972	1,954	2,196	4,680
Age 65 Over Population	3,157	1,719	6,924	3,708	1,049	2,724	1,102	1,253	2,854
Age 85 Over Population	417	253	1,280	717	174	289	152	196	592
Maximum Temperature - Change from Baseline (%)	9.8%	9.6%	8.5%	9.1%	10.2%	9.0%	10.2%	10.2%	9.3%
Heat Health at 30C (Days) - Change from Baseline (%)	318.0%	318.0%	254.9%	284.8%	344.9%	299.0%	345.5%	345.5%	310.2%
Total Annual Rainfall - Change from Baseline (%)	-5.3%	-4.5%	-3.0%	-3.5%	-4.5%	-3.8%	-4.4%	-4.4%	-4.0%
Combined Flooding and Storm Event (SLR 82cm, 1% AEP) - Coverage (%)	12.0%	1.6%	11.5%	7.3%	1.6%	8.1%	11.2%	12.5%	6.8%
Hospital Count			3			1			3
Police Station Count									1
Public Transport - Bus Stop Count	72	27	123	62	40	80	34	44	61
Health - Doctor Count	1		3	2			2	1	2
Health - Pharmacy Count	3	2	4			1	2		1
Services - Post Office Count	1	2	3						1
Services - Banks Count	4	1	8	1		2	1	1	5

In this table, a quick interpretation of key observations indicates that Cheltenham has some of the higher vulnerabilities in older people. Linked to this are likely high-heat events around 2050. This is also noted in Hampton and Highett, although the vulnerability ranks are not as high for these suburbs. However, they are still significant compared with the rest of the region.

In contrast, Brighton has some of the higher population numbers for older people, as well as some of the higher inundation and flooding coverage values. However, Brighton's vulnerability is one of the lowest in the region, possibly due to income. There are also a number of assets in this suburb that service the population. Therefore, even with significant flooding risk, this suburb is not a priority.

For flooding and inundation, a focus should be placed on Hampton East and Highett, where the coverage is significantly high and vulnerability ranks are high. Even though populations are not high in these areas, there are still people who are seen as vulnerable.

Although this is a high-level summation of the links within the population profile, there can be clear links derived from the data tables. Leveraging expert interpretation, a greater understanding of vulnerabilities and priorities can potentially be derived from these resources. Furthermore, this information can be combined with spatial outputs for an even greater level of insight.

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Appendix A – Vulnerable population component tables

NESB – recent arrivals

Table 7. Component identification and ranking output for Non-English speaking background (NESB) – recent arrivals vulnerable population

Component	Sector	Weight	
Sensitivity			
Low income – $500 or less p.w.	Economic	0.52	0.50
Mortgage and rental stress at 30%			0.50
Mental health condition – medically diagnosed	Health	0.48	0.12
Recent arrival	Social		0.24
Aged < 14 or aged > 65			0.12
Capacity – social and economic			
Lives alone	Social	0.33	0.34
English proficiency			0.32
Education level – Year 12 or equivalent			0.17
Housing occupancy (renting)	Economic		0.17
Capacity – physical and environmental			
Dwelling/housing structure	Physical	0.33	0.33
Housing condition and/or age			0.25
Proximity to other services			0.25
Proximity to public transport			0.17
Capacity – institutional and services			
Service assets	Institutional and Services	0.33	0.33
Service provision level			0.34
Suburb provision score			0.33

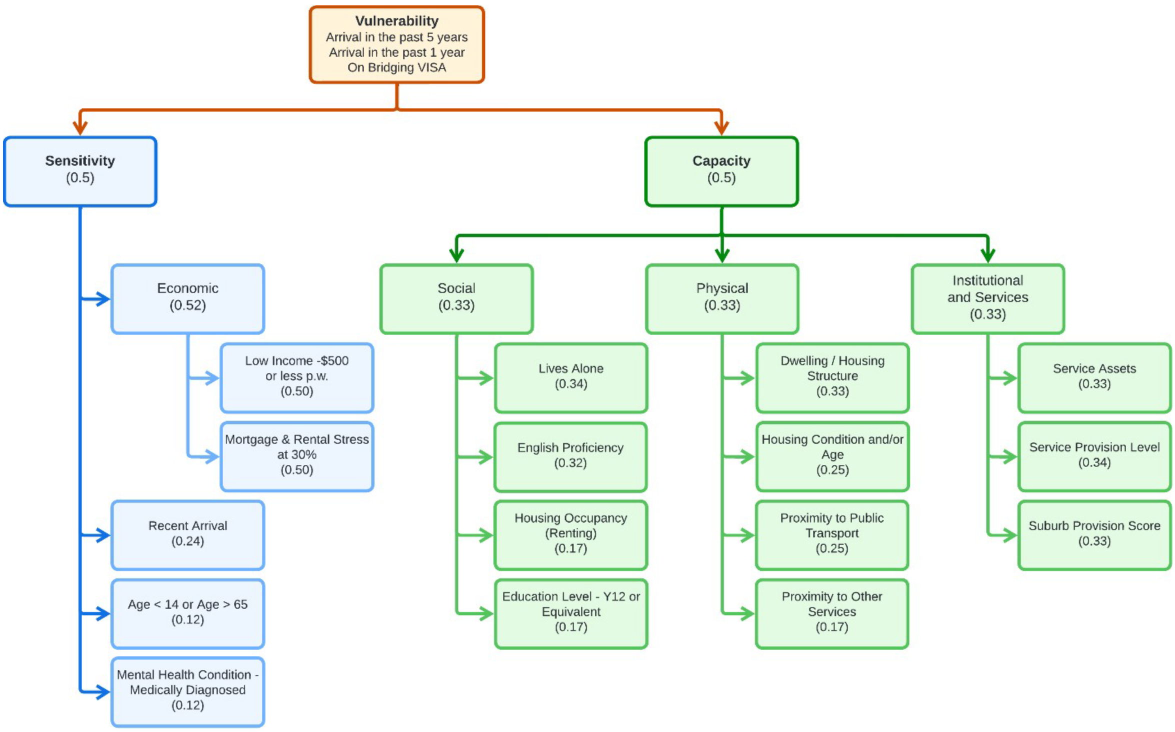

Figure 15. NESB – Recent Arrivals vulnerability modelling framework.

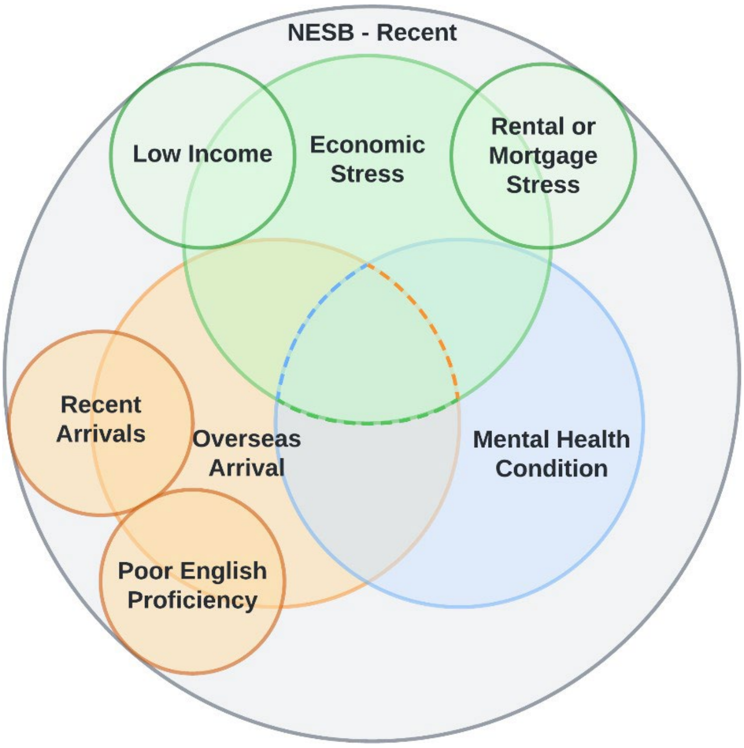

Figure 16. Vulnerability definition filtering diagram showing those in NESB – recent arrivals that are most vulnerable.

NESB – established communities

Table 8. Component identification and ranking output for NESB – established communities vulnerable population

Component	Sector	Weight	
Sensitivity			
Low income – $500 or less p.w.	Economic	0.47	0.50
Mortgage and rental stress at 30 per cent			0.50
Mental health condition – medically diagnosed	Health	0.53	0.11
Long-term health condition – one or more			0.20
Established populations	Social		0.11
Aged < 14 or Aged > 65			0.11
Capacity – social and economic			
Lives alone	Social	0.33	0.34
English proficiency			0.32
Education level – Year 12 or equivalent			0.17
Housing occupancy (renting)	Economic		0.17
Capacity – physical and environmental			
Dwelling/housing structure	Physical	0.33	0.33
Housing condition and/or age			0.25
Proximity to other services			0.25
Proximity to public transport			0.17
Capacity – institutional and services			
Service assets	Institutional and Services	0.33	0.33
Service provision level			0.34
Suburb provision score			0.33

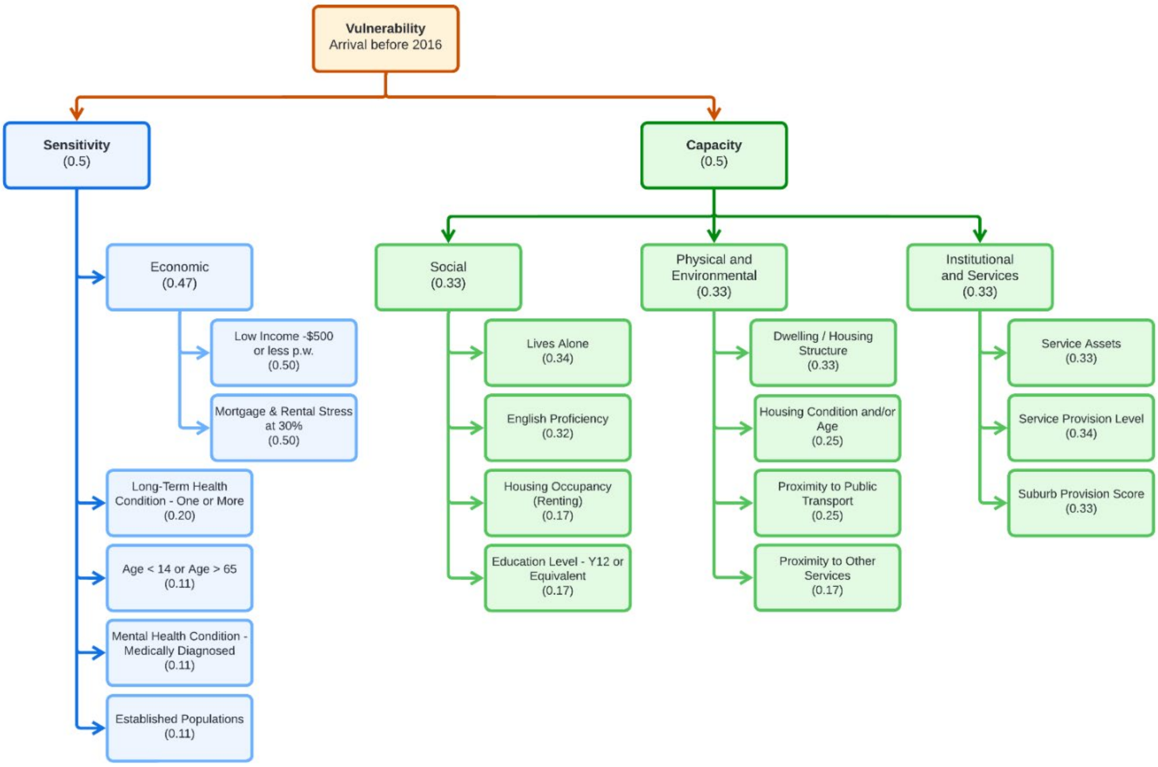

Figure 17. NESB – established communities vulnerability modelling framework.

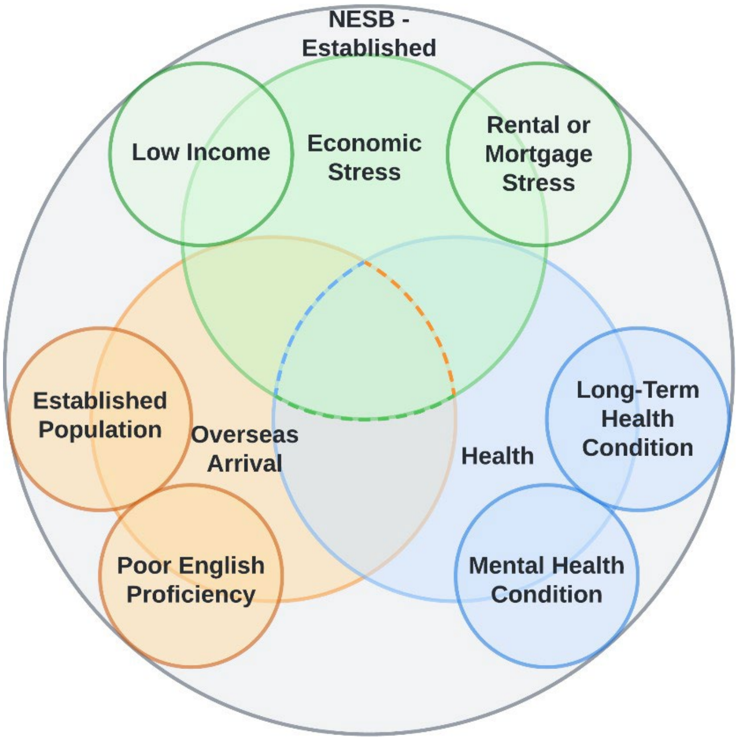

Figure 18. Vulnerability definition filtering diagram showing those in NESB – established communities that are most vulnerable.

High level of care

Table 9. Component identification and ranking output for high level of care vulnerable population

Component	Sector	Weight
Sensitivity		
Needs assistance for core activities	Health	0.37
Long-term health condition – one or more		0.33
Lives alone	Social	0.15
Aged < 65		0.15
Capacity – social and economic		
Economic stress*	Economic	0.48
Low income – $500 or less p.w.		
Income stress at 30 per cent rent or mortgage		
Housing occupancy (renting)		0.24
Social capital – level of connections	Social	0.28
Capacity – physical and environmental		
Dwelling/housing structure	Physical	0.11
Housing condition and/or age		0.14
Care facilities localities		0.11
Proximity to medical services		0.17
Proximity to other services		0.23
Proximity to public transport		0.23

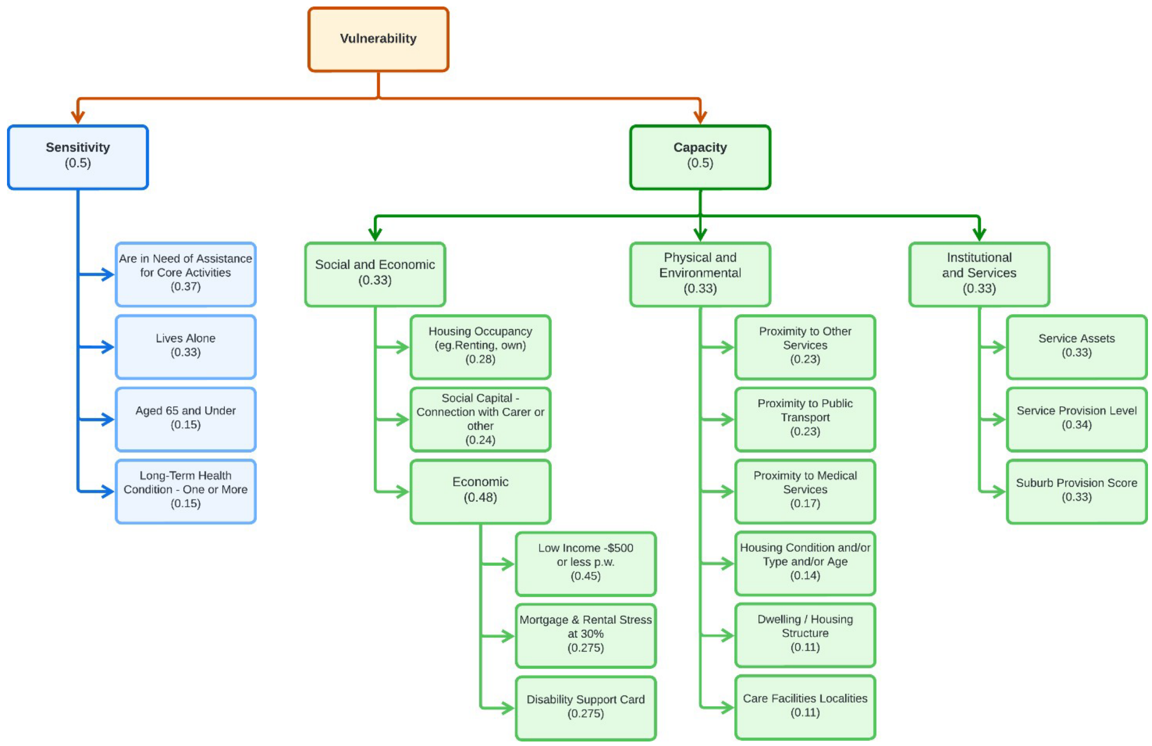

Figure 19. High level of care vulnerability modelling framework.

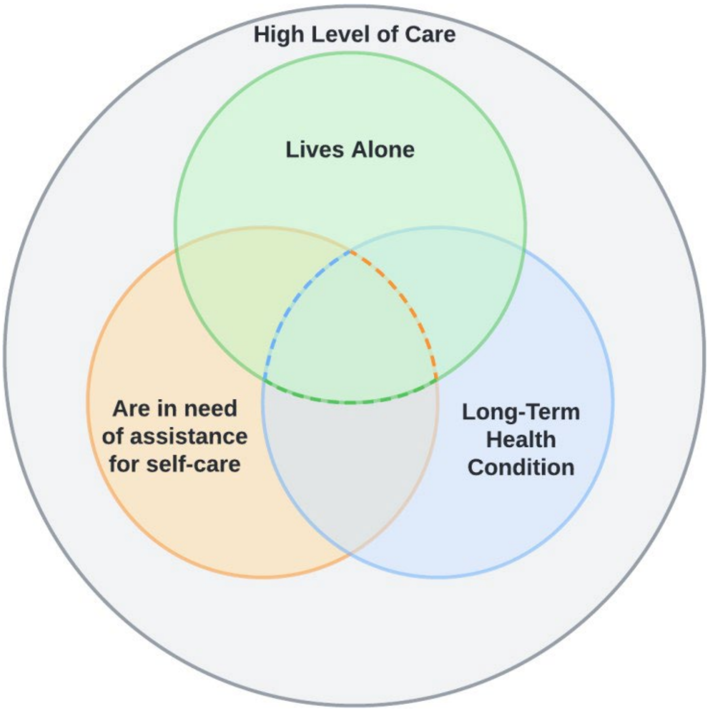

Figure 20. Vulnerability definition filtering diagram showing those in high level of care that are most vulnerable.

Homelessness and insecure housing

Table 10. Component identification and ranking output for homelessness and insecure housing vulnerable population

Component	Sector	Weight
Sensitivity		
Economic stress*	0.22	
Low income individual income	Economic	
Income stress at 30 per cent rental		
Housing occupancy – rent paid to public authority	Economic	0.21
Mental health condition – medically diagnosed	Health	0.19
Long-term health condition(s)		0.19
Domestic abuse or family violence	Social	0.19
Capacity – social and economic		
Not employed or in labour force		0.22
Digital inclusion		0.20
Has no car	Social	0.26
Education level		0.32
Capacity – physical and environmental		
Dwelling/housing structure		0.33
Housing condition and/or age		0.15
Proximity to other services		0.15
Proximity to medical services	Physical	0.15
Boarding house/residential services		0.25
Proximity to public transport		0.10
Urban canopy and veg density	Environmental	0.43
Heat island index and vulnerability		

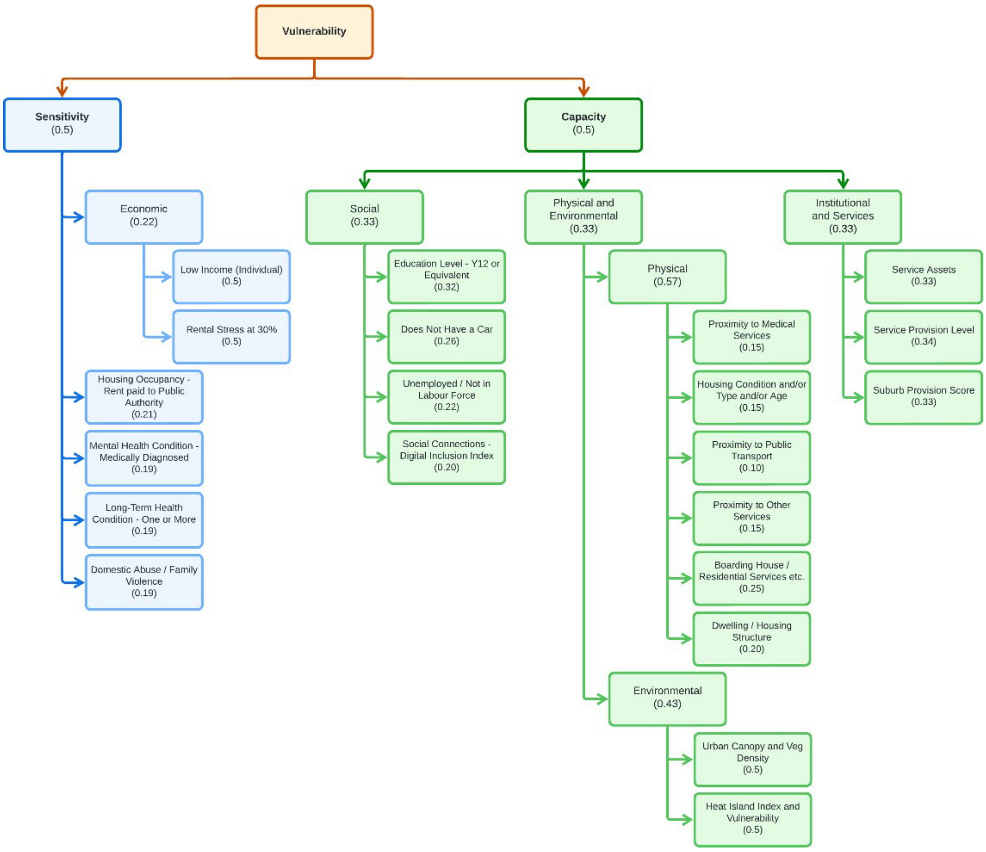

Figure 21. Homelessness and insecure housing vulnerability modelling framework.

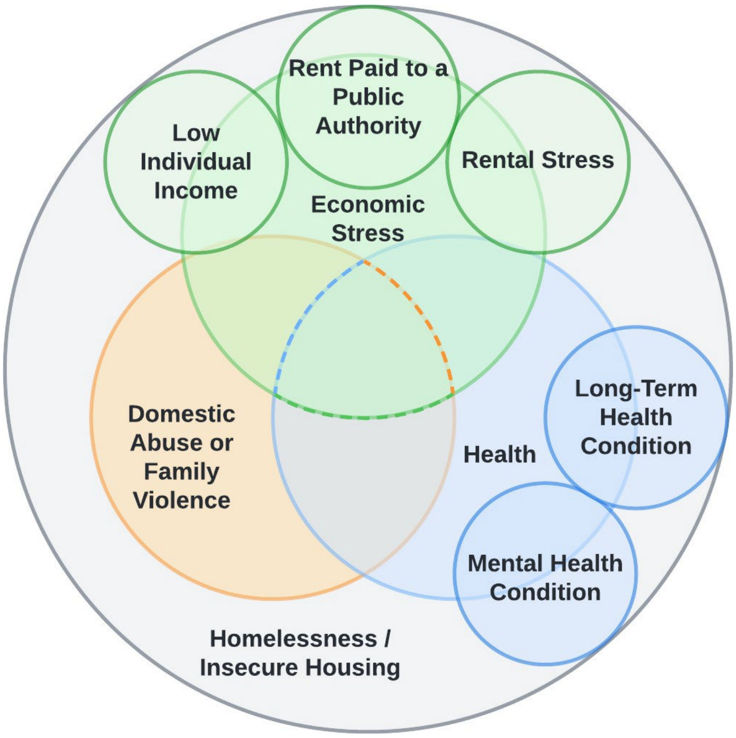

Figure 22. Vulnerability definition filtering diagram showing those homelessness and insecure housing that are most vulnerable.

Single mothers

Table 11. Component identification and ranking output for single mothers vulnerable population

Component	Sector	Weight
Sensitivity		
Domestic abuse or family violence	0.22	
Dependants under the age of 14	Social	
Sole parent		
Mental health condition – medically diagnosed	Health	0.19
Long-term health condition(s)		0.19
Capacity – social and economic		
Does not have car		0.25
Not employed or in labour force	Social	0.165
Care support – unpaid child care		0.165
Housing occupancy		0.42
Low income – below $500 p.w.		0.33
Income stress – at 30 per cent rental or mortgage repayments	Economic	0.37
Is on a single parent card		0.30
Capacity – physical and environmental		
Proximity to child care and key services	Physical	0.67
Proximity to medical services		0.33

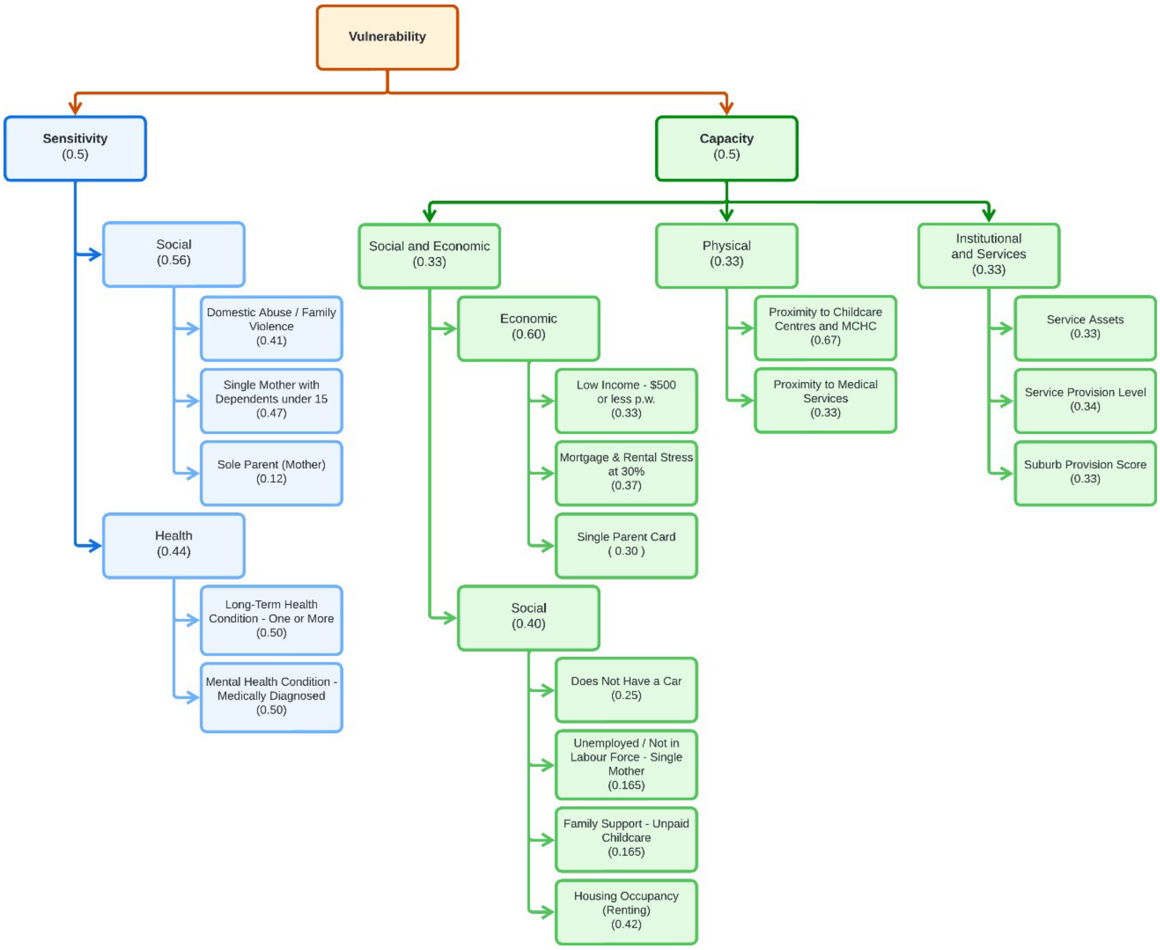

Figure 23. Single mothers vulnerability modelling framework.

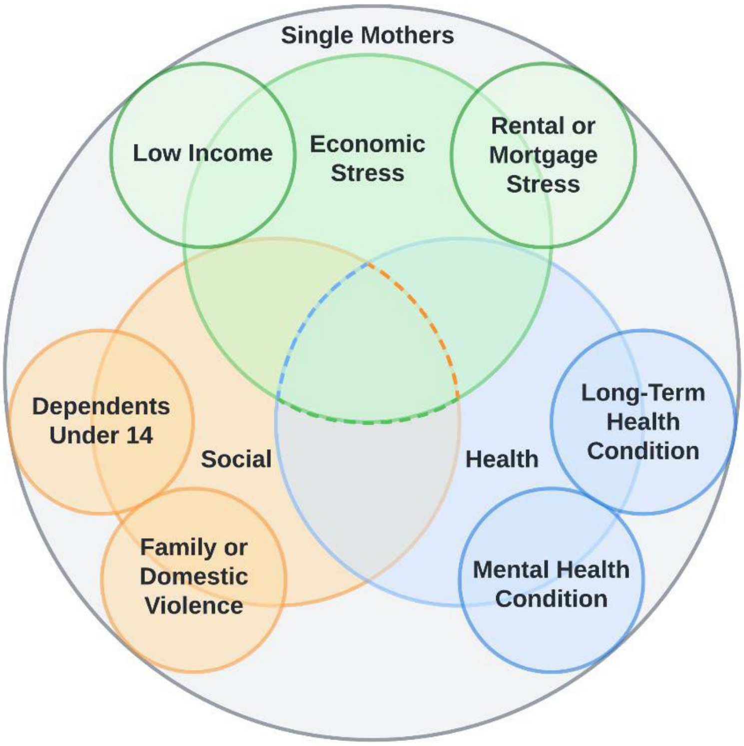

Figure 24. Vulnerability definition filtering diagram showing those single mothers who are most vulnerable.

Youth

Table 12. Component identification and ranking output for youth vulnerable population

Component	Sector	Weight
Sensitivity		
Education level – Y12 or equivalent		0.20
Recent arrival into Australia (1 and 5 years)	Social	0.18
Population density		0.18
Mental health condition(s) – medically diagnosed	Health	0.22
Long-term health condition(s)		
Mortgage and rental stress at 30 per cent	Economic	0.22
Centrelink Youth Allowance		
Capacity – social and economic		
Number of siblings		0.16
Social connections – digital inclusion index		0.19
Social capital – volunteerism	Social	0.18
Sole parent		0.18
Physical activity participation		0.18
Unemployed/not in labour force		0.11
Capacity – physical and environmental		
Proximity to child care centres and MCHC		0.16
Proximity to education facilities		0.17
Proximity to medical services	Physical	0.16
Proximity to open space		0.18
Proximity to other services		0.16
Proximity to public transport		0.17
Heat island index and vulnerability	Environmental	0.48
Urban canopy and vegetation density		

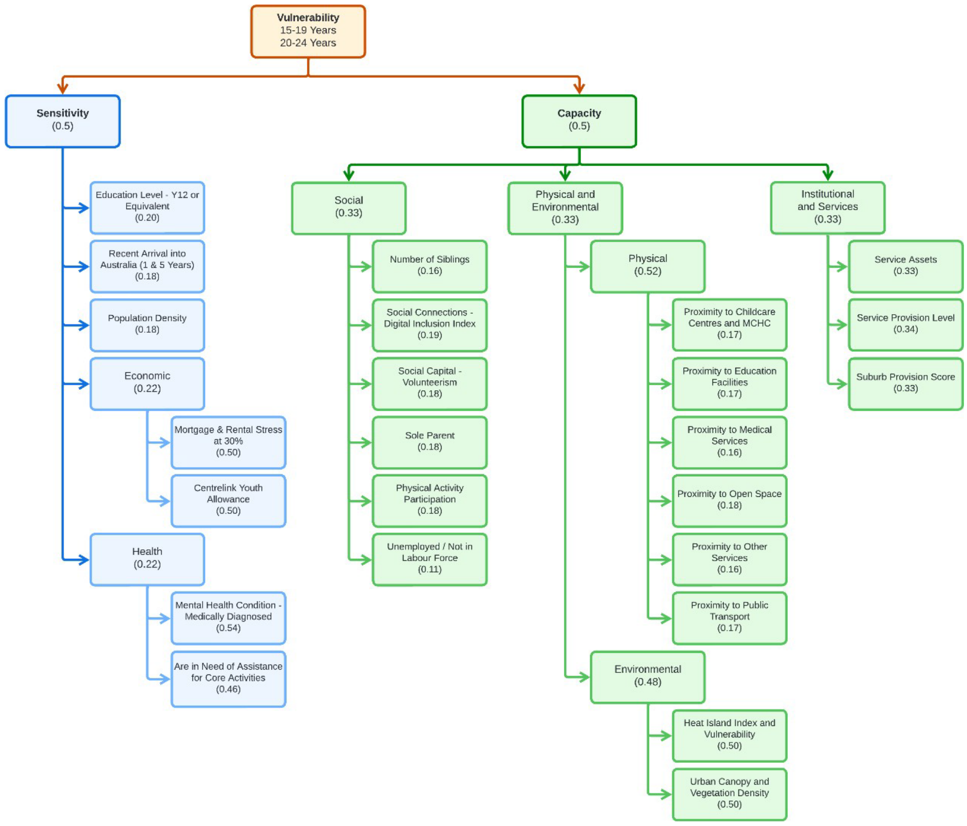

Figure 25. Youth vulnerability modelling framework.

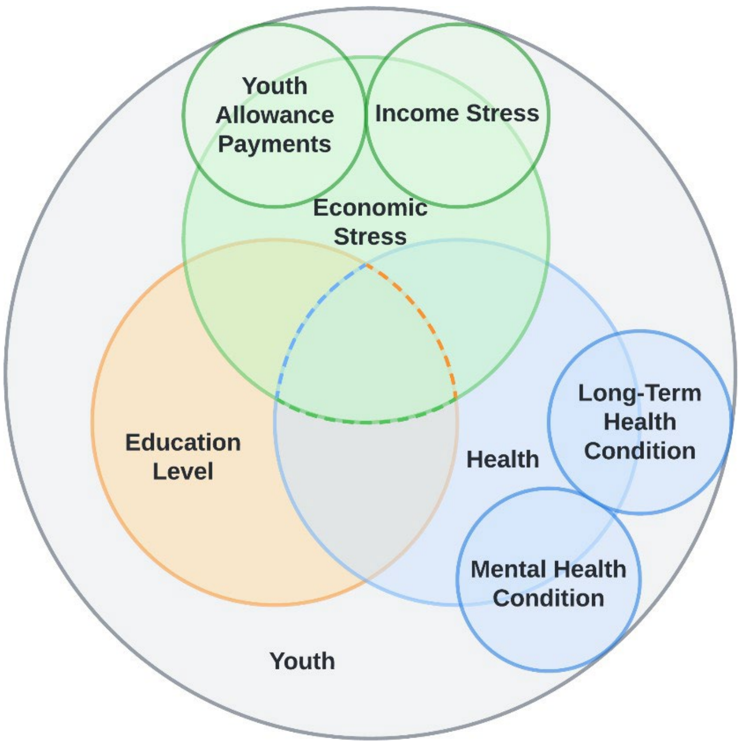

Figure 26. Vulnerability definition filtering diagram showing those youth who are most vulnerable.

Low income

Table 13. Component identification and ranking output for low income vulnerable population

Component	Sector	Weight
Sensitivity		
Domestic abuse or family violence	Social	0.08
Long-term health condition – one or more	Social	0.19
Need of assistance for core activities	Health	0.08
Rental affordability	Economic	0.31
Economic		0.35
Mortgage and rental stress at 30 per cent	Economic	0.35
Low household income – family or non-family		0.30
Low income card		0.35
Capacity – social		
Social capital and social connectedness		0.15
Not employed or in labour force		0.30
Lives alone	Social	0.15
Sole parent		0.20
Social connections – digital inclusion index		0.15
Capacity – physical and environmental		
Dwelling/housing structure		0.32
Housing condition and/or age		0.32
Proximity to medical services	Physical	0.09
Proximity to other services		0.09
Proximity to public transport		0.18

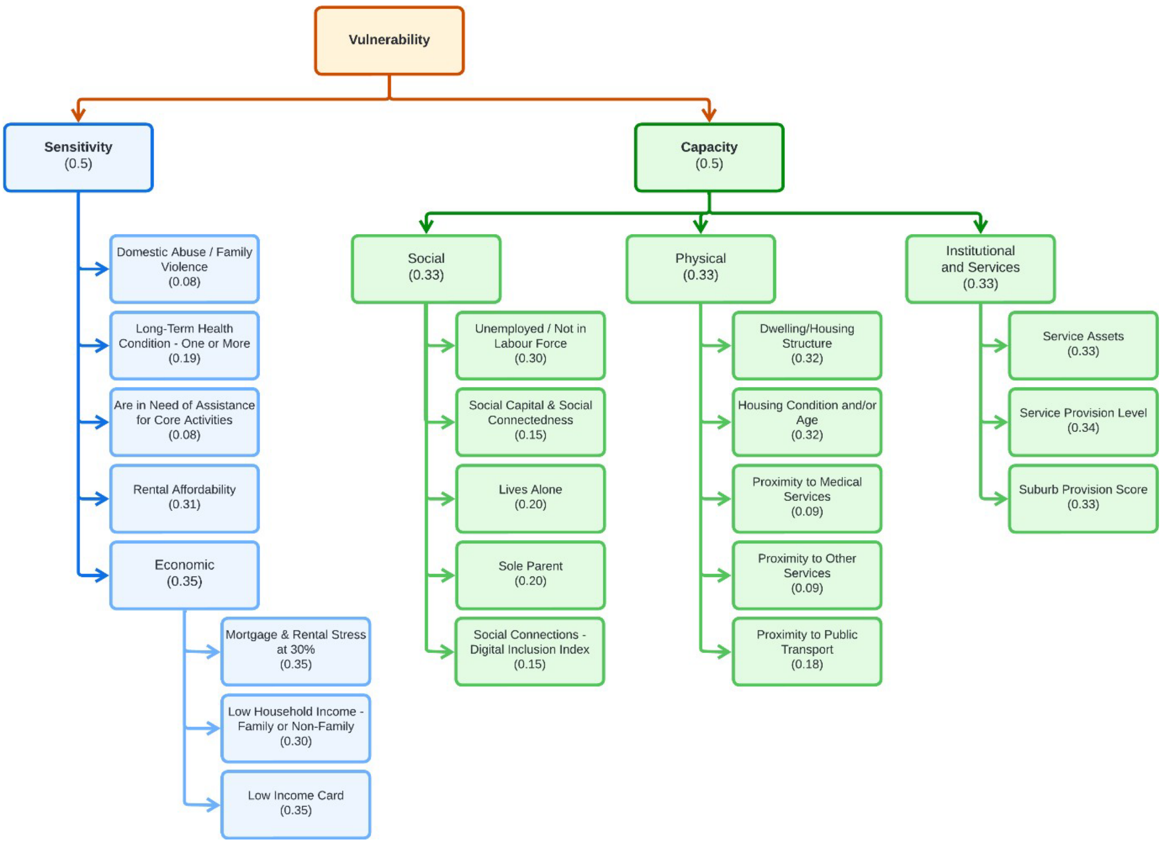

Figure 27. Low income vulnerability modelling framework.

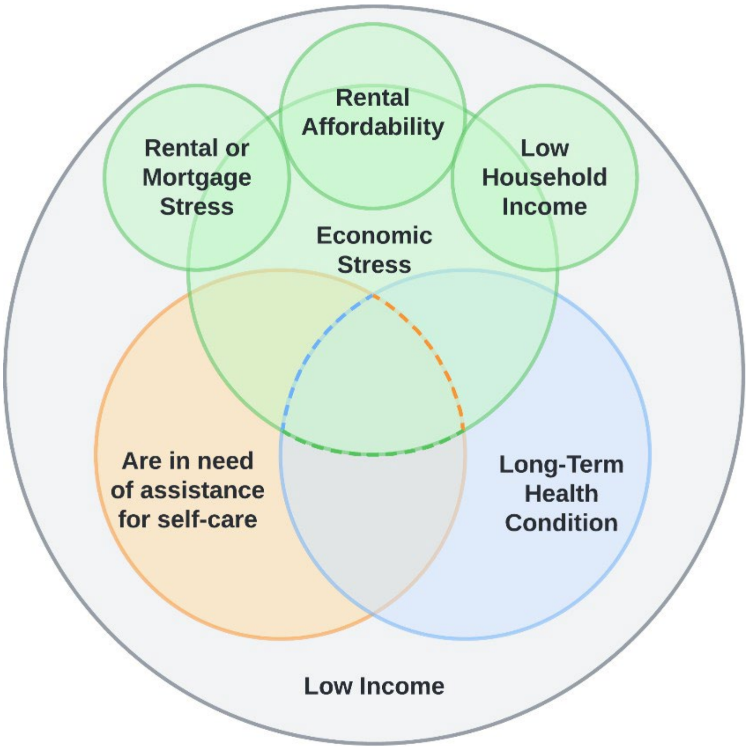

Figure 28. Vulnerability definition filtering diagram showing those low income who are most vulnerable.

Appendix B – suburb-based services (example)

Example of suburb-based services targeting vulnerable sub-populations. The example shows the community-based assets that potentially provide services for areas of Bass Coast LGA to the older people sub-population.

	Council	Suburb	Service Asset Within Suburb	Services Provided to Suburb	Explanation	Service Assets	Service Providers
2	BASS COAST	ADAMS ESTATE				Seniors Citizens - Cowes Inverloch Wonthaggi	Mecwacare
3		ALMURTA				Rotary Inverlcoh Wonthaggi	Rotary
4		ANDERSON	Yes	Low	Anderson only has an outdoor transit centre for Vline	Lions Clubs Inverloch Wonthaggi San Remo Cowes	Lions Clubs
5		ARCHIES CREEK				Mens Sheds	Probus
6		BASS	Yes	Low	Has a Community Centre that runs support programs for elderly	Neighbourhood Houses	
7		CAPE PATERSON	Yes	Low	Use services at Wonthaggi	Warrawee Club Inverloch	
8		CAPE WOOLAMAI	Yes	Low	Has bus service. Utilises health and comm services mainly at Cowes	Inverloch Community Hub	
9		CHURCHILL ISLAND				Bass Coast Health - Wonthaggi hospital- Cowes Health Hub San Remo? Throughout BC clinics	
10		CORINELLA	Yes	Low	Has community house that provides food relief and activities	Community Facilities - this is too hard to define	
11		CORONET BAY	Yes	Low		health facility - gyms? GP clinic?	
12		COWES	Yes	Medium	Has medical hub, community house, rotary, health faciliities, senior citz	Civic Centre/City Hall	
13		DALYSTON	Yes	Low	Recreation reserve is really the only thing there.	Clubs/Community Groups	
14		GLEN ALVIE	Yes	Low		Library	
15		GLEN FORBES	Yes	Low		Town/Community Hall	
16		GRANTVILLE	Yes	Low?	Library, clinic	Education - Support BCAL U3A - wonthaggi - Chisholm? Country Uni	
17		HARMERS HAVEN				Hall/Sports Centre regional halls approx 30	
18		INVERLOCH	Yes	Medium	There is a community hub, house, senior citz, library and mecwacare office		
19		JAM JERRUP	Yes	Low	There is very little here.		
20		KERNOT	Yes	Low	There is a hall.	It is hard to provide a rating because BCSC don't provide services except kindergarten registration and vaccination services.	
21		KILCUNDA	Yes	Low	There is a hall.	When aged care services were outsourced, all of that information and insight dispapeared. Mecwacare are the main contact for this now.	
22		KROWERA	Yes	Low	There is a hall.		
23		LANCE CREEK					

Senior | Suburbs | Lists

Appendix C – Acronyms

ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHP	Analytical Hierarchy Process
AVA	Asset Vulnerability Assessment
CMSI	Climate Measurement Standards Initiative
GCM	General Circulation Models
GCP	General Community Profile
MCA	Multi-Criteria Analysis
MS	Microsoft
NESB	Non-English Speaking Background
RCP	Representative Concentration Pathway
SA1	ABS Statistical Area Level 1
SECCCA	South East Councils Climate Change Alliance
SME	Subject Matter Expert

Spatial
Vision