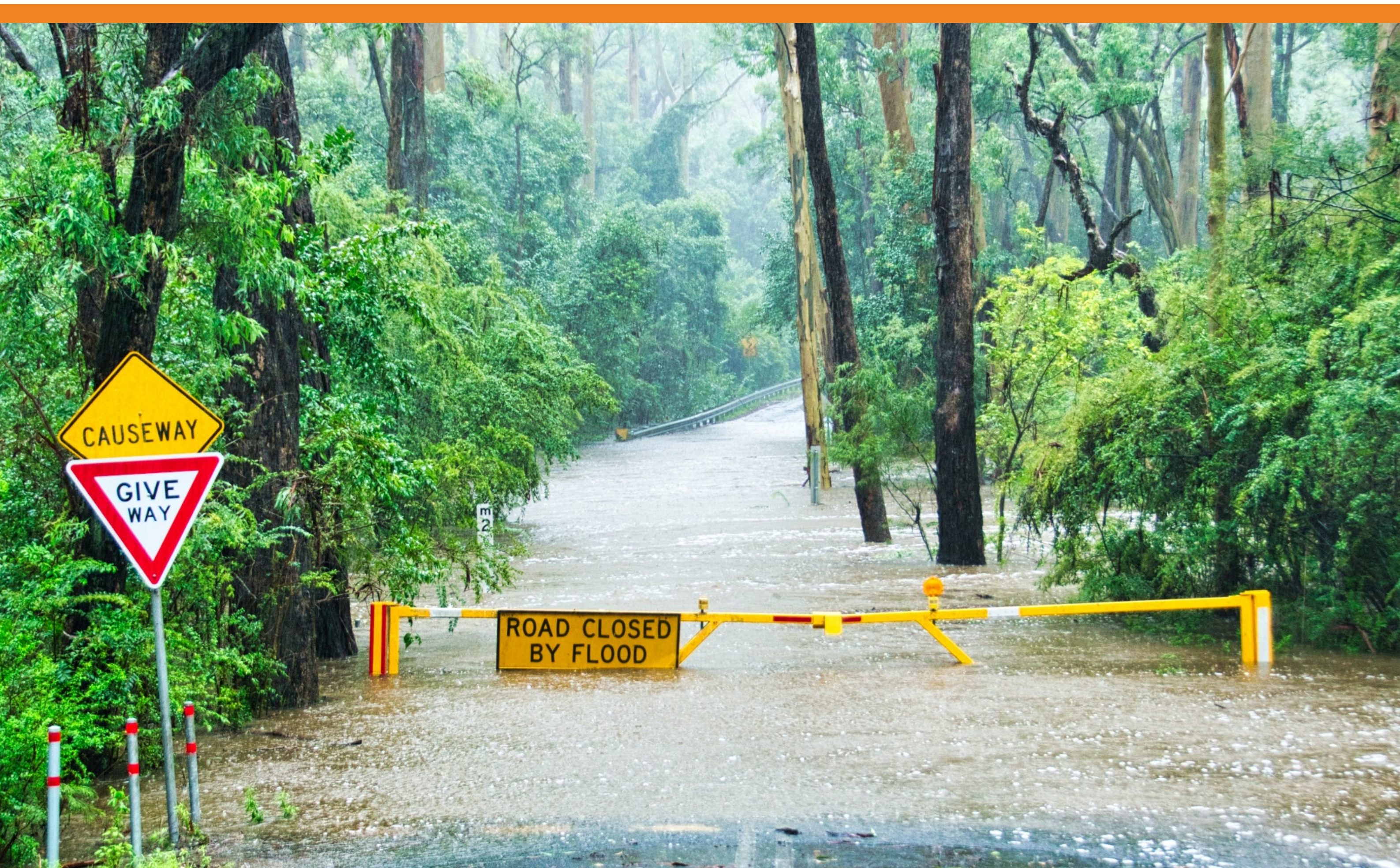
Asset Vulnerability Assessment Project

Part 1 - Findings Report

Prepared for: South East Councils Climate Change Alliance (SECCCA)

Final

17/11/2021



About This Document

Project Number	SV005891
Project Name	Climate Change – Asset Vulnerability Assessment
File Name	SECCCA_AVA_Part1_Findings_Report_Final
Project Client	South East Councils Climate Change Alliance (SECCCA)
Date of Issue	25/11/2021
Version Number	3.0 (Final)
Document Title	Asset Vulnerability Assessment Project | Part 1 - Findings Report
SV Contact	Stephen Farrell
Email	stephen.farrell@spatialvision.com.au

Disclaimer

Spatial Vision Innovations Pty Ltd

Level 8, 575 Bourke St, Melbourne 3000 VIC

P (03) 9691 3000

E info@spatialvision.com.au

W www.spatialvision.com.au

ABN 28 092 695 951

Table of Contents

Figures

Tables

1. This Document

This report presents the key findings and a description of key project outputs from the high-level vulnerability assessment applied to agreed council assets as part of the SECCCA Asset Vulnerability Assessment (AVA) project. This high-level assessment approach has been identified as part one of a two-part vulnerability assessment and is viewed equivalent to what is generally termed a first pass climate change assessment study in that it comprises a high-level generic assessment based on an agreed set of asset attributes. This part one assessment was applied to assets identified in the nine councils that are members of SECCCA.

A more detailed part two vulnerability assessment, or second pass assessment, was undertaken in the form of case studies. These case studies include a detailed review of anticipated costs in relation to specific climate related impacts, and an evaluation of adaptation and replacement options to reduce projected climate change costs.

2. Background

2.1. This Project

This project was aimed at assisting SECCCA member councils to better understand how their buildings, roads, drainage and open space will be impacted by climate change and associated extreme weather events.

More specifically, SECCCA notes that the project is aimed at assisting councils to understand:

- how will climate change impact a particular asset
- how might service delivery be impacted by climate change
- how much extra will an asset or service cost to maintain or deliver assuming no adaptation action
- how much extra can councils expect to pay to respond to damages or pay in insurance
- how much would be the expected cost of making assets resilient; and
- how might council income streams be impacted by climate change.

Through the case studies, the project identifies how related council income and expenditure will be impacted, and provide guidance on how councils can appropriately plan – financially and strategically - for the anticipated changes. By having a greater understanding of asset vulnerability and the potential financial impacts of climate change, councils can appropriately plan and cost work plans in order to make assets more resilient. In turn this will assist to improve understanding of how climate change is likely to impact the delivery of community services.

The project also helps councils understand the potential impact of climate change and associated extreme weather events on local communities. The project aligns with climate risk methodologies and standards such as the CMSI (Climate Measures Standards Initiative).

2.2. Understanding Likely Change

To better plan for likely climate change related impacts, council staff need to better understand the anticipated changes in the climate, and the associated flow on effects. This change in the climate can be expressed in terms of climatic variables, such as the number of days over 35°C per month, or in terms of sea level rise and likely area impacted by this and associated storm surge events.

Spatial views of where change is likely to occur, such as which areas are more likely to be flooded, or be subjected to a greater number of heatwaves, are required to identify the likely impact of the anticipated changes.

By utilising the most recent climate projections from CSIRO and DELWP, as well as region wide inundation and in-house flood modelling, the level of change across the SECCCA region can be identified. Critically this change needs to be defined relative to an appropriate baseline or reference period in time so that future exposure to change and associated impacts can be accurately identified.

Hence, a key first step in this project was the suitable collation and standardisation of data, including climate and climate projection data, and relevant council climate event or event modelling data.

2.3. Understanding likely Asset Impacts and Vulnerability

Vulnerability is a function of exposure to climate factors, sensitivity to change and capacity to adapt to that change. To suitably identify or model the likely vulnerability of a particular asset requires an understanding of how sensitive a particular asset is to different levels of change, and whether there are factors, such as condition, that increase or reduce the impact of the anticipated change.

It is important that key attributes of an asset that influence its sensitivity, such as the materials it is built from, the design standard under which it was built, or its age, are identified so that the likely impact of an identified level of exposure to change can be expressed in terms of the likely impact this change will have on an asset. These attributes essentially define an asset, and are generally unable to be changed.

In addition, there are factors about an asset that you can change, such as its maintenance level, or barriers built to protect an asset. These can be termed adaptation activities (or adaptive capacity factors). Bringing these together in a well-defined and consistently applied framework is critical in determining and assigning a meaningful impact and vulnerability rating to an asset.

Each council asset type will be influenced by, and have different levels of sensitivity to, particular hazards. A key aspect of this vulnerability assessment was to determine the likely exposure over time to hazards (such as heat waves, storm surge events and sea level rise).

The first pass assessment, or high-level assessment applied in this study used spatial analysis to assign a high-level vulnerability assessment rating to council assets for different climate variables.

2.4. Case Studies on how we plan for climate change and its impacts

More detailed vulnerability assessments were undertaken in the form of case studies, which have been termed a second pass assessment process in this project.

These case studies use a scenario (or set of) to describe how a particular extreme weather event that is exacerbated by climate change, impacts a particular location and how the impacts can be reduced through adaptation measures. The adaptation responses presented range from broad strategic evaluations through to local planning related responses. The results were aimed at assisting higher level decision making by council officers and managers rather than finer level planning decisions.

Due to the sensitive nature of some of the information in the case studies, the information has not been included in this report. However, the process has been documented and will be included in the AVA process toolkit to be found on the SECCCA web-site.

The three case studies selected from the 19 candidate case studies nominated by councils for consideration, and for which separate and more detailed analysis was undertaken, were:

- Port Phillip - Inundation at Elwood Foreshore
- Mornington Peninsula - Inundation at Rosebud
- Cardinia - Bushfire at Gembrook and Cockatoo

Details concerning these case studies, including the adaptation options considered and financial analysis undertaken are contained in separate case study reports.

2.5. Extreme Weather Events and Climate Change Projection Data

While extreme weather events are not readily modelled in the latest climate science and down-scaled modelling available through the CSIRO, the latest modelling outcomes were 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 under a particular scenario was identified.

2.6. Alignment with CMSI

This project, including the development of the second pass case studies, is aligned with the Climate Measurement Standards Initiative (CMSI) in terms of principles, concepts and definitions and methodologies applied.

The overarching principles of the CMSI are:

1. Use credible scientific sources, assessments and research published in peer-reviewed scientific literature or from reputable scientific authorities.
2. Use multiple lines of evidence to assess risk and, where possible, use existing assessments of multiple lines of evidence.
3. Where possible and appropriate, survey multiple model ensembles.
4. Appropriately communicate uncertainty.
5. Use model outputs appropriate for the question addressed.

The principles have been further developed by the CMSI to advise:

- support for international standard Representative Concentration Pathways (RCPs) as plausible trajectories.
- using a range of plausible regional climate change. A broad range of possibilities can be considered, including consideration of a 'best case' or 'worst case' change if that is more useful.

- before using a climate projections dataset for assessing impacts, the projections should be examined to ensure they are fit-for-purpose.
- developing hypothetical scenarios to 'stress test' systems that invoke compound events is recommended where feasible.

A detailed explanation of these principles, concepts and definitions is provided in *Scenario analysis of climate-related physical risk for buildings and infrastructure: climate science guidance* (CMSI, Earth Sciences and Climate Change Hub, 2020).

3. Project Delivery and Consultation

3.1. Project Delivery

Successful delivery of Part 1 of SECCCA Asset Vulnerability Assessment project involved significant consultation and engagement with SECCCA and relevant local government staff. This engagement included various management and technical groups to assist with key project decisions and direction, weekly reporting on project progression, ongoing consultation with various groups, workshops, and data output mentoring. These groups are briefly identified below.

Project Governance

- Project Control Group – responsible for direct project oversight and decisions as required to ensure project delivery.
- Technical Reference Group – comprised SECCCA staff, one member from a SECCCA member council's asset team, Insurance Council of Australia (ICA), DELWP and CSIRO. TRG provided expert advice into the project.
- Project Working Group – comprised of one member from each SECCCA member council's asset team. The group was tasked to assist in coordinating the project internally and liaising with SECCCA and the consultants (SV and MJA).

Reporting

Weekly reports were provided to the Project Working Group members and Sustainability Representatives to identify the project progress and work completed throughout each week, the planned work for the following week, dates of project milestones completed and any project issues.

3.2. Consultation

A series of consultations with various relevant groups were conducted to assist project direction and ensure successful delivery of the project. The main focus for these consultation activities was with Project Working Group (PWG) members as the key contact for each participating LGA. Council Sustainability Representatives were included in all PWG correspondence to ensure they were across the project in terms of its findings, deliverables and general progress.

Project Working Group Meetings

Meetings and on-going communication with Project Working Group members occurred on an as-necessary basis, for example to outline data requirements for analysis and to follow up with required data. Table 1 below identifies the primary PWG member and Sustainability Representative for each council.

Table 1. Council PWG members and Sustainability Representatives

Council	PWG Member	Council Sustainability Representative
City of Casey	Jack Fang	Simon King
Mornington Peninsula Shire Council	Amir Noorbakhsh (previous), Aaron Hunter	Chris Yorke
Cardinia Shire Council	Craig McLennan	Aruna Dias
Kingston City Council	Brian Trower	Helen Scott
Bass Coast Shire Council	Simon Harris	Benita Russell
City of Greater Dandenong	Russell Tait	Darren Wilson
City of Port Phillip	John Tran	Renae Walton
Bayside City Council	Eugene Stackpole	Julian Donlen
Frankston City Council	Gayani Jayawardena	Rachael Weaver

Asset Management Group Meetings

Three meetings for each of the three asset types (buildings, roads and drainage) were held with asset managers from all councils to discuss and receive feedback on the sensitivity and adaptive capacity scoring of the asset attributes.

Dates held:

Buildings Asset Type Meeting: 24th February 2021

Roads Asset Type Meeting: 24th February 2021

Drainage Asset Type Meeting: 26th February 2021

Purpose:

- To present and receive feedback on initial sensitivity and adaptive capacity scorings of asset attributes.

Findings:

- Adjustment of sensitivity and adaptive capacity scoring based on feedback from asset managers gathered in the Asset Type Meetings and follow up email communication.
- The outcomes and advice presented in these sessions were incorporated into the Asset Vulnerability Assessment methodology and tables used in the application of the method.

Workshops

Three key workshops were held throughout the duration of the project. These workshops aimed to present the project status and outputs, and generate discussion and obtain feedback from participants. They were attended by the Asset Representatives and the Sustainability Representatives for each council.

Workshop 1:

Date held: 19th November 2020

Workshop Purpose:

- To outline the proposed approach and scope of the asset vulnerability assessment
- To better understand the climate change issues (events and assets) of concern to the Councils – through in-workshop presentation and discussions prepared by each council
- To explore the climate change projections
- To confirm the role of case studies, and;
- To confirm available asset and climate-related data and key studies.

Workshop Findings:

Before the workshop each Project Working Group member was asked to prepare a 5-minute presentation on climate related issues of greatest concern to their council, in response to the two following questions:

- Describe a recent extreme weather event, the assets most impacted, where the greatest costs were incurred, and the lessons learnt.
- Describe one or two climate change or extreme weather events or scenarios of greatest concern to you or your council and why?

Table 2 is a summarisation from these presentations that highlight the extreme weather events and assets of concern.

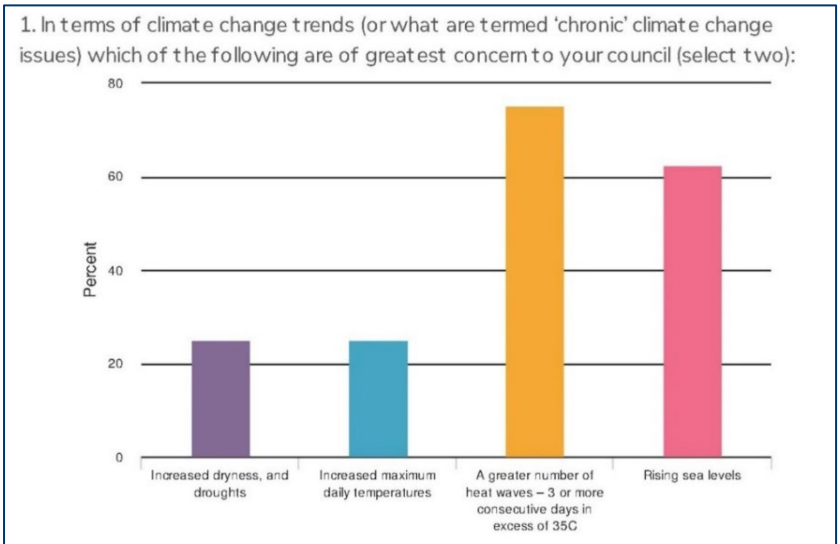
Table 2. Extreme weather and assets of concern

Council	Spokesperson	Extreme Weather events of Concern	Assets of Concern
Casey	Jack Fang	Heavy rainfall	Roads & trains, foreshore assets, open spaces
Mornington Peninsular	Amir Noorbakhsh	Storm surges	Storm water network, coastal structures
Cardinia	Craig McLennan	Heavy rainfall	
Kingston	Brian Trower	Sea level rise, Storm surges	Foreshore properties, sand dunes
Bass Coast	Simon Harris	Storm surge with sea level rise	Roads, coastal assets
Dandenong	Russel Tait	Major rainfall and flooding	Road and drainage assets.
Port Phillip	John Tran	Storm surges	Storm water assets, road network, Fishermans Bend
Bayside	Julian Donlen	Heatwaves	Bathing boxes (public concern); bayside bike park; aging population; piers and jetties
Frankston	Gayani Jayawardena	Flash flooding events	Roads and drainage

Alongside the request to prepare a presentation, the workshop participants were also asked to complete an online survey with three questions to identify the climate change and extreme weather trends of concern, as well as the assets of concern.

The findings of Workshop 1 were used as the starting point and foundation for further project discussions regarding case study direction.

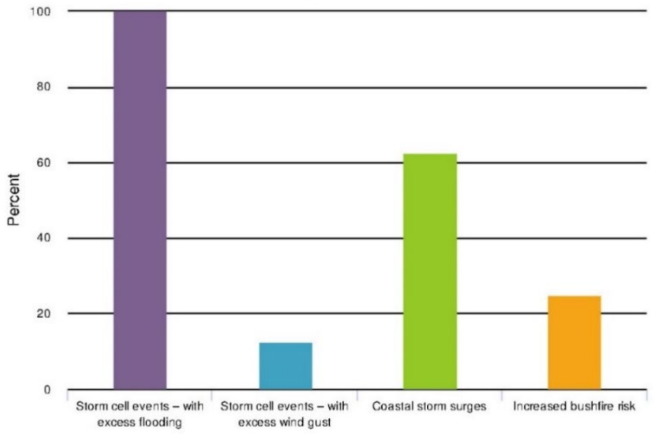
The results of this online survey are presented in the following figures.



Value	Percent	Responses
Increased dryness, and droughts	25.0%	2
Increased maximum daily temperatures	25.0%	2
A greater number of heat waves – 3 or more consecutive days in excess of 35C	75.0%	6
Rising sea levels	62.5%	5

Figure 1. Response of Workshop 1 participants to question concerning key long term impacts of climate change of concerns.

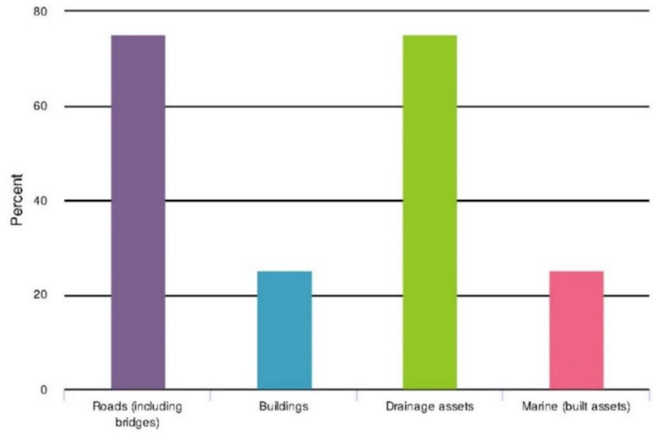
2. In terms of extreme weather events (or what are termed 'acute' climate change issues) which are of greatest concern to your council (select two):



Value	Percent	Responses
Storm cell events – with excess flooding	100.0%	8
Storm cell events – with excess wind gust	12.5%	1
Coastal storm surges	62.5%	5
Increased bushfire risk	25.0%	2

Figure 2. Response of Workshop 1 participants to question concerning 'acute' climate change issues of concerns.

3. In terms of the types of assets at risk, which are of greatest concern to your council (select two):



Value	Percent	Responses
Roads (including bridges)	75.0%	6
Buildings	25.0%	2
Drainage assets	75.0%	6
Marine (built assets)	25.0%	2

Figure 3. Response of Workshop 1 participants to question concerning assets of most concern in relation to impacts of climate change.

Workshop 2:

Date held: 11th February 2021

Workshop Purpose:

- Present preliminary results for Part 1 asset vulnerability assessment
- Confirm case studies of interest to Councils and rationale for nomination
- Present Case Study (Part 2) AVA example.

Workshop Findings:

Each council was requested to prepare and present up to two case study nominations in Workshop 2, highlighting the particular event type of interest, and the extent of the impact. For each case study presented, participants were encouraged to scope their suitability against the following criteria:

- The priority of the extreme weather or climate change issue
- The availability of data to support a full vulnerability assessment and review of adaptation options
- Geographic and council type category representation, and;
- Availability of staff to support the process and development of the case study.

Refer to Appendix 3 for further information on these four case study selection criteria.

Table 3 below presents an overview of each council-nominated case study presented at Workshop 2.

Table 3. Overview of Nominated Case Studies

LGA	Case Study Number	Climate Change/Extreme Weather Event	Title of Nominated Case Study
Kingston	1	Inundation	Mordialloc Creek - Inundation
	2	Inundation	Aspendale to Carrum – Land Subject to Inundation
Port Phillip	1	Inundation	Inundation (SLR, storm surge, inland flooding) of the Elwood Foreshore Precinct
Casey	1	Inundation	Inundation of Warneet/Blind Bight
	2	Bushfire	Bushfires at Endeavour/Lysterfield South
	3	Inundation (Flooding)	Flooding at Hallam Road, Cranbourne Road and Clyde Road
Cardinia	1	Bushfire	Bushfire at Gembrook and Cockatoo
Frankston	1	Inundation	Flooding Drainage and Road Assets in Seaford
	2	Sea Level Rise and Erosion	Sea Level Rise and Erosion at Seaford Life Savers Club
Bass Coast	1	Inundation and Erosion	Sea Level Rise, Storm Surge and Erosion at different coastal locations
	2	Inundation	Inundation at Silverleaves, Phillip Island
	3	Extreme heat (Heatwaves and high temperature days)	Extreme heat impacts on Roads
Bayside	1	Inundation and Erosion	Sea Level Rise, Storm Surge and Erosion around Bayside and Elster Creek
	2	Heatwaves	Heatwave impact on community in Bayside
	3	Temperature/Rainfall	Vulnerability of Street Trees to Climate Change in Bayside
Mornington Peninsula	1	Flooding	Elevated maintenance requirement & unserviceability in coastal drainage assets from flooding
	2	Inundation	Inundation of drainage assets in easements in Dromana Bowl and Safety beach low lying areas
	3	Inundation	Efficiency comparison between traditional coastal outfalls and dune infiltration outfalls.
Dandenong	1	Flooding	Flooding in Dandenong LGA

Workshop 3:

Date held: 20th May 2021

Workshop Purpose:

- Present findings for Part 1 asset vulnerability assessment
- Obtain guidance on how Part 1 outputs may be used
- Present Part 2 case studies being pursued and rationale
- Obtain input into case study adaptation options
- Confirm project next steps.

Workshop Findings:

- Agreement with Project Working Group and Sustainability Representatives on the general format and proposed presentation of the Part 1 Vulnerability Assessment outputs – noting the challenges of the data presentation given its complexities. Figure 1 and Figure 2 below present the data presentation within the QGIS Viewers.
- Agreement on the proposed approach to the mentoring sessions that proceeded Workshop 3.

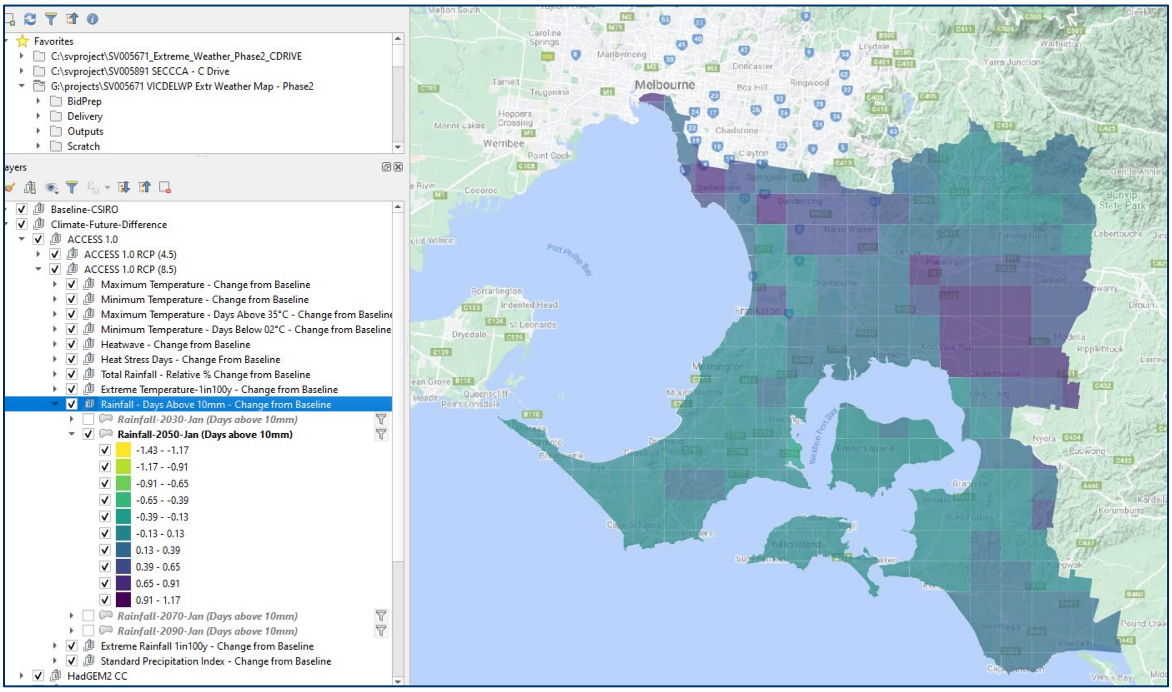


Figure 4. Screen view of online QGIS Climate Viewer that was developed to assist a review of anticipated climate change.

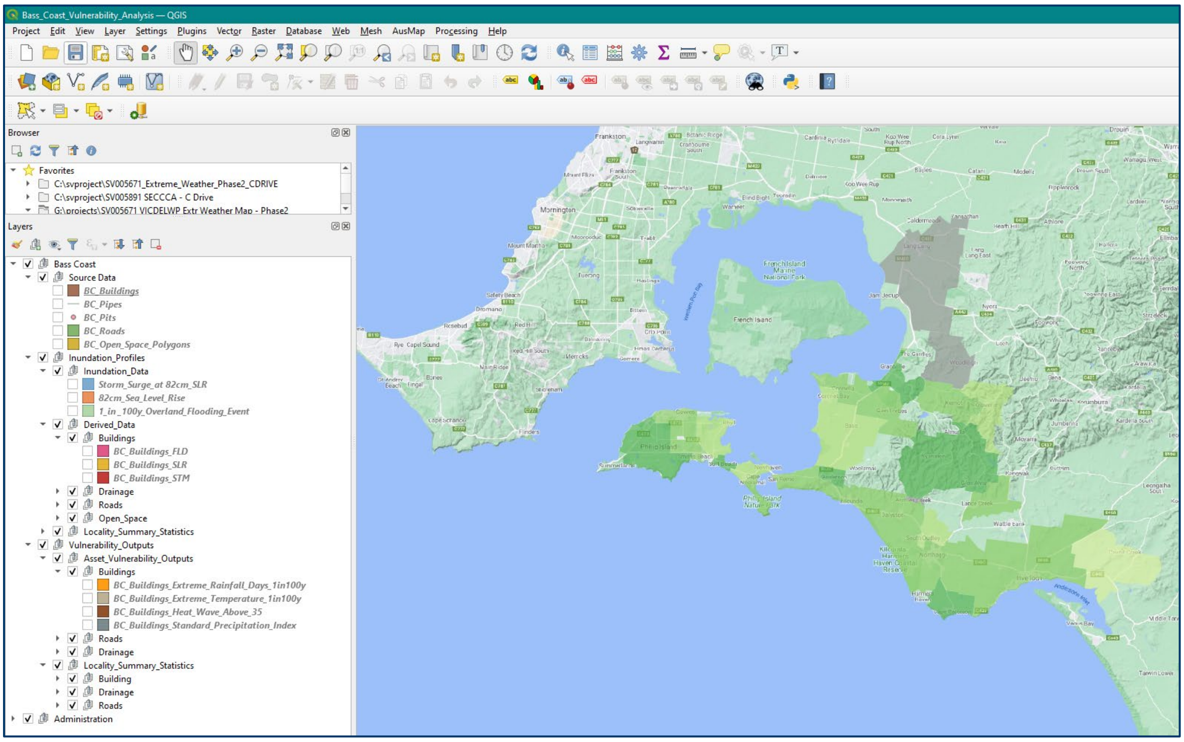


Figure 5. Screen view of online Council AVA Viewer

3.3. Mentoring Sessions

Mentoring sessions were provided to councils on an individual-level basis to explore the outputs generated in Part 1 of the SECCCA AVA Project. Each online mentoring session lasted approximately 2 hours long, and provided opportunity for discussion, questions and the exploration of the data to support council planning.

Table 4 below notes the mentoring session dates and participants for each member council.

Table 4. Mentoring sessions dates and participants

Council	Session Date	Participants
Kingston	06/07/2021	Helen Scott; Steven Li; Juli Stickler; Christine Han; Surag Kulkarni; Mychi Lam; Craig Macaulay
Casey	07/07/2021	Jack Fang; Simon King; Shiranga Jayawardena; Karen Borton; Luke Bassett; Joseph Antony; Kumar Prathapa
Cardinia	07/07/2021	Aruna Dias; Nuwan Jayasekera; Craig McLennan; Gavin Manuel
Bayside	09/07/2021	Eugene Stackpole; Bruce Robertson; Julian Donlen
Greater Dandenong	13/07/2021	Mingchao Che; Stephanie Karras; Darren Wilson; Russel Tait
Bass Coast	13/07/2021	Simon Harris; Laurie Gervasi; Michael McClean; Phillip Pritchard; Christine Kirby; Simon Woodland
Mornington Peninsula	14/07/2021	Aaron Hunter; Joshua Geoghegan; Harish Kirubakaran; Lachlan McKenzie
Port Phillip	15/07/2021	Renae Walton; John Tran; Mohamed El-Saafin; Sam Innes, David Hehir; Daniel Pleiter (SECCCA); Anthony Boxshall (SIA)
Frankston	15/07/2021	Mitchell Morris; Gayani Jayawardena; Rachael Weaver

Purpose:

The purpose of the mentoring sessions was:

- To introduce participants to and explore the data outputs generated from Part 1 of the SECCCA AVA Project.
- Use worked examples with the output data in a QGIS environment to exemplify how it can assist decision making and planning.
- To familiarise participants with the data to build internal capacity within the councils.

Findings:

Outputs generated in Part 1 of the AVA Assessment were presented and symbolised in two QGIS projects:

1. *Climate Viewer:* Presents the climate data (baseline, projected and historical climate variable data) across the SECCCA region.
2. *Council AVA Viewer:* Outputs of the Vulnerability Assessment (including the Inundation Profile Analysis and the Asset Vulnerability Analysis), on a council-specific basis.

Participants were mentored in the use and application of the generated outputs within the QGIS environment to assist with decision making by providing worked examples of how key questions could be answered.

These worked example questions included:

1. Climate Viewer – Worked Example #1
   "What's the relative change in the number of heatwaves per year in X (location) expected to be over time?"
2. Council AVA Viewer – Worked Example #1
   "Will Building 'X' be impacted by different inundation scenarios?"
3. Council AVA Viewer – Worked Example #2
   "Which building assets are the most vulnerable to extreme temperature in my LGA?"
4. Council AVA Viewer – Worked Example #3
   "Which localities in my LGA should I be most concerned about in regards to the vulnerability of roads to extreme temperature?"

Alongside the live demonstration of these worked examples in the mentoring session, the process and steps were also documented in the 'Asset Vulnerability Assessment Worked Example User Guide' (see Appendix 6).

A key outcome of this stage was for LGA participants to develop an understanding of how to consume and apply the outputs of the project into their business processes and decision making. The worked examples presented and walked through in the mentoring sessions provide significant guidance to LGA staff on how both the asset-based outputs and locality based outputs can be applied. These worked examples are presented in the mentoring notes provided in Appendix 6.

4. Vulnerability Assessment Approach Overview

4.1. Use of recent climate change modelling data

The asset vulnerability assessment approach applied in this project used the most recent climate projections for Victoria the Victorian Climate Projections 2019. The Victorian Government worked with CSIRO to provide dynamically downscaled 5km x 5km state wide projections for six Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5) global climate models. This application ready data has been applied in this project.

These modelled climate variables and associated impacts were processed into a vulnerability rating.

4.2. Vulnerability Method Overview

The concepts and definitions adopted in this project drew on elements of the overall vulnerability assessment method as outlined and adopted in: *Guidelines for Developing a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment; November 2012*; (Local Government Association of South Australia, 2012).

This method describes how likely exposure to climate scenarios, coupled with the sensitivity and adaptive capacity of the asset to these climate scenarios, are used to assess the likely vulnerability of assets to these changes. This process was developed by the Allen Consulting and is based on that developed by the IPCC (Brunckhorst, 2011).

This approach generates an impact rating based on the assessed inherent sensitivity of an asset to different climate change parameter exposure scenarios. The adaptive capacity of an asset in relation to impacts is also assessed and used to assign asset vulnerability, where adaptive capacity primarily relates to attributes that can be altered, such as the condition or context of an asset.

Spatial datasets depicting council assets were utilised in this process.

A detailed description of the methodology applied in this part 1 assessment, including the conceptual framework and definitions on which this process is based, are available in the separate project methods paper (*Asset Vulnerability Assessment Project First Pass Methods Report*, prepared by Spatial Vision) for the Stage 1 vulnerability assessment.

4.3. Climate Change Variables and Inundation Impacts

Areas likely to be impacted by some climate change variables, such as those subject to increased overland flooding due to increased rainfall events, are differentiated across the region and municipalities at a finer scale than anticipated climate change variables such as heat waves and rainfall variation. While anticipated climate related changes, and the impacts on individual assets will also vary across the region and municipalities based on the asset location, climate variable data is still at a very coarse 5km by 5km resolution, and hence was applied to an entire asset.

Given the variation in resolution between inundation modelling and modelled climate variables such as temperature and rainfall, the following two approaches were undertaken to assess the likely impact of climate change based on the type of climate change information:

- Vulnerability assessment
- Inundation profile

Vulnerability Assessment

The first pass vulnerability assessment was conducted for each asset grouping (that comprise buildings, roads and drainage) and applied at the individual asset level. This vulnerability assessment assists in understanding the climate parameters that are driving the assessed vulnerability rating in that it reflects how the anticipated 'broader' climate change under each climate change scenario - using latest climate projections for Victoria (Clarke et al 2019) prepared by CSIRO - is likely to broadly impact each asset type.

During the data collation stage, asset data provided by each member council was assessed for completeness and suitability for a vulnerability assessment.

While all assets were assigned a vulnerability rating, the final rating assigned was dependent on available council data.

For some assets, a generalised rating, or in some situations, no first pass vulnerability assessment rating, were assigned. Assets for which this applies includes those with:

- 'ghost' entries such as assets held by other non-council aligned organisations, but still being recorded spatially by council in asset management systems,
- incomplete data records from information held by third parties,
- incorrectly entered or incomplete data, or
- data that is not captured 100% for a given attribute or asset, such as condition for underground pipes.

Inundation Profile

An inundation profile was applied to all agreed Council assets (buildings, roads, drainage and open space) and involved using detailed spatial data for inundation (from anticipated sea level rise and flooding scenarios).

In applying these two assessment approaches the following two categories of asset assessment results was prepared to assist users:

a. Vulnerability assessment based on asset attributes.
b. Inundation assessment profile based on inundation extent.

4.4. Asset Vulnerability Assessment – First Pass Approach

A first pass asset vulnerability assessment involved using individual asset characteristics to assign a likely estimate of an asset's sensitivity to particular climate change variables, and features of the asset impacting its adaptive capacity to such change. Suitable asset attribute information was required to support such an assessment.

The final approach adopted for each asset type and climate change variable was agreed with the Project Technical Reference Group prior to implementation.

Figure 6 presents how a Vulnerability Assessment Framework was applied in the SECCCA project. As indicated, this framework has been developed by the International Panel on Climate Change (IPCC 2001, IPCC 2007) and previously applied in multiple climate change vulnerability assessments (Spatial Vision 2013, 2021) (Spatial Vision 2020).

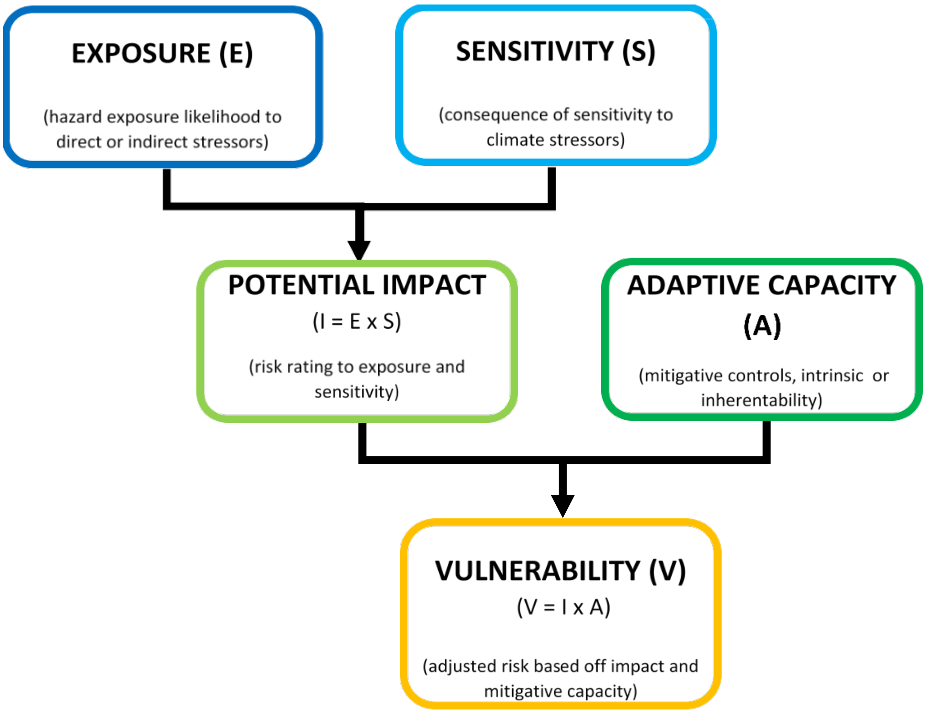


Figure 6. Proposed conceptual framework for assessing vulnerability to climate change.

Key definitions relating to this framework are detailed briefly below, with a longer definition provided in the glossary in Appendix 2.

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability (in relation to climate variables) and extremes.

Exposure: relates to the changes in climate variables, influences or stimuli that impact on a system (such as heat waves, or sea level rise).

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. This responsiveness relates to 'inherent' characteristics of the asset to deal with a particular climate stressor.

Adaptive Capacity: is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Impact: refers to the effect on the natural or built environment to particular climate variables or hazards, including extreme events such as heat waves, storms and other climate events.

For the purposes of this project, adaptive capacity was assigned in terms of the ability of the asset to adjust to climate variables based on its current state rather than a projected future state. As an example, assuming it was applied to council managed buildings:

- Exposure would include hazards such as heatwaves, or more days over 35°C, or greater dryness influencing foundations. These are identified as potential key climate variables,
- Sensitivity attributes would relate to roof, foundation or external wall material, asset function and age,
- Adaptive Capacity factors that may be considered in reducing vulnerability are identified as building condition, where a well-maintained building will be less vulnerable to the same climate change than a poorly maintained building.

In relation to climate-related changes (or exposure to them), ratings and scores for exposure are provided through the initial climate analysis. Translation tables to convert above-normal climate-related changes to ratings, or probabilities were generated. From these tables, scores can be applied to a stressor for each emission scenario over the different time points. For example, a small change in Mean Maximum Daily Temperature would be assigned a low value (of say '1') and a large change a high value (a value of '5').

Similar with sensitivity and adaptive capacity factors, scores were generated and applied back to a range of attributes inherent within the asset. These were then combined with exposure scores to calculate an overall Vulnerability score. The full application and assignment of these values are expanded upon in Section 5. Appendix 5 provides a worked example of the methodology by which vulnerability rating were assigned.

Additional details on the methodology are available in the separate project methods paper (*Asset Vulnerability Assessment Project First Pass Methods Report*, prepared by Spatial Vision) for the Stage 1 vulnerability assessment.

4.5. Inundation Profile Approach – First Pass Approach

Sea level rise and associated storm surge, overland flow or flood events, are climate-related variables that can be applied as a differentiated change across the municipality. For these two variables an inundation profile for all individual council assets were undertaken. This profile comprises the following two key elements for each climate change variable assessed:

- absolute extent (area or length) of the asset impacted.
- percentage of the total asset extent that this impacted extent represented.

This process generated a profile for each asset that provides both absolute asset quantity values and percentage breakdowns for each category.

5. Climate Change Data

5.1. Climate Change Data

Several climate change related variables and impacts were assessed to identify 'high risk' or priority assets within the SECCCA Study Region. These climatic related variables include:

- Temperature (minimums and maximums)
- Extreme temperature and heat waves (defined as 3 or more consecutive days above 35°C)
- Rainfall (monthly and seasonal)
- Extreme rainfall and rainfall deficiencies (Dryness Index)
- Overland flooding
- Inundation

The following sections will explore each of these variables in more detail, primarily around the use of data and available sources that were leveraged in the process of the climate impact and vulnerability assessment.

5.2. Inundation Climate Change Events

The first pass Asset Vulnerability Assessment considered the following three inundation events:

- Sea Level Rise of 82cm
- Sea Level Rise of 82cm with 1% Annual Exceedance Probability (AEP) Storm Surge Event
- 1% Annual exceedance probability (AEP) rainfall event year based on historical data

An inundation profile was prepared for each individual council asset (buildings, roads, drainage and open space) for these three inundation events.

5.3. Projected Climate Change and Climate Change Related Events

The first pass asset vulnerability assessment included consideration of the following projected climate change variables that were derived from the most recent climate modelling prepared by CSIRO and made available as part of the Victorian Climate Projections 2019 Project (VCP2019):

- Number of annual hot days (defined as days with a maximum temperature greater than 35°C)
- Degree increase of annual extremely hot days (defined as change that occurs to the top 1% of events)
- Number of annual heat waves (defined as three or more consecutive days greater than 35°C)

- Percentage change of annual extremely wet days (defined as change to events that occurs to the top 1%)
- Number of months in a given year in which a dryness index measure falls below a threshold value (based on a Standard Precipitation Index approach)
- Percentage change in annual rainfall (from baseline).

The baseline climate data was the same as that used in the VCP2019 project which is the period 1981 to 2010.

The VCP2019 projections comprise downscaled, application-ready data derived from the most recent climate modelling prepared by CSIRO as an outcome of the IPCC 5th Assessment Report (AR5). In relation to the application of these climate variables, the two or three most critical projected climate variables likely to impact the vulnerability of an individual asset by type were considered.

An initial starting list on which projected climate change variables to apply to asset types on this basis are presented in Table 5. This list was reduced to the 2 or 3 most important variables on the basis of a review of the climate findings and available data.

Table 5. Initial thoughts of the two or more most critical projected climate variables likely to impact the vulnerability of individual assets by type

Projected climate change variables	Buildings	Drains	Road	Open Space
Number of annual hot days				●
Degree increase of annual extremely hot days	●		●	●
Number of annual heat waves	●			●
Percentage change of annual extremely wet days		●	●	
Number of months that dryness index falls below agreed threshold value	●	●	●	●
Percentage change in annual rainfall				●

Application of the latest climate change data from CSIRO involved evaluating relevant annual and monthly climate variable data for agreed carbon emissions scenarios. This information was 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 were used to inform trends in key variables such as rainfall and daily maximum temperatures.

Views of future heat wave events for the SECCCA region are presented in

Figure 7. This map view shows the significant variation in the frequency of heat wave events across the region anticipated in the year 2070, where orange represents the higher level of heat wave frequency. The graph view shows the change from a baseline period (on the left in grey) to 2050 (on the right in red).

The data on which these views are based are from the ACCESS 1.0 model, with an RCP 8.5 carbon emissions scenario future. These models and RCPs are discussed in the next session.

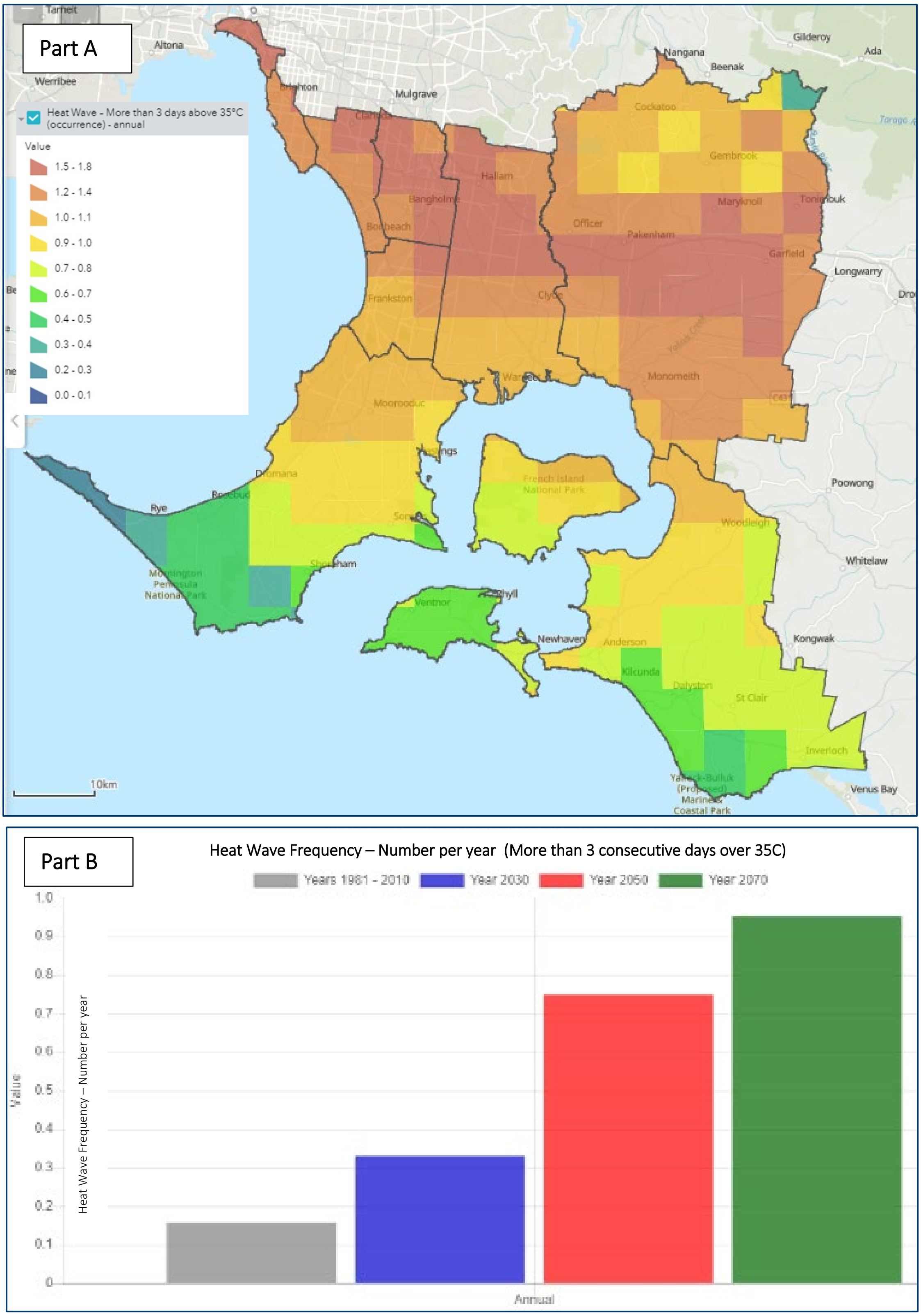


Figure 7. Views of future heat wave events (under ACCESS 1.0 GCM and RCP 8.5) for the SECCCA region (Part A map view is for 2070).

5.4. Climate Models and Climate Scenarios

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

a. Maximum consensus future climate (based on all six available VCP19 models (Clark et al 2019))
b. Hotter and drier future climate
c. Warmer and wetter future climate

This approach is also in line with climate change modelling advice provided directly by the Project Technical Reference Group that advised that futures represented by each GCM are equally possible and ideally 2 or 3 different GCMs should be considered in any vulnerability evaluation.

The three models selected to represent the range of likely futures for both temperature and rainfall projections include 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

5.5. Carbon Emission Futures

In terms of climate projections based on carbon emission future scenarios, while SECCCA expressed interest in the Representative Concentration Pathway (RCP) emissions scenarios of 4.5 and 8.5 (RCP 4.5 and RCP 8.5), the CMSI proposes use of a lower emissions scenario represented by RCP 2.6. The VCP2019 projections are only available for an RCP 4.5 and RCP 8.5 carbon emission future.

To assist compliance with the CMSI principles, CSIRO together with DELWP have provided guidance on how RCP 4.5 climate projection data can be downscaled and converted to model a RCP 2.6 future. The relationship between an RCP 4.5 and RCP 2.6 future is presented in Table 6 which has been formulated by Dr Michael Grose (Climate Projections Scientist, CSIRO). Michael has been assisting with the development of CMSI and has provided this advice to assist with the translation of an RCP 4.5 future to an RCP 2.6 scenario. This translation can be applied to each of the three climate models at each time frame for each respective climate variable.

Table 6. RCP4.5 to RCP2.6 conversion factor table.

Period centred on:	RCP2.6	RCP4.5
2030	+0.7 °C annual temp	+0.7 °C
	-3 % annual rainfall	-4%
2050	+0.8 °C	1.1 °C
	-4%	-4%
2090	+0.8 °C	+1.5 °C
	-5%	-5%

The first pass vulnerability assessment will present the findings for an RCP 4.5 future, and an RCP 8.5 future.

5.6. Time Frames

The VCP2019 projections are available for the years of 2030, 2050, 2070 and 2090.

This projection data is based on a baseline climate represented by the period from 1981 to 2010. It was proposed that while the project compiled and reviewed the projection data for all four future time periods, there would be a focus on presenting results and outputs for the period up until 2050. Inclusion of three models for two RCPs and four time points resulted in a significantly large volume of data and outputs.

It is noted that for the period to 2030 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 Figure 8 below) (IPCC 2007).

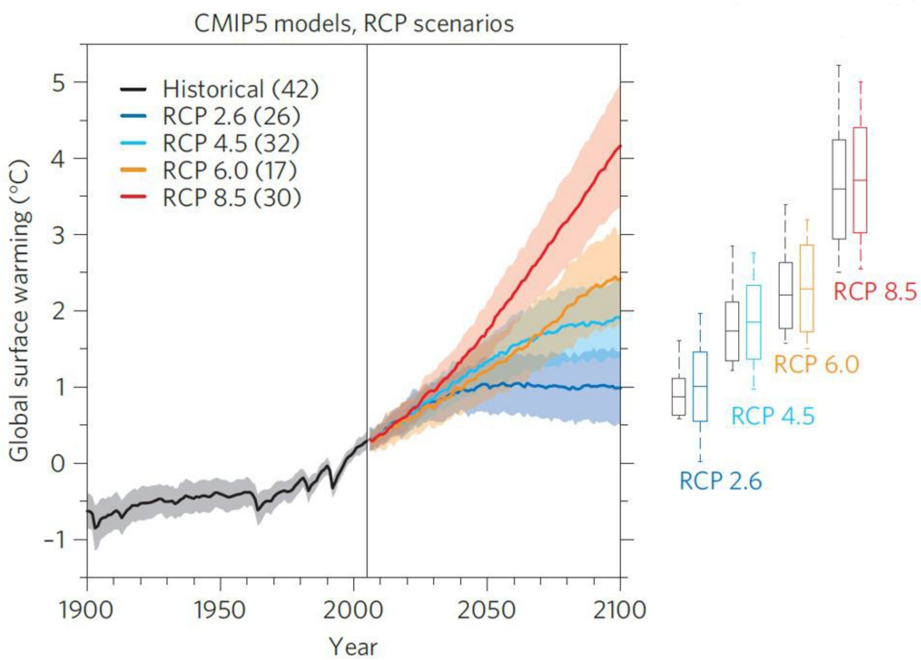


Figure 8. Relationship between four RCP scenarios, where RCPs provide standardised greenhouse gas concentration inputs for running climate models.

5.7. Other Climate Variables

Fire Risk

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

Fire risk and bushfire variables were thought to be something that could 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 is undertaking fire variable analysis for DELWP as part of the VCP19 program, it was understood that a single index will not provide an accurate indication of fire change and risk into the future.

Figure 9 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.

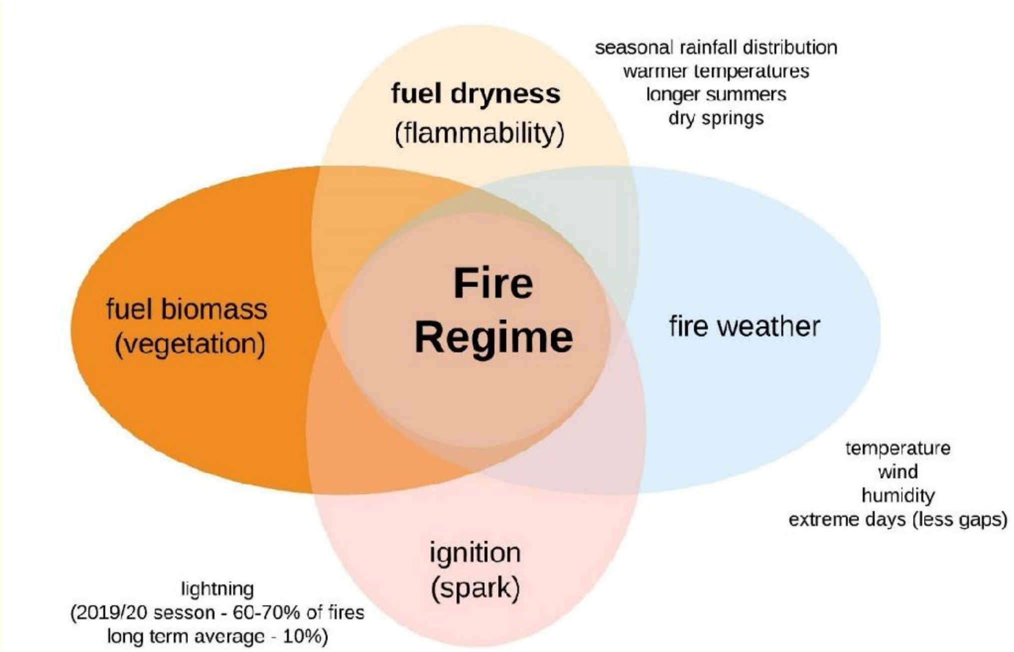


Figure 9. Relationship between climatic variables and landscape factors associated with increase fire risk

Figure source: (University of Melbourne 2020).

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 behind fuel dryness and fire weather.

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

Wind Speed

Current observed and future climate change data projections for wind factors is another variable that was explored by the project team for inclusion in the project. The VCP19 database includes wind speed as part of their suite of variables. However, it is at a coarser time scale of monthly periods and not available as daily data (as provided for other climatic variables).

Further, the available data only presents average projected wind speed over a given month, and not details on wind direction and wind gust speeds. Further to this, 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 was not used.

6. Climate Change Findings – General Observations

6.1. Climate Change

The sixth assessment report of the United Nations Intergovernmental Panel on Climate Change, the latest of its major assessments, released in early August 2021, has found the globe's ocean, lands and air temperatures are rising, and the human influence is "unequivocal". Its findings confirm that Australia as a whole, and regions such as those covered by SECCCA, will experience the changes outlined in this section.

Fire and heat

- Australia's land area has warmed by about 1.4°C in the 110 years since 1910.
- The year-to-year changes in temperatures are now above anything that could have been caused by natural variation.
- The report says land and ocean across the world was 1.09°C hotter between 2011 and 2020 than it was in preindustrial times, taken as the period between 1850 and 1900. All the warming was caused by human activities.
- There are now more incidents of extreme heat and less cold extremes, and the report says those trends for Australia will continue.
- Australia's fire season has lengthened since 1950 and the number of days with extreme fire danger has increased.
- "The intensity, frequency and duration of fire weather events are projected to increase throughout Australia (high confidence)," says the report.
- As global temperatures rise from 1.5°C to 2°C and beyond, heatwaves, droughts, floods and other impacts become more widespread.

Sea level rise

- With Australia's population heavily concentrated along the coast and in coastal cities, rising sea levels pose a major risk.
- "It is virtually certain that global mean sea level will continue to rise over the 21st century" the report says.
- Sea levels are forced upwards through thermal expansion because warmer ocean water holds more space, and also because ice attached to land – mainly at glaciers and ice sheets – is melting.
- Ice sheet loss has increased by a factor of four between 1992-1999 and 2010-2019 and ice melting from glaciers and ice sheets has overtaken thermal expansion as the main contributor.
- The most recent period from 2006 to 2018 saw global oceans rising at a rate of 3.7mm a year. In Australasia, sea levels rose faster than the global average in recent decades.

- There will be an increase in coastal flooding and the shore will retreat in the 21st century and beyond.
- Beaches have already started to retreat and if emissions remain very high, then sandy shorelines could retreat by 50 metres or more by the end of the century.
- Many sandy coastlines in Queensland, Northern Territory and the north of Western Australia could retreat by more than 200 metres in the absence of building barriers, the report says.
- Even under the most ambitious cuts to emissions, the world's oceans will probably rise between 28cm and 55cm from levels in the 20-year period of 1995 and 2014. But if emissions remain very high, seas will rise between 63cm and 1.01m.
- But the report also says increases of 2 metres "cannot be ruled out" because of the challenges in modelling how the massive ice sheets in Greenland and Antarctica will react to rising heat.
- Extra heat taken up by oceans is having profound affects around the globe. The changes in heat are "irreversible" on scales of a century or greater.

Floods and droughts

- The IPCC report is less confident about changes in rainfall and drought in Australia, but there is medium confidence that heavy rainfall and river floods will increase in the future.
- But in the south and east of the continent, rainfall has generally decreased and the instances of droughts affecting ecosystems and agriculture have risen.
- Across the east of the continent, the average rainfall in cool seasons will fall, but there is medium confidence that there will be more extreme downpours. Droughts are projected to increase at 2°C of warming.
- The most pronounced changes in rainfall have been seen in the south-west of Australia, where higher greenhouse gases have seen significant loss of rainfall which is very likely to continue, even if emissions are cut drastically.

6.2. Use of Climate model outcomes

The Victorian Climate Projections 2019 (VCP) initiative provides information about the state's future climate based on the best available climate science. This AVA project had drawn on the outputs from three of the six global circulation models (GCMs) that were dynamically downscaled to produced local-scale climate projections data for Victoria.

CSIRO and DELWP climate scientists have advised that each model represents a single possible future with no one model 'more likely' or 'better' than any other model. They also provided guidance on selecting a smaller range of models to assist with decision making. In providing this advice they also note that "given the deep uncertainty about the far future, projections should only be used as a guide when managing future risk, and it's important to remember that changes above or below the projected ranges could still occur in individual years".

In line with this advice, the AVA project has selected the following three models that represent the range of possible futures for both temperature and rainfall:

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

Carbon emission future scenarios in terms of Representative Concentration Pathway (RCP) emissions scenarios of 4.5 and 8.5 (RCP 4.5 and RCP 8.5), are also explored.

Views of the anticipated climate futures from these various models and different carbon emission scenarios for the SECCCA region are presented in the following section.

6.3. SECCCA Region changes

A summary of the anticipated climate changes for the SECCCA region, in terms of maximum temperatures, heatwaves and rainfall, is presented in this section. These climate change projections draw on CSIRO's latest findings, where the historical baseline, or the climate normal, is based on average climate observations for the period 1981 to 2010.

Climate change data used in this study was the 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 Victorian Climate Projections 2019 Project. This updated modelling includes downscaled datasets to a resolution of 5 km2 Victoria-wide.

While the CSIRO data includes the modelling results for 8 climate models, the results for the CSIRO and Bureau of Meteorology ACCESS 1.0 model are presented in this section based on advice from CSIRO that this is the Maximum Consensus model for southern Victoria. In several cases the results for the ACCESS 1.0 model are compared with the results for the HadGEM2-CC and NorESM1-M models

The climate change projections information presented is based on moderate and high carbon emission scenarios (RCP 4.5 and 8.5). A key reference year of 2050 is used in the presentation of the projections.

Annual Average Maximum Temperature

The general distribution of annual average maximum temperatures and maximum temperature varies across the SECCCA region, and increase generally from south to north and inland. Annual average maximum temperatures are anticipated to increase for the majority of the region from 1.1C to 1.5C and 2.1C to 2.5C, under an RCP4.5 and RCP8.5 future respectfully, by 2050.

Figure 10 presents the modelled changes in Annual Average Maximum Temperatures by the year 2050 using the ACCESS 1.0 maximum consensus model for both an RCP 4.5 (top panel) and RCP 8.5 (bottom panel) future.

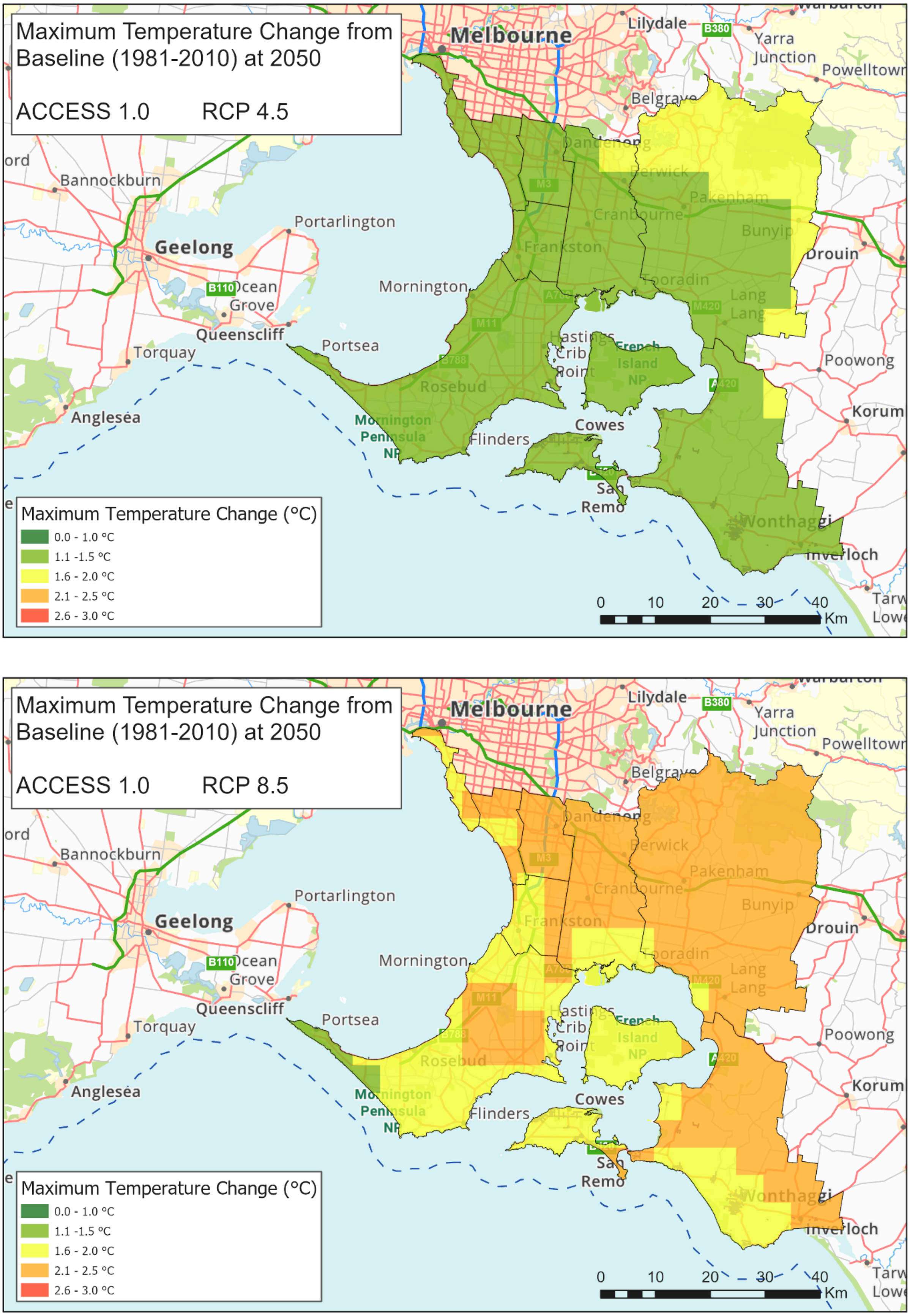
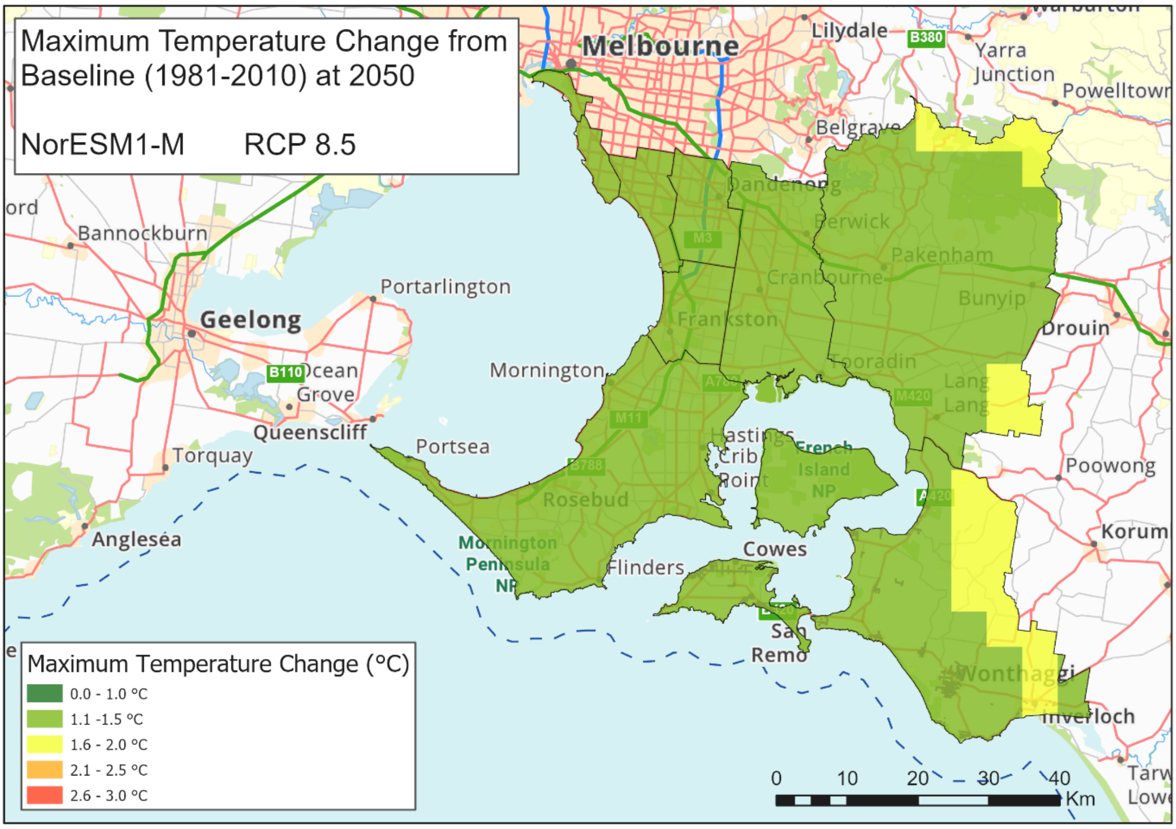


Figure 10. Modelled changes in Annual Average Maximum Temperatures by the year 2050 using the ACCESS 1.0 maximum consensus model for both an RCP 4.5 (top) and 8.5 future

These views show the general distribution of Annual Average Maximum temperatures and maximum temperature changes across the SECCCA region.

Figure 11 presents the modelled changes in Annual Average Maximum Temperatures by the year 2050 under an RCP 8.5 future using two other models HadGEM2-CC (hotter and drier) and NorESM1-M (warmer and wetter).



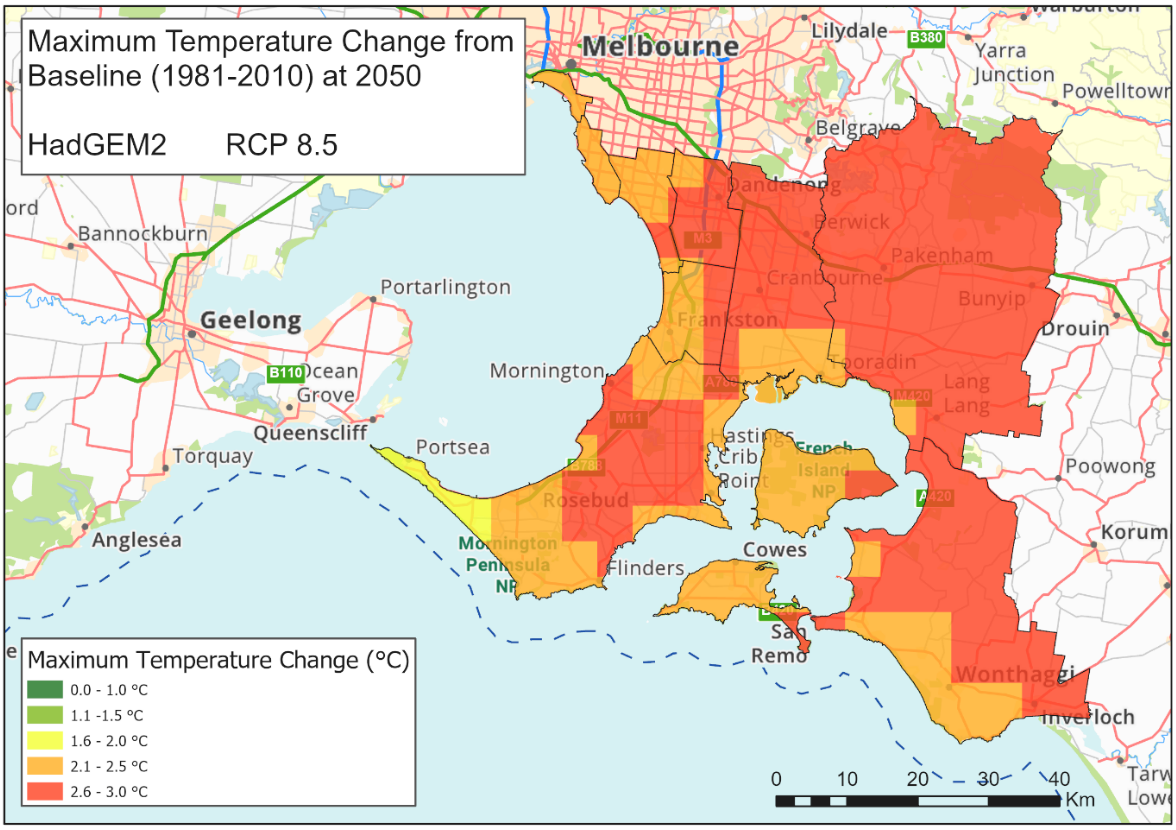


Figure 11. Modelled changes in Annual Average Maximum Temperatures by the year 2050 under an RCP 8.5 future using two other models.

Monthly and Annual Rainfall

Unlike much of Victoria, the SECCCA region is expected to vary little in its total annual rainfall over the forecast period, although it is expected to have longer dry spells interrupted by more intense rainfall events. Annual rainfall distribution across the SECCCA region increases generally from west to east and inland, particularly with elevation. It is anticipated that the majority of the region will experience a reduction in annual rainfall of up to 5% under an RCP4.5 future, and by 5 to 10% under RCP8.5 by 2050.

Significant variability in seasonal and monthly rainfall is anticipated into the future. Figure 12 presents the modelled variation in average monthly rainfall for the years 2030, 2050 and 2070 from a baseline period of 1981 to 2010 (shown in grey) using the ACCESS 1.0 maximum consensus model for an RCP 8.5 future. The anticipated average monthly rainfall in 2050 is indicated in a red line.

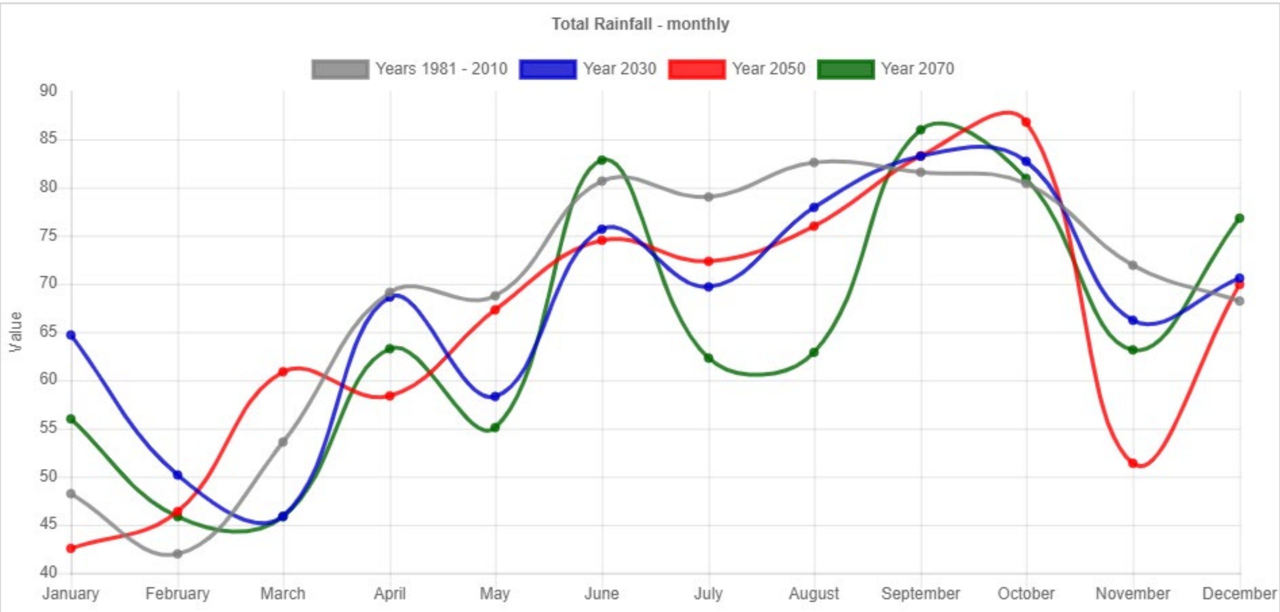
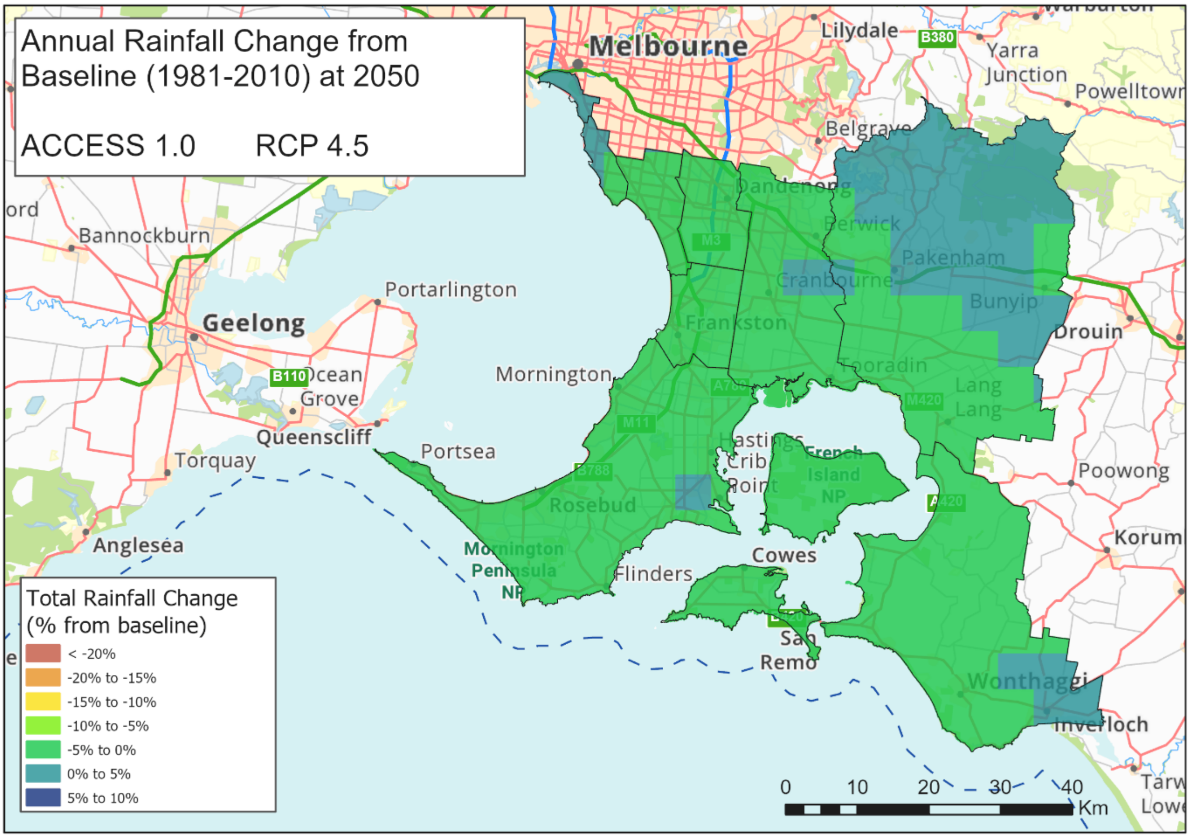


Figure 12. Modelled variation in average monthly rainfall for the years 2030, 2050 and 2070 from a baseline period of 1981 to 2010 (shown in grey) using the ACCESS 1.0 maximum consensus model for an RCP 8.5 future

Figure 13 presents the modelled changes in Annual Rainfall by the year 2050 using the ACCESS 1.0 maximum consensus model for both an RCP 4.5 (top panel) and RCP 8.5 (bottom panel) future.

These views show the general distribution of Annual Rainfall changes across the SECCCA region.

Figure 14 presents the modelled changes in Annual Rainfall by the year 2050 under an 8.5 future using two other models: HadGEM2-CC (hotter and drier) and NorESM1-M (warmer and wetter).



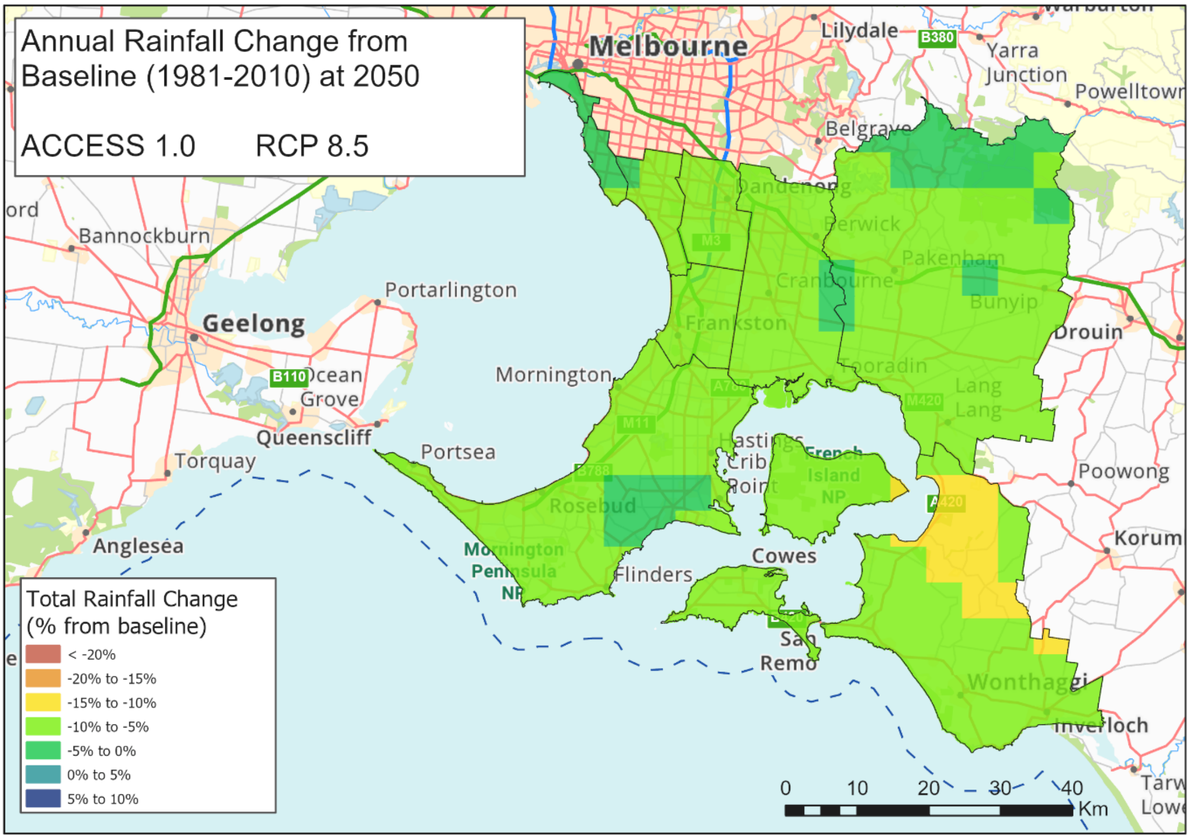


Figure 13. Modelled changes in Annual Rainfall by the year 2050 using the ACCESS 1.0 maximum consensus model for both an RCP 4.5 (top) and 8.5 future

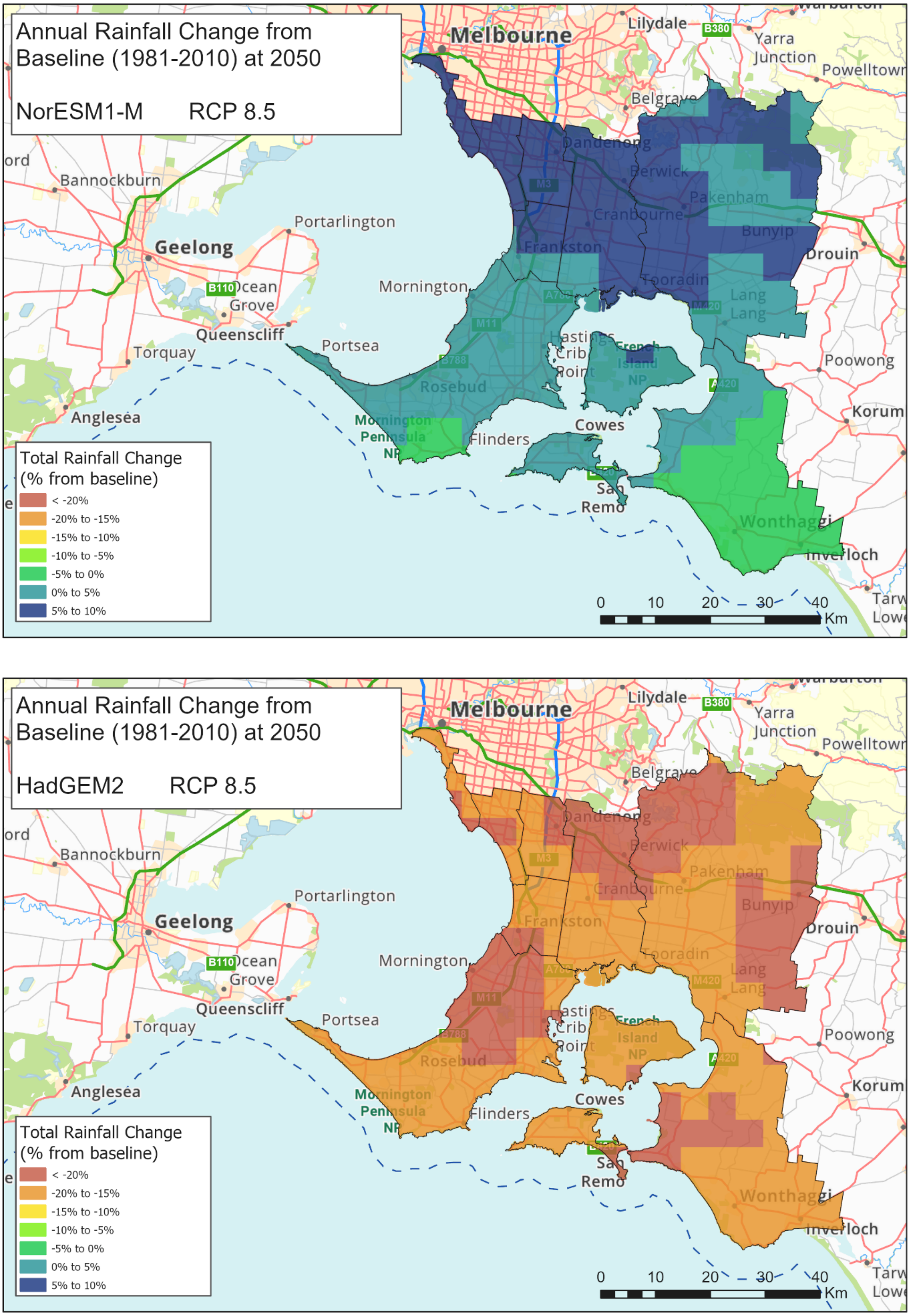


Figure 14. Modelled changes in Annual Rainfall by the year 2050 under an 8.5 future using two other models: HadGEM2-CC (hotter and drier) and NorESM1-M (warmer and wetter)

Heatwaves

In addition to increased temperatures, the occurrence of heatwaves is also expected to increase across the SECCCA region. The general distribution of heatwaves frequency across the SECCCA region is similar to that of maximum temperatures.

Figure 15 presents the modelled changes in the occurrence of Heatwaves by the year 2050 using the ACCESS 1.0 maximum consensus model for an RCP 8.5 future. Heatwaves are defined as 3 or more consecutive days with a Daily Maximum Temperature above 35°C.

Under an RCP4.5 future, heatwave frequency across the regions is anticipated to increase 2.4 fold by 2050 on average with smaller changes along the coast, and with the largest increases inland and focussed particularly on Casey and Cardinia. Under an RCP8.5 future, an average 3.9 fold increase across the region is anticipated by 2050.

Of greatest concern is that the last ten years (from 2010 to 2019) have already seen a 1.8 fold increase in heatwaves on the 1981 to 2010 baseline period used in the CSIRO climate projections.

Using the HadGEM2-CC model that represents a hotter and drier future, and under an RCP8.5 scenario, heatwave frequency across the region is anticipated to increase around eight fold by 2050. The figure below presents the anticipated changes by 2030, 2050, 2070 and 2090 under this model from the 1981 to 2010 baseline period.

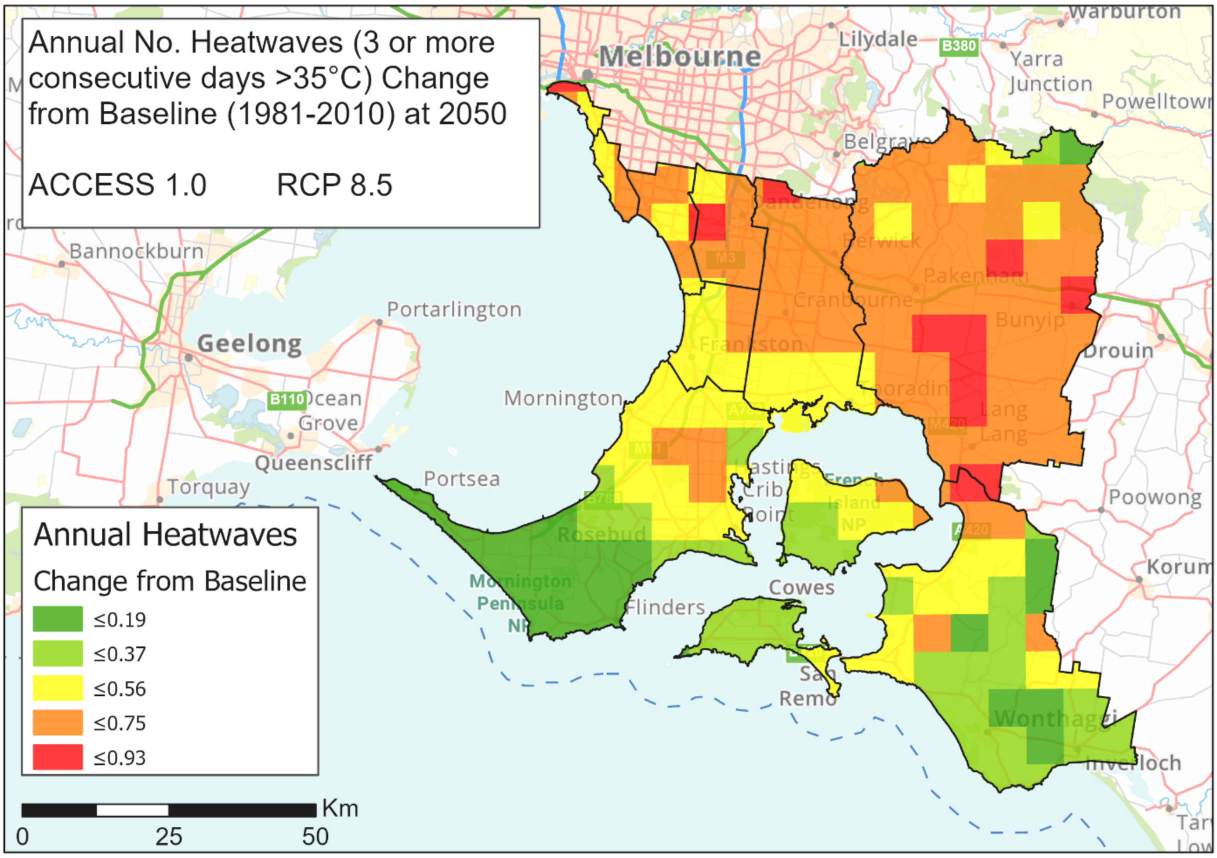


Figure 15. Modelled changes in Heatwaves by the year 2050 using the ACCESS 1.0 maximum consensus model for an RCP 8.5 future

Figure 16 presents the modelled variation in heatwave frequency for the years 2030, 2050 and 2070 from a baseline period of 1981 to 2010 (shown in grey) using the ACCESS 1.0 maximum consensus model for an RCP 8.5 future. The anticipated heatwave frequency in 2050 is indicated in red.

The historical trend in the occurrence of heatwaves across the SECCCA region is presented in Figure 17. The figure presents the average number of heatwaves per year for the last 5 decades (from the 1970s to the 2010s).

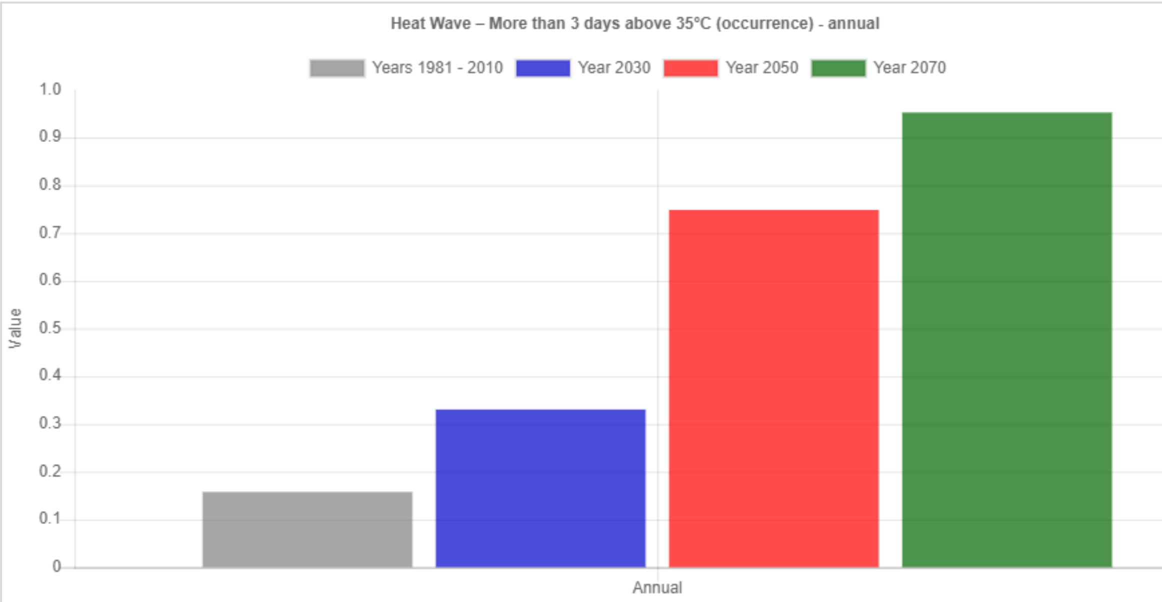


Figure 16. Modelled number of heatwaves for the years 2030, 2050 and 2070 from a baseline period of 1981 to 2010 (shown in grey) using the ACCESS 1.0 maximum consensus model for an RCP 8.5 future

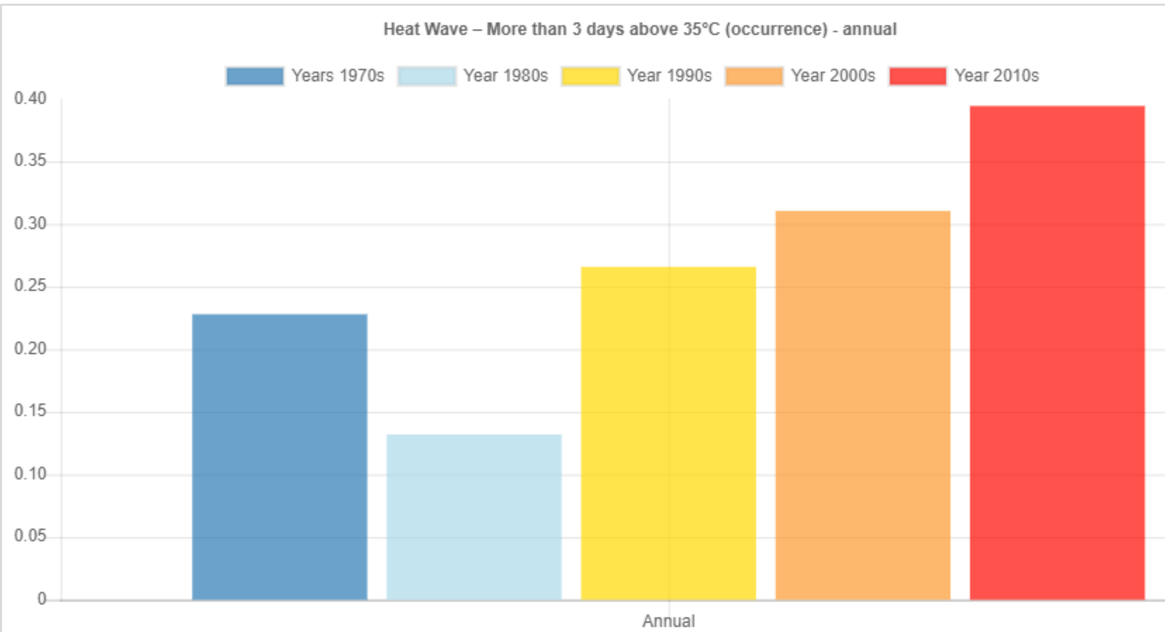


Figure 17. Historical trend in the average number of heatwaves per year for the last 5 decades (from the 1970s to the 2010s).

Inundation and Sea level rise

Areas in the SECCCA region subject to 1 in 100 year flood events, and impacted by an 82cm rise in sea levels (with a 1% AEP) are focused on low lying coastal areas and watercourses. Significant areas likely to experience increased overland flooding and the coastal inundation are located around Western Port and on the bayside sections of Kingston and Frankston.

Areas in the SECCCA region subject to 1 in 100 year flood events, and impacted by an 82cm rise in sea levels (with a 1% AEP) are presented in Figure 18.

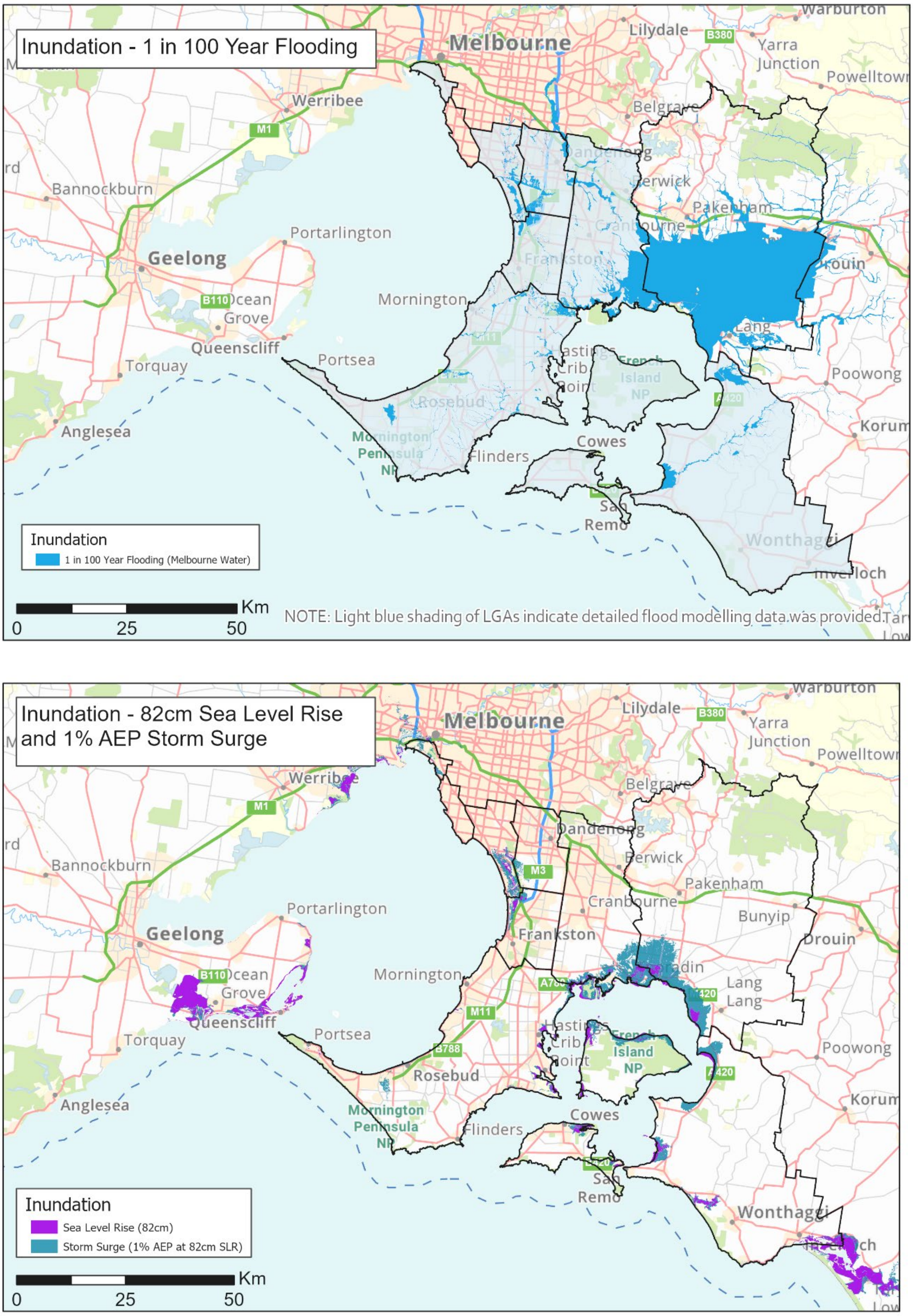


Figure 18. Areas subject to 1 in 100 year flood events (top), and impacted by an 82cm rise in sea levels (with a 1% AEP).

7. Asset Data Used

7.1. Asset Data

The inundation profile analysis and the asset vulnerability analysis required the provision of spatial and attribute data related to the key council asset types of concern:

- Buildings
- Roads
- Drainage (Pits & Pipes)
- *Open Spaces (additional asset type)*
- *Marine Assets (additional asset type)*

Table 7 below identifies the total number of records in each asset type for each member Council.

Table 7. Council asset data counts

Council	Asset Type				
	Buildings	Roads	Drainage Pits	Drainage Pipes	Open Space
Bass Coast	493	4 506	17 617	17 380	446
Bayside	432	2 108	17 446	20 349	501
Cardinia	318	7 116	31 445	33 108	626
Casey	1 380	6 582	93 463	91 132	2 937
Dandenong	545	3 684	40 141	3951	234
Frankston	332	3 834	45 074	39 924	708
Kingston	720	7 998	35 069	33 413	570
Mornington Peninsula	1 327	9 272	142 182	138 910	-
Port Phillip	224	5 991	136 98	13 760	494
TOTAL ASSETS	5771	51 091	436 135	391 927	6 516

7.2. LGA Asset Data Considerations

Asset spatial representation

The first pass vulnerability assessment process required a spatial delineation of all assets in either point, line, or polygon representation.

The sensitivity and adaptive capacity attributes were provided as attributes in the spatial datasets, or provided in tables that could be linked to assets based on asset ID values.

Asset data attributes

The attribute details provided for particular assets determined the level of detail of the sensitivity and adaptive capacity ratings. Assets with little attribute information were placed in a general category and were assessed based on more general rules with respect to their sensitivity to climate variables or their adaptive capacity factors.

More detailed sensitivity or adaptive capacity ratings were assigned where more detailed attribute information supports this based on known relationships.

This assessment approach does not replace the need for on-site evaluations to support operational response decisions.

Data cleaning

Processing of data for use in the assessment involved:

- Standardisation in format, projection, and structure as required.
- Identifying missing attributes or attribute values assigned as required.
- Removing duplicate datasets and features.
- Assigning a master version where there are multiple versions of the one dataset.
- Consolidating data based on agreed rules where multiple datasets for the one asset cover the one LGA.
- Undertaking an attribute type alignment process (where different types of classification are used).

This process involved ensuring the data was suitable for use in the first stage of the vulnerability assessment which was undertaken on ArcGIS.

Spatial data was standardised into one common spatial format and file type for use throughout the project.

See Appendix 5 for additional details on the data provided by individual LGAs.

8. Asset Vulnerability Assessment Findings

The vulnerability of an asset is highly dependent on the asset's age, construction materials, level of service and use. For the purpose of this project, these factors have been termed 'attributes' and have been used to identify the likely sensitivity or adaptive capacity of an asset to climate change.

Asset attributes used in the vulnerability assessment based on a review of the council attribute data obtained for building, drainage, road and open space assets are presented in Table 8. The table identifies the attributes that were considered in relation to the assignment of a sensitivity rating, and attributes that were viewed as a potential indicator of an asset's adaptive capacity (based on features that can be changed such as maintenance schedules for example).

Table 8. Attributes of potential value in vulnerability assessment based on a preliminary review of the SECCCA council asset attribute data

	Sensitivity				Adaptive Capacity			
Asset Attribute	Buildings	Drains	Road	Open Space	Buildings	Drains	Road	Open Space
Material	●	●	●	●				
Hierarchy	●		●	●	●			●
Level of service	●			●	●			●
Type	●	●		●	●			●
Condition					●		●	
Design life	●	●				●		
Useful age	●	●				●		
Install date	●	●				●		
Age	●	●				●		
Vehicles per day							●	
Depth		●						
Diameter		●						
<u>Context</u>								
Area				●				
Perimeter				●				
Population		●		●				
Proximity to water		●	●	●				
Proximity to roads				●				

Some of the asset attributes, depending on each council's usage, are interchangeable. For example, hierarchy, level of service and type can be the same attribute in one area, or mean completely different things in another council. How these attributes were used in relation to adaptive capacity or sensitivity was determined through a series of asset data collation meetings where the Spatial Vision team talked to each council group to help understand the context of their data and ensure that the data was used in an appropriate manner.

8.1. Assignment of Asset Vulnerability Ratings

The first pass asset vulnerability assessment involved applying a vulnerability assessment for two to three agreed projected climate change variables for each asset, as presented in Table 5 (in Section 5) and reporting on the outcome of each.

Hence, for each asset class (buildings, roads, and drainage), there can be up to three individual vulnerability assessments. These results may be combined on the basis of, either the rating, a weighted approach, or another approach to combining the results.

This first pass asset vulnerability assessment process was applied for the agreed projected climate change variables for each climate scenario, for each future time point. This resulted in each asset having three vulnerability scores, for three projected climate change scenarios, under two RCPs under four time points.

8.2. Relative Climate Changes Application

For each of the three climate projection scenarios, or possible carbon emission futures (RCPs), relative change from a baseline was determined rather than absolute values.

These changes were classified into categories of change ranging from '1 Very Low' to '5 Very High', which can then be used as the basis for identifying the likely exposure of assets to various levels of climate change. An example of this classification is shown in Table 9 as applied to temperature variables.

Table 9. Example of climate relative change classifications for temperature variables.

Change		Degree change from baseline - temperature	Day change from baseline – very hotdays (35C)	Day change from baseline – heat wave	Description
Very High	5	> 2.0°	> 4 days	> 0.8 days	Extreme Increase (i.e., Much Hotter)
High	4	1.5° – 2.0°	3 – 4 days	0.6 – 0.8 days	Major Increase (i.e., Hotter)
Moderate	3	1.0° – 1.5°	2 – 3 days	0.4 – 0.6 days	Moderate Increase (i.e., Warmer)
Low	2	0.5° – 1.0°	1 – 2 days	0.2 – 0.4 days	Small increase (i.e., Slightly Warmer)
Very Low	1	0.0° – 0.5°	0 – 1 days	0 – 0.2 days	Little to no change

This output was then fed into the exposure arm of the vulnerability framework.

8.3. Sensitivity and Adaptive Changes Application

Sensitivity

A key consideration for a given asset are its characteristics or assigned attributes that would indicate any given asset was more or less sensitive to a particular climate variable (such as heat waves or more hot days). The rating system assigned a score between 1 and 5. A score of '1' indicates assets with a particular characteristic that makes it less sensitive (more resilient) and '5' indicates assets with a particular characteristic that makes it more sensitive (or less resilient).

This sensitivity relates to particular characteristics or attributes of the asset that are essentially an intrinsic element of the asset that cannot be readily changed. For example, a tree may be a particular species or age that makes it more or less sensitive to heat.

Adaptive Capacity

Similar, Adaptive Capacity is a characteristic of a given asset (or asset type) that makes it more or less resilient to a particular climate variable (such as heat waves or more hot days). The rating system assigned a score of between 1 to 5. A score of '1' indicates assets with a particular characteristic that makes it have a higher adaptive capacity (more resilient) to the variable and '5' indicates assets with a particular characteristic that makes it have a low adaptive capacity (less resilient).

This adaptive capacity relates to particular characteristics or attributes of the asset that can be modified through adaptive features or mitigative actions. For example, a tree may be maintained, or have irrigation facilities put in that will make it more resilient to a given variable, such as heat.

Application to Attributes

For each assigned sensitivity or adaptive capacity attribute, values within data layers were classified using the 5 level classification systems described based on values within attributes on an LGA basis. An example of this process in relation to sensitivity attributes for buildings and roads is provided in Table 10. Ratings, attributes and values will differ between council areas, and hence scoring can change.

Table 10. Sensitivity classification examples for Roads and Buildings.

Attribute	Value	Score	Comment
Level of Service	Aquatic and Leisure	2	Level of Service (LoS) can define how often an asset is maintained or how robust/well built an asset is. Higher LoS, greater maintenance or greater design integrity as it is built for a higher level of purpose or life.
	Community	3	
	Corporate	2	
	Libraries and Arts	3	
	Public Toilets	4	
	Special Purpose	3	
	Sports and Recreation	2	
	Structures	4	
Level of Service – Road Hierarchy	Arterial	5	
	Citylink	5	
	Council Major	4	
	Council Minor	3	
	Freeway	5	
	Lease/Reserve	1	
	Parks Victoria	1	
	Port Roads	2	
	Private	1	
	Proposed Public	3	
Design Life	0 or None	3	Higher design life can indicate greater resilience to climate variables
	15	5	
	20	5	
	24	5	
	25	4	
	30	4	
	40	3	
	50	2	
	100	1	

Application of scores to any attribute group was considered in isolation to other attributes and only in relation to the exposures in questions. Links between attributes was not considered. Once all layers are processed, there is an overlaying process which assumes all input layers are equal. To this end, there should be consideration of the number of inputs into the overlaying processing.

If there are too many layers, there can be an over-saturation of inputs. What may happen is that all scores will even out into a neutral score. As such, it was recommended to only have up to three attributes per type (sensitivity or adaptive capacity) to capture the critical attributes to the particular asset grouping.

8.4. Asset Attribute and Climate Assignment Quality Assurance

The process for assigning a sensitivity and adaptive capacity rating to assets involved a review of available asset attributes and an evaluation of their suitability for use in the assessment.

The project team applied the rating values for adaptive capacity and sensitivity in relation to climatic variables based on asset data attributes.

For climatic variable ratings, the first step in the process was to assess the range of values for each climate variable and the change relative to a baseline (i.e. changes in the average rainfall). This was used, together with the insights obtained from previous studies, to assign a score range appropriate for each climate variable and asset type across the SECCCA project area.

How these relative changes in a climate variable relate to assets and the rating assigned for sensitivity and adaptive capacity also drew on the insights obtained from previous studies. The project team have gained a good understanding of what principles to apply and the scores to assign in this process. This has been tested with relevant field experts, asset managers in previous studies and literature reviews and research undertaken in prior projects (Fussel and Klein (2006), Spatial Vision (2013), Spatial Vision (2021), Spatial Vision (2020)).

This process drew significantly on work undertaken in collaboration with Professor Roger Jones from Victoria University (Professorial Research Fellow, Institute for Sustainable Industries & Liveable Cities). His knowledge on urban ecology and climate risk assessment has been invaluable in framing an understanding how urban environs and assets respond to projected changes in the climate. The first pass vulnerability assessment process involved a review and subsequent refinement stage following an initial application of the assessment process. This review and validation stage was critical for quality assurance purposes.

Asset sensitivity and adaptive capacity ratings assigned on the basis of asset attributes was discussed and reviewed with relevant asset managers in SECCCA member councils prior to their application, to ensure local knowledge is captured in the process.

8.5. Climate Impact and Vulnerability Application

The vulnerability assessment process described resulted in a significant number of vulnerability ratings for individual assets.

A key component of the process was the asset impact assessment rating for each climate variable assessed based on an assigned sensitivity of an asset to the anticipated change.

Adaptive capacity assigned at the asset level was then used in combination with the assessed impact to determine a final vulnerability assessment rating.

The results of this process for three climate models was then used to assign climate model-based vulnerability ratings for an asset.

This process will be repeated for each combination of the four future time points under consideration (2030, 2050, 2070, and 2090), and for each RCP scenario (RCP 4.5 and RCP 8.5).

Hence, each asset had a vulnerability assigned based on multiple climate change variables, for three global climate models, four time points, and two carbon emission futures.

8.6. Process in Applying Asset Vulnerability Assessment

In terms of a process to apply the Asset Vulnerability Assessment (AVA) Part 1 outcomes, it was suggested that the maximum consensus climate model outcomes (which for the SECCCA region is ACCESS 1.0) can be used as a starting point, and that the outcomes under a hotter and dryer, and warmer and wetter future (based on the other climate models – HadGEM2-CC and NorESM1-M respectively) be explored in relation to this maximum consensus climate model future.

It is proposed that the vulnerability results for the year 2050 and an RCP8.5 emissions future should be used as the starting point to review vulnerability assessment outcomes.

9. Stage 1 Outputs and Mentoring Sessions

9.1. Project Output overview

Mentoring sessions with each council were conducted to ensure each council understood what the outputs comprised and how they could incorporate them into their processes and decision making.

The outputs and how they can be applied is outlined in this section.

1. The key deliverables of Part 1 of the AVA project were:
   - SECCCA region-wide gridded Climate Data for:
   - the baseline of 1981-2010
   - Future Projection data for three GCMs (ACCESS 1.0, HadGEM2-CC, NorESM1-M), two RCPs (4.5 and 8.5) and four timeframes (2030, 2050, 2070 & 2090)
   - Historical observed climate data
2. Vulnerability Analysis Outputs
   - Vulnerability for each asset of each asset type (buildings, roads and drainage), for the three climate variables (extreme temperature, extreme rainfall and Standard Precipitation Index), for all climate models/RCPs/timeframes
3. Inundation Profile Outputs
   - Identification and statistics around absolute area/length impacted and percentage of total area/length impacted for individual assets impacted by three inundation scenarios (82cm sea level rise, storm surge on 82cm sea level rise and 1 in 100 year overland flooding)

In delivering the Asset Vulnerability Project, the Spatial Vision team packaged the data outputs from the first pass assessment process into a spatial data viewer. The viewer used is QGIS.

The data outputs are aimed at assisting asset managers better understand the likely climate change under various climate futures, and the likely impacts.

The data is packaged in two separate viewers:

- one that displays climate information prepared by the CSIRO (and sponsored by the Victorian Department of Environment, Land, Water, and Planning under the Victorian Climate Futures Project (VCF19)); This viewer also includes historical climate observation data. This is referred to as the Climate Viewer.
- second that presents the inputs and outputs from the first pass asset vulnerability assessment (AVA) for building, roads and drains. This second viewer includes both the inundation profile for assets under various inundations scenarios, in addition to the full vulnerability assessment for assets based on three different climate models and futures, two carbon emission scenarios, and four different time points. This is referred to as the AVA Council Viewer.

Figure 19 provides a schematic representation of the data handover structure for Part 1 of the AVA

Project, as provided to each council. The diagram also indicates the input data to the two viewers described above.

The following page provides an explanation of the different folders and their contents.

Handover Structure Folders

Source Data and Supporting Data

The Source Data and Supporting Data folder contains the un-analysed data provided to Spatial Vision by the Council.

Inundation Profile Analysed Derived Data

This folder contains the outputs of the inundation profile analysis. The *Asset Inundation Profiles* contain the feature classes that identify the assets impacted by the three inundation scenarios:

‘_FLD’ = 1 in 100 year flooding event

‘_SLR’ = 82 cm Sea Level Rise

‘_STM; = Storm Surge on 82 cm Sea Level Rise

The *Locality Summary Statistics* geodatabase contain geodatabase tables that identify the number of assets (per asset type) in each locality within the LGA impacted by the three inundation scenarios.

AVA Derived Data

This folder contains the outputs of the vulnerability assessment. The *AVA Outputs* geodatabase contains feature classes that identify the vulnerability of the assets (per asset type) to the climate variables. The below table identifies the climate variables for which vulnerability was determined for each asset type.

Table 11. Climate variables for each asset type

Asset Type	Climate Variables
Buildings	Extreme Rainfall, Extreme Temperature, Standard Precipitation Index (SPI)
Roads	Extreme Rainfall, Extreme Temperature, Standard Precipitation Index (SPI)
Drainage (Pits and Pipes)	Extreme Rainfall, Standard Precipitation Index (SPI)

The *Locality Summary Statistics* geodatabase contains geodatabase tables that present the ‘average asset vulnerability’ score for a particularly climate model, RCP future, and time fame (e.g. ACCESS 1.0 RCP 8.5 2050 climate future) (%) for all assets that intersect locality.

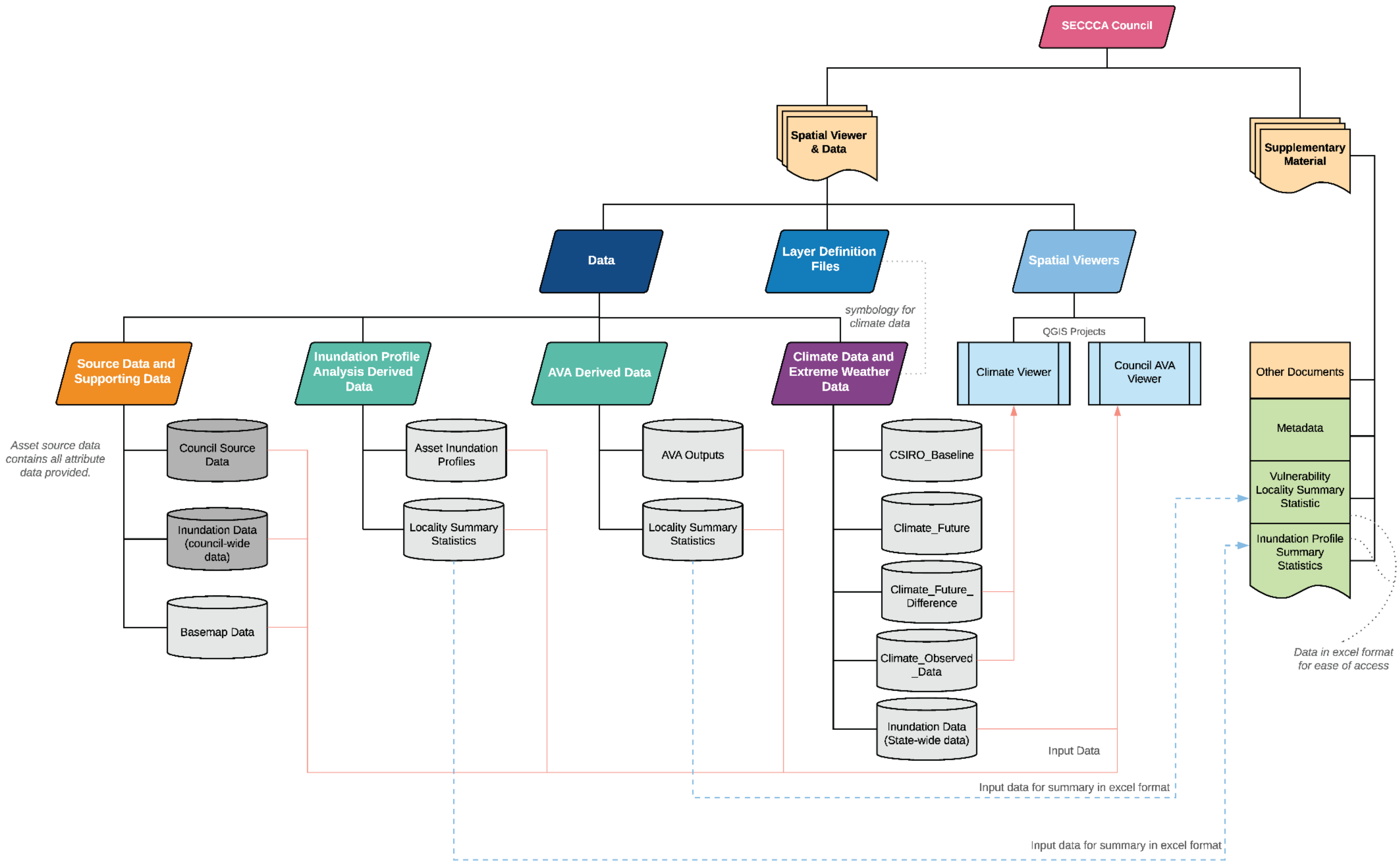


Figure 19. Schematic representation of data handover structure for Part 1 of the AVA Project

Climate and Extreme Weather Data

This folder contains all climate and extreme weather-related data for the project. The Sub-folders include:

1. CSIRO Baseline Data – 5 km gridded climate data that the projections are based on. The baseline period is from 1981 to 2010.
2. Climate Future Data - 5 km gridded climate projection data (absolute values) for the climate variables. This data is not presented in the QGIS Climate Viewer, but is provided as part of the data package.
3. Climate Future Difference Data - 5 km gridded climate projection data, showing the change in values from the baseline for the climate variables.
4. Historic Climate Data – this contains the 5 km gridded observed climate data (source: SILO) for the same variables mentioned above. These datasets contain observed historical climate data for the decades: 1970, 1980, 1990, 2000, 2010.
5. Inundation Data (state-wide) – this folder contains data of the different inundation scenarios (Flooding Scenarios; storm surge at the different sea level rise increments) from various state-wide sources.

Layer Definition Files

The Layer Definition Files folder contains Layer files that can be brought directly into a QGIS environment, that refers to the data within the *Climate Data and Extreme Weather Data* folder, and has all symbology set.

Spatial Viewers

This folder contains the QGIS Projects that relate to:

1. The Council AVA viewer, with symbolised layers
2. Climate projected and observed polygrids, with symbolise layers

The purpose of these projects with pre-symbolised layers is to allow the user easy viewing and exploration of the data outputs to assist decision making.

Reference Videos

Reference Videos on AVA Outputs and QGIS which has been used to present the results are as follows:

Intro to QGIS:

"This video is a brief overview and introduction to the council-specific QGIS viewer that presents the inundation profile and vulnerability analysis outputs.

This video was produced as part of the SECCCA Asset Vulnerability Assessment Project in May 2021."

See: Intro to QGIS: https://youtu.be/NKZ0Z073cuk

Climate Viewer:

"This video presents an exploration of the QGIS climate data viewer (baseline, projected and historic climate data) for the SECCCA region, including how to compare views of different climate future models and timeframes.

This video was produced as part of the SECCCA Asset Vulnerability Assessment Project in May 2021."

See: Climate Viewer: https://youtu.be/IxF9--U7iNk

***Note: the reference videos may show the QGIS viewer with slight variances to the final viewer.*

9.2. Vulnerability Assessment Outputs

This section provides an overview and example of the vulnerability outputs generated for each council.

Each council were provided with:

1. Vulnerability ratings for each analysed asset in a spatial format (feature classes).
    - *Findings:*
      Enabled council to identify individual assets of concern with high vulnerabilities to the three climate variables. 24 vulnerability scores were generated for each asset to reflect the different possible future climates (incorporating the 3 climate models, the two carbon emission scenarios and the four timeframes).
    - *Example of findings:*
      Table 12 below presents an example of the vulnerability scores generated for a building asset in Inverloch, as well as the exposure, sensitivity and adaptive capacity scorings incorporated within vulnerability analysis.

The way in which users were given guidance as to how to use the breadth of information is outlined in the Worked Example User Guide document, which is included as a separate appendix (Appendix 6).

Table 12. Vulnerability scores of Building Asset

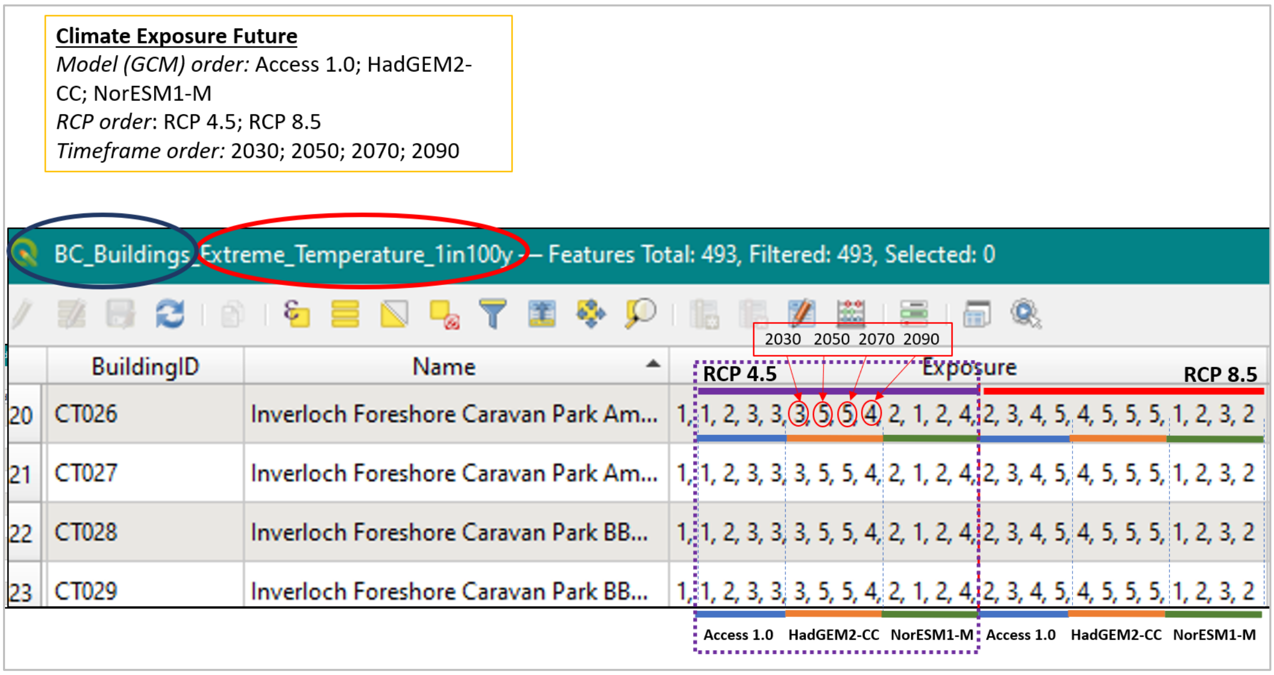
Name	Inverloch Foreshore Angling Club Rooms
Exposure*	1, 2, 3, 3, 3, 5, 5, 4, 2, 1, 2, 4, 2, 3, 4, 5, 4, 5, 5, 5, 1, 2, 3, 2
Sensitivity	Field: Superstructure_Type. Row: Timber. Value: 5
Adaptive Capacity	Field: Roof_cond. Row: 5. Value: 3

Name	Inverloch Foreshore Angling Club Rooms		
	Extreme Temperature Vulnerability	Extreme Rainfall Vulnerability	Standard Precipitation Index Vulnerability
ACCESS 1.0 RCP 4.5 2030	12	24	12
ACCESS 1.0 RCP 4.5 2050	24	60	24
ACCESS 1.0 RCP 4.5 2070	36	48	36
ACCESS 1.0 RCP 4.5 2090	36	60	12
HadGEM2-CC RCP 4.5 2030	36	12	24
HadGEM2-CC RCP 4.5 2050	60	12	36
HadGEM2-CC RCP 4.5 2070	60	24	24
HadGEM2-CC RCP 4.5 2090	48	48	12
NorESM1-M RCP 4.5 2030	24	36	36
NorESM1-M RCP 4.5 2050	12	36	36
NorESM1-M RCP 4.5 2070	24	24	12
NorESM1-M RCP 4.5 2090	48	24	24
ACCESS 1.0 RCP 8.5 2030	24	36	36
ACCESS 1.0 RCP 8.5 2050	36	24	36
ACCESS 1.0 RCP 8.5 2070	48	48	12
ACCESS 1.0 RCP 8.5 2090	60	36	24
HadGEM2-CC RCP 8.5 2030	48	24	24
HadGEM2-CC RCP 8.5 2050	60	24	36
HadGEM2-CC RCP 8.5 2070	60	12	36
HadGEM2-CC RCP 8.5 2090	60	36	24
NorESM1-M RCP 8.5 2030	12	24	60
NorESM1-M RCP 8.5 2050	24	12	36
NorESM1-M RCP 8.5 2070	36	36	36
NorESM1-M RCP 8.5 2090	24	36	36

Note:

Each asset has a vulnerability rating (between 1 and 100) assigned based on multiple climate change variables, for three global climate models, four time points, and two carbon emission futures.

* In relation to Exposure, the values assigned to an individual asset are as follows:



2. Average vulnerabilities of all assets (of an asset type) within each locality across their LGA (for all future scenarios), provided in spatial format (feature classes) as well as tabular format (dynamic pivot table in excel).
    - *Findings:*
      Enables councils to identify the locality of concern where the average vulnerability of assets is high, or higher than for other localities.
    - *Example of Findings:*
      Each council was provided a dynamic pivot table in excel format that presented the average vulnerability score of all asset of an asset type (Buildings/Roads/Drainage Pits/Drainage Pipes) within each locality of an LGA, for a given time frame and RCP scenario. The asset vulnerability scores were given for each of the three climate future models.

   Table 13 below presents an example of these outputs in a static tabular view of the average building vulnerability within Bass Coast LGAs, for a carbon emission scenario of RCP 4.5 and a 2050 timeframe.

   The way in which users were given guidance as to how to use the breadth of information is outlined in the Worked Example User Guide document, which is included as an appendix (see Appendix 7).

Table 13. Locality summaries for vulnerability of buildings within Bass Coast (as an example)

		Extreme Rainfall			Extreme Temperature			Standard Precipitation Index		
Locality	**No. of assets**	**ACCESS 1.0**	**HadGEM2-CC**	**NorESM1-M**	**ACCESS 1.0**	**HadGEM2-CC**	**NorESM1-M**	**ACCESS 1.0**	**HadGEM2-CC**	**NorESM1-M**
ANDERSON	2	7	5	5	5	8	3	7	7	7
ARCHIES CREEK	1	0	0	0	0	0	0	0	0	0
BASS	17	30	20	20	26	43	17	40	40	30
CAPE PATERSON	20	14	14	14	9	17	9	21	21	27
CAPE WOOLAMAI	3	13	13	13	14	24	10	27	27	20
CORINELLA	16	15	15	16	17	28	11	40	38	32
CORONET BAY	5	17	17	17	23	30	15	42	42	34

The rows in this table present an example of how an 'average asset vulnerability' score for a particular climate model, RCP future, and timeframe (eg.ACCESS 1.0 RCP8.5 2050 climate future), represented as a value between 1 and 100, can be assigned on the basis of all assets within a locality. It shows that the highest vulnerability rating for buildings is for Bass based on Extreme Temperature under a hotter and drier future (as defined by the HadGEM2-CC model).

9.3. Inundation Profile Outputs

Each council were provided with:

1. Inundation Profiles for each asset to identify the impact of the three inundation scenarios. Statistics such as the absolute area/length impacted and the percentage of the total asset impacted were included. Outputs were provided in spatial format (feature classes).
    - *Findings:*
      Enables the identification and extent of key assets at risk of being impacted by sea level rise, storm surge and overland flood events.

   Findings Example:
   Figure 20 and Table 14 exemplify the inundation profile outputs, by presenting the inundation of the Inverloch Foreshore Bowling Club Rooms by a 1 in 100 year overland flood event. The example below highlights that 29% of the Club Rooms by area will be inundated in the event of a 1 in 100 year overland flood.

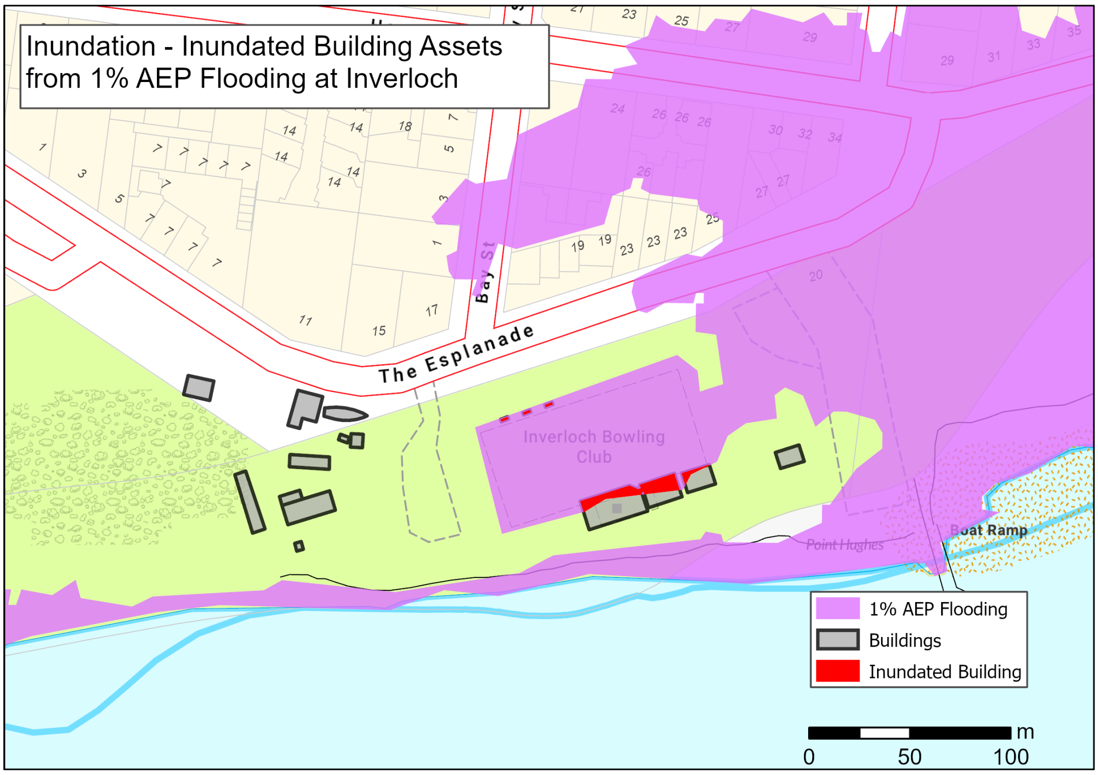


Figure 20. Example of Inundation Profile spatial outputs – presenting the buildings impacted by a 1 in 100 year inundation event in Inverloch.

Table 14. Example of the derived metrics associated with an impacted asset

Asset Name	Total Area (m2)	Inundated Area (m2)	Percentage Inundated (%)
Inverloch Foreshore Bowling Club Rooms	$273m^2$	$80m^2$	29%

2. <u>Summary statistics</u> for the number of impacted assets for a given asset type and inundation scenario per locality within the LGA. Outputs were provided in geodatabase tables and summarised in excel tables.
    - *Findings:*
      Enables the identification of localities within an LGA that have higher numbers of impacted assets.

    Findings Example:
    Table 15 identifies the number of impacted assets per locality, and the total area/length impacted if applicable, within Bass Coast Shire Council for a 1 in 100 year overland flood event. From the table it can be seen that the localities of Wonthaggi and Cowes have the highest number of impacted buildings for this type of inundation event. Only seven localities are presented for illustrative purposes.

Table 15. Summary statistics of inundation impacted assets per locality within Bass Coast Shire Council (example)

Locality Name	BUILDINGS		ROADS		PIPES		PITS	OPEN SPACES	
	No. Impacted Buildings	Total Area Impacted (m2)	No. Impacted Roads	Total Area Impacted (m2)	No. Impacted Pipes	Total Length Impacted (m)	No. Impacted Pits	No. Impacted Open Spaces	Total Area Impacted (m2)
ADAMS ESTATE	0	0.00	0	0.00	0	0.00	0	0	0.00
ALMURTA	0	0.00	8	537.43	0	0.00	0	0	0.00
ANDERSON	0	0.00	0	0.00	0	0.00	0	0	0.00
ARCHIES CREEK	0	0.00	0	0.00	0	0.00	0	0	0.00
BASS	10	201.03	32	20930.09	34	457.12	6	6	6753.12
CAPE PATERSON	0	0.00	0	0.00	1	70.23	0	3	65.34
CAPE WOOLAMAI	1	79.03	170	37773.46	813	7460.27	397	9	34.82

10. Concluding Comments

This report presents the outputs and findings obtained through Part 1 of the Asset Vulnerability Assessment Project.

The data package outputs and supporting tools, alongside the mentoring undertaken in the use of these outputs, assisted in building the capacity of participants to use the climate data and Asset Vulnerability Assessment outputs developed within their internal processes and assist with decision making. Outputs can also be incorporated within councils' own spatial and decision making systems.

Additional details on the methodology by which vulnerability rating were assigned are available in the separate project methods paper for the Stage 1 vulnerability assessment.

Possible next steps and ways in which it is envisaged councils may apply the outputs of this project include:

- Identify areas most likely at risk to climate change parameters such as sea level rise, overland flooding, excessive heat (using the locality based findings). Risk areas can be identified based on the number of assets or amount (in terms or area or length) of individual assets impacted.

- Identifying the individual assets most at risk from climate change, and the parameters or most concern.

- Identifying the areas and assets most at risk in short and long term timeframes, and under which climate scenarios – hotter/drier or wetter /warmer futures, in addition to carbon emission scenarios.

.

References

Allen Consulting (2005). *Climate Change Risk and Vulnerability. Report to the Australian Greenhouse Office,* Department of the Environment and Heritage, Canberra, Commonwealth of Australia, 159 pp.

Brunckhorst, J. (2011). *Hunter and central coasts New South Wales.* Australian Government Dept of Climate change and energy efficiency: Department of Climate Change and Energy Efficiency, Australia.

Capon, S., L. Chambers, R.C. Mac Nally, R. J. Naiman, P. Davies, N. Marshall, J. Pittock, M. Reid, T. Capon, M. Douglas, J. Catford, D.S. Baldwin, M. Stewardson, J. Roberts, M. Parsons, S.E. Williams (2013). *Riparian ecosystems in the 21st century: hotspots for climate change adaptation?* School of Biological Sciences. Ecosystems 16, 359-381.

Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C & Wilson L. (2019). *Victorian Climate Projections 2019 Technical Report.* CSIRO, Melbourne Australia.

Fussel, H.M., & Klein, R.J.T. (2006). Climate change vulnerability assessments: an evolution of conceptual thinking. Climatic Change, 75, 301-329.

IPCC. (2001) Climate Change 2001: Impacts, Adaptation, and Vulnerability - Technical Summary. A Report of Working Group II of the Intergovernmental Panel on Climate Change. Review Editors: M. Manning (New Zealand) and C. Nobre (Brazil), IPCC 2001

IPCC. (2007) Climate Change 2007 – Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Cambridge University Press 2007.

Local Government Association of South Australia. (2012). *Guidelines for Developing a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment; November 2012; Local Government Association of South Australia*.

Spatial Vision. (2013, 2021). *Case Study: NRM Planning for Climate Change* | Spatial Vision. Retrieved 23 April 2021, from https://spatialvision.com.au/case-study-nrm-planning-for-climate-change/

Spatial Vision. (2018). *Case Study: Coastal Climate Change Impact Assessment* | Spatial Vision. Retrieved 23 April 2021, from https://spatialvision.com.au/case-study-coastal-climate-change-impact-assessment/

Spatial Vision. (2020). Final Project Report – First Pass Asset Vulnerability Assessment. City of Melbourne. Report submitted July 2020. (unpublished)

University of Melbourne. (2020). *Bushfires: Our past, present and possible futures*. Presentation, https://events.unimelb.edu.au/science/event/6825-bushfires-our-past-present-and-possible-futures.

Victorian Climate Projections. (2019). (see: Clarke JM, Grose M, Thatcher M, Hernaman V, Heady C, Round V, Rafter T, Trenham C & Wilson L. 2019. Victorian Climate Projections 2019 Technical Report. CSIRO, Melbourne Australia).

Additional references of Interest

Balston, J., S. Li, I. Iankov, J. Kellett, and G. Wells, (2017) *Quantifying the financial impact of climate change on Australian local government roads.* Infrastructures, 2, 2.

Gerl, T., H. Kreibich, G. Franco, D. Marechal, and K. Schröter, (2016) *A review of flood loss models as basis for harmonization and benchmarking.* PloS one, 11, e0159791.

McEvoy, D., I. Ahmed, and J. Mullett, (2012) The impact of the 2009 heat wave on Melbourne's critical infrastructure. Local Environment, 17, 783-796.

Nafari, R. H., T. Ngo, and W. Lehman, (2016) *Development and evaluation of FLFAcs–A new Flood Loss Function for Australian commercial structures.* International Journal of Disaster Risk Reduction, 17, 13-23.

Wang, X., M. G. Stewart, and M. Nguyen, (2012) *Impact of climate change on corrosion and damage to concrete infrastructure in Australia.* Climatic Change, 110, 941-957.

Appendices

Appendix 1: Acronyms

AEP	Annual Exceedance Probability
AR5	(IPCC) 5th Assessment Report
BOM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CMIP5	Coupled Model Inter-comparison Project, Phase 5
CSMI	Climate Measurement Standards Initiative
DELWP	Department of Environment, Land Water and Planning
GIS	Geographic Information System
GCM	Global Climate Model
ICA	Insurance Council of Australia
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Area
RCP	Relative concentration pathways for carbon emissions
SECCCA	South East Council Climate Change Alliance
SILO	Scientific Information for Land Owner
SLR	Sea Level Rise
SPI	Standardised Precipitation Index
STM	Storm Surge
SV	Spatial Vision
VCP19	Victorian Climate Projections 2019 (See: Clarke et al 2019)

Appendix 2: Glossary

The following definitions below were used through this project and may have been alreadyoutlined in the preceding text. These draw significantly on the IPCC (2007) definitions.

Acute: Climate change events that refer to climate exposures or variables that have a short time frame and sharp response. Can relate more so to extremes in climate or flooding/storm events, the extreme 1% Annual Exceedance Probability (AEP) events or 1 in 100-year events.

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic variables or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation

Anticipatory adaptation – Adaptation that takes place before impacts of climate change are observed. Also referred to as proactive adaptation.
Autonomous adaptation – Adaptation that does not constitute a conscious response to climatic variables but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.
Planned adaptation – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Adaptive Capacity: is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with theconsequences. The adaptive capacity of a system or society describes its ability to modify its characteristics or behaviour so as to cope better with changes in external conditions. The more adaptive a system, the less vulnerable it is. It is also defined as the property of a system to adjust its characteristics or behaviour in order to expand its coping range under existing climate variability or future climate conditions. For the purposes of this project, adaptive capacity has been considered in terms of the ability of the asset to adjust to climate variables based on its current state

Attributes: Refers to parameters or features of an asset that are described in the form of database fields. These range for the materials from which the asset is built, to the maintenance schedule for an asset.

Chronic: Climate change events that refer to climate exposures or variables that are a long-term variable with a slow response. Mainly relates to climate change over time, for example, temperature increases over time.

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 on the natural or built environment to particular hazards, including extremeevents such as storms and other climate events. It relates to the exposure of an asset to a particular hazard and the sensitivity of that asset to that exposure.

Mitigation: An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.

Risk: is the potential of losing or gaining something of value based on particular actions or inactions.A risk assessment, or analysis, is the process in which these potential risks are evaluated, and the projected consequences are defined based on this action or inaction.

Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.

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 arehighly responsive to climate and can be significantly affected by small climate changes. This term is often used interchangeably with the term susceptibility.

Spatial view: An online or hardcopy map view of spatial data

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effectsof climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Appendix 3: Stage 2 - Case Study Selection Criteria

Selection Criteria and Definitions used in AVA Case Study evaluation

Criteria		Rating (H/M/L/U)
1. Priority		
2. Available data		
3. Available staff to assist		
4. Adaptation options		(Y/N)

1. Priority

Rating	Description
High	High threat to life; high probability; large asset damage costs in past; high community service impact.
Moderate	Significant threat to life; moderate probability; significant asset damage costs in past; moderate community service impact.
Low	No significant threat to life; moderate probability; modest asset damage costs in past; low community service impact.
Unknown	Difficult to assess

2. Available Data

Rating	Description
High	*Overland Flooding events (including coastal storm surge events)* Recent overland flood modelling study looking at differing return events supported with detailed spatial data on business as usual and one or more options to reduce flooding and impact extent. Asset values and ability (with LGA support) to cost likely adaptation options. *Coastal Inundation and Erosion events (including coastal storm surge events)* Recent local coastal inundation and erosion modelling study looking at differing return events supported with detailed spatial data on business as usual and one or more options to reduce inundation extent.

	Asset values and ability (with LGA support) to cost likely adaptation options. *Bushfire event* Recent study supported with detailed spatial data on business as usual and one or more options to reduce bushfire risk. Asset values and ability (with LGA support) to cost likely adaptation options. *Heat wave or daily high temperature events* Recent study supported with detailed spatial data on business as usual and one or more options to reduce impacts of heat wave or high temperature risk. Asset values and ability (with LGA support) to cost likely adaptation options.
Moderate	No recent study, as identified above, but an equivalent or comparable study for a similar region that can be used.
Low	No recent study, as identified above, nor equivalent or comparable study for a similar region that can be used. But staff that can provide advice on the practical components of a scenario in terms of areas impacted and costs associated with adaptation options.
Unknown	Difficult to assess

3. **Available staff to assist case study process**

Rating	Description
High	Have staff with deep knowledge of issue and possible adaptation options – high availability when required via email and online meetings.
Moderate	Have staff with good knowledge of issue and possible adaptation options – moderate availability when required via email and online meetings.
Low	Have staff with adequate knowledge of issue and possible adaptation options – low availability when required via email and online meetings.
Unknown	Difficult to assess

4. **Adaptation Options**
   Are adaptation options available for the case study impact, and are they council's responsibility (in part)?

Appendix 4: Application of Vulnerability Assessment Framework

Vulnerability Assessment Approach – Worked example for Open Space

This appendix presents a worked example for indicative vulnerability results for are area of open space. The results illustrate the detailed information assigned in the asset vulnerability assessment process to each asset depicted in the relevant spatial dataset.

Map views of the results for a section of a representative area of Melbourne are presented in Figure 21 to Figure 23. The views show the vulnerability rating assigned to individual open space for three scenarios comprising the 2030 2050 and 2070 results for the RCP 8.5. The views show how open space transition from lower to higher vulnerability ratings over time.

Green indicates a low vulnerability rating; yellow a moderate rating; and red a high rating.The factors determining the vulnerability rating of each open space include:

Exposure:

- High maximum temperatures
- Extreme heat days
- Heat waves
- Reduced rainfall
- Extreme rain events
- High wind

Sensitivity:

- Use or type of park
- Level of service
- Size (overall area)
- Size (variable to area metric)

Adaptive Capacity:

- Risk
- Proximity to water bodies
- Context to surrounding buildings (proximity)
- Context to roads (proximity to busier roads)
- Canopy and shrub bed layer coverage (% coverage)

The views show that the largest change appears to occur between 2030 and 2050.

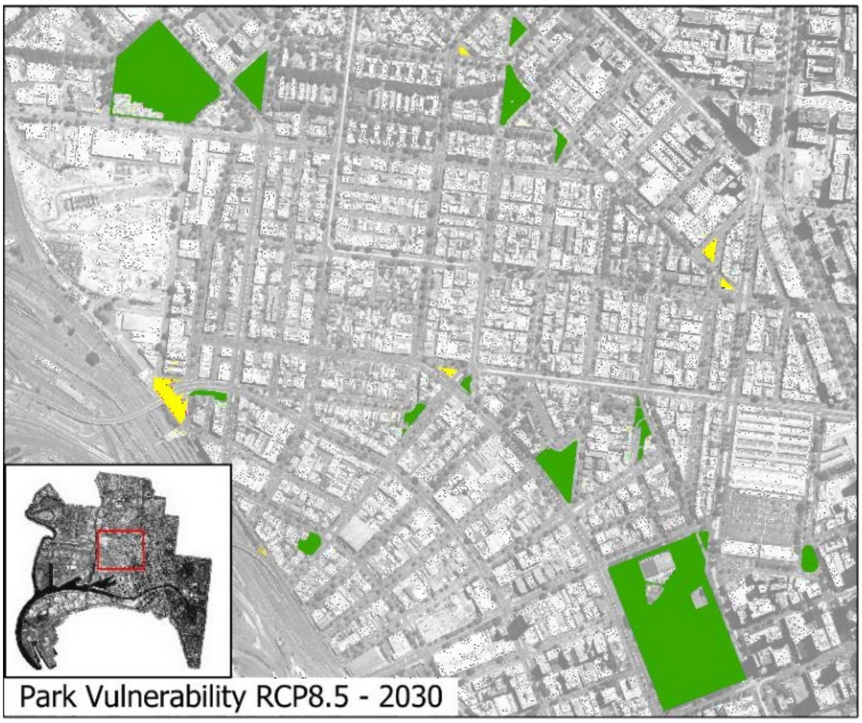


Figure 21. Open Space - Vulnerability ratings (2030 – RCP8.5) where green is low, red is high.

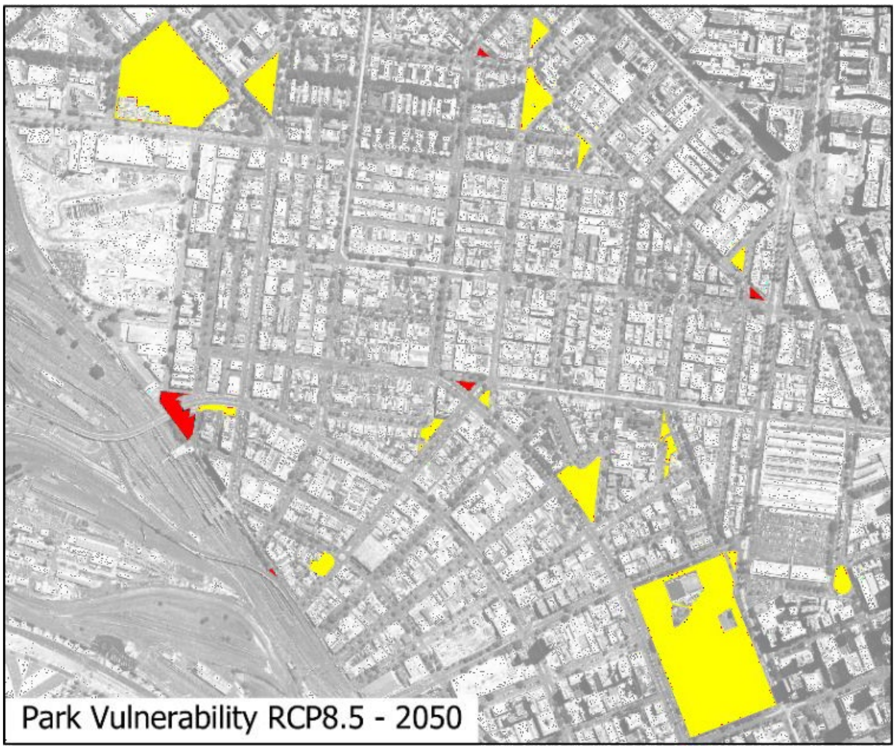


Figure 22. Open Space - Vulnerability ratings (2050 – RCP8.5) where green is low, red is high.

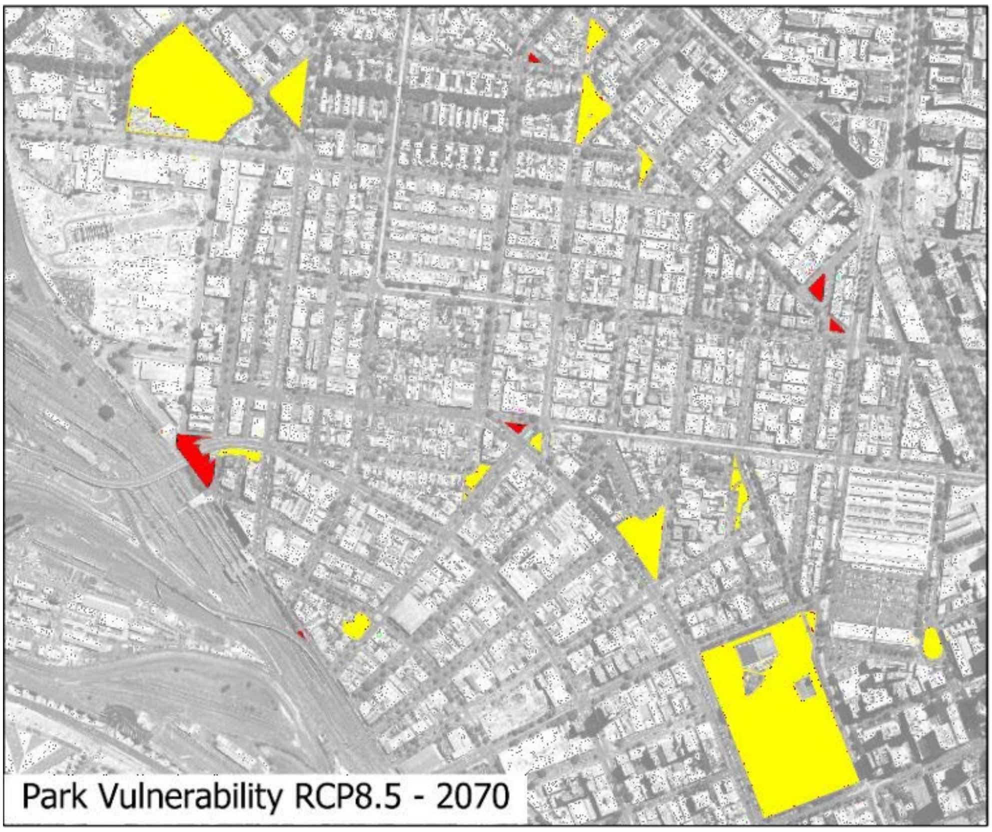


Figure 23. Open Space - Vulnerability ratings (2070 – RCP8.5) where green is low, red is high

Figure 24 shows how two open space areas that appear similar in size can score very differently based on their individual characteristics.

In the example presented, the open space area on the left and identified in red, is assessed to have a poorer level of service (since it is classified as a streetscape park) and less tree canopy than the open space area on the left (Asset ID 1747748) that is identified in yellow.

A summary of the open space area characteristics, as reflected in open space area dataset attributes, is presented in Table 16. This table identifies how:

- The driving factors for the difference in vulnerability rating for the two open space assets are:
    - The park category (which is reflects the level of service (LOS), where '5' indicates apoor service and high sensitivity, and '2' indicates a high level of service and lower sensitivity)
        - streetscape parks are less maintained than landscape parks (hence the LOS ratingof 5 for the latter)
        - percentage cover of canopy and shrub beds (where the higher the value the lower the adaptive capacity). This is visually identifiable in the above maps, whereHawke & King Street reserve (Asset ID 1747748) contains large trees.
- Proximity to water bodies and proximity to busy roads (additional adaptive

capacity ratingswhere the higher the value the lower the adaptive capacity) cancel each other out.

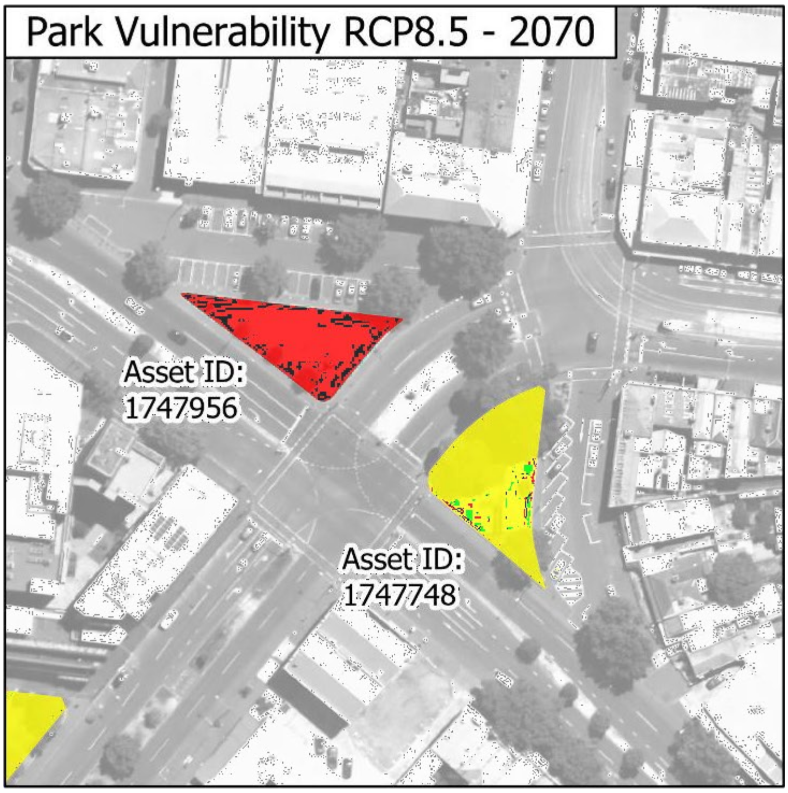


Figure 24. Open Space vulnerability example showing two open space area results (yellow is moderate, red is high).

Table 16. Factors affecting difference in vulnerability rating for two Open Space assets

	Asset ID	1747748	1747956
Asset Information	Property name	Hawke & King StreetReserve	King & Victoria StreetReserve
	Park category	Landscape Park	Streetscape
	Area of park	576.1	482.5
Exposure (combined)	**Exposure (RCP8.5 2070)**	**4.17**	**4.17**
Sensitivity	Sensitivity type	2	2
	Level of service	2	5
	Size (area)	5	5
	Size (perimeter to area)	3	3
	Overall Sensitivity	**3**	**3.75**
Impact	Impact (RCP8.5 2070)	**12.5**	**15.6**
Adaptive Capacity	Risk	1	1
	Proximity to water bodies	4	3
	Context to surrounding buildings (proximity)	4	4
	Context to roads (proximity tobusier roads)	3	4
	Canopy and shrub bed layercoverage (% cover)	3	5
	Overall Adaptive Capacity	**3**	**3.4**
Vulnerability	**Overall Vulnerability**	**37.5**	**53.125**

Note: Red - highlights values that are significantly different; yellow – identifies minor differences; blue - highlightsvalues that are the same.

For sensitivity ratings the higher the value the greater the sensitivity.

For adaptive capacity ratings the higher the value the lower the adaptive capacity.

Appendix 5: LGA asset data collation and processing

(Final version of LGA asset data collation and processing document).

Appendix 6: AVA Part 1 Outputs and their Application Mentoring Notes

(Final version of LGA mentoring notes document).

Asset Data Collection Process

Document Overview

This document provides an overview of the asset data collection process for Part 1 of the Asset Vulnerability Analysis. Key sections within this document include:

- Requested Data
- Data Cleaning
- Observed Data Gaps
- Key Communication with Council

Requested Data

Data associated with three key asset types and two additional asset types were requested from each participating Council:

- Buildings
- Roads
- Drainage (Pits & Pipes)
- *Open Spaces (additional asset type)*
- *Marine Assets (additional asset type)*

Any data relating to extreme weather (e.g. inundation extents, bushfire history, etc.) were also requested from Councils.

Table 1 below identifies the total number of records in each asset type for each Council.

TABLE 1. COUNCIL ASSET COUNTS

Council	Asset Type				
	Buildings	Roads	Drainage Pits	Drainage Pipes	Open Space
Bass Coast	493	4 506	17 617	17 380	446
Bayside	432	2 108	17 446	20 349	501
Cardinia	318	7 116	31 445	33 108	626
Casey	1 380	6 582	93 463	91 132	2 937
Dandenong	545	3 684	40 141	3951	234
Frankston	332	3 834	45 074	39 924	708
Kingston	720	7 998	35 069	33 413	570
Mornington Peninsula	1 327	9 272	142 182	138 910	-
Port Phillip	224	5 991	136 98	13 760	494
TOTAL ASSETS	**5771**	**51 091**	**436 135**	**391 927**	**6 516**

Asset Attribute Data

Attribute data refers to the type of information associated with each individual asset record in an asset type. For example, the construction date of each building recorded in the building's asset dataset.

Attribute data may be integrated within the asset GIS layers, or alternatively can be held in excel spreadsheets, reports or documents. Key to this analysis was ensuring that provided attribute data had a unique identifying code for each record that could be joined via GIS to the corresponding asset GIS layer. Without this unique identification code (i.e. asset id), attribute data cannot be reliably joined to the spatial representation of that asset.

Attribute data that was requested to Councils related to the potential *Sensitivity* or intrinsic *Adaptive Capacity* of that asset to climate change. Spatial Vision requested specific attributes, however also indicated to Councils to provide any additional attributes available that may relate to sensitivity or adaptive capacity.

Table 2 below identifies the types of requested attribute information for each asset type.

TABLE 2. REQUESTED ASSET ATTRIBUTES

Buildings	Roads	Drainage Pits	Drainage Pipes	Open Spaces
Material	Material	Material	Material	
Hierarchy	Hierarchy			Hierarchy
Level of Service	Level of Service			Level of Service
Type	Type	Type	Type	Type
Condition	Condition	Condition	Condition	
Design Life/Useful Age/Install Date/Age	Design Life/Useful Age/Install Date/Age	Design Life/Useful Age/Install Date/Age	Design Life/Useful Age/Install Date/Age	
	Vehicles per Day			
		Diameter	Diameter	
			Depth	

Data Cleaning

Data was provided to Spatial Vision in multiple formats:

- Shapefiles
- Tab files
- Feature classes
- Excel documents

For the inundation profiles and vulnerability assessment analysis, the data was required to be standardised into feature classes with all attribute data attached to the GIS representation (polygon, line, or point).

As such, tab files and feature classes were transformed into feature classes.

For data in excel format to be joined to a GIS layer, the tables needed to be 'cleaned' by the removal of spaces and symbol characters, and the shortening of field name lengths.

For consistency and alignment to extreme weather/climate change data, all datasets used within the analysis for each council were also projected into the VICRID 1994 projection. Data outputs are provided back to Councils in this coordinate system.

Data Gaps in Provided Data

Identified gaps in the provided asset data are identified below.

- Not all councils have the required attribute data
  - In some circumstances, contextual or GIS-determined information can be used in its place (e.g. population as an Adaptive Capacity measure for Drainage assets)
  - In cases where specific attribute data is not available and contextual or GIS-determined information is not possible to use in its place, a vulnerability assessment is not possible.
- Empty or Null fields in attribute data
  - Although some GIS layers may have the appropriate attribute fields, the records may have null values or empty fields (see Figure below).
  - These redundant fields can appear in databases as: <NULL>; < >; <-1>; <999>; <0>; <Unknown>, etc.

Pipe_Lengt	pipetype	material	INSTDATE	PIPEDIAM
0				300
0				0
0			17-Feb-98	825
0			10-Feb-03	825
0				600
0			23-Feb-12	225
0				0
0				1050
0				1725

  - In the example screenshot above, some fields such as *Pipe_Lengt* can be populated through GIS, while others such as *material* and *pipetype*, are unknown and therefore cannot be populated.
  - Those records that have empty/null attributes and are also critical for the analysis, and that cannot be substituted for another populated attribute field, will not have a vulnerability rating associated with them.
  - Details on each asset attribute null/blank values for each asset type are recorded in the metadata.

Communication with Councils - Data Collection

Efficient communication with each council was key to obtaining the necessary data required for the Vulnerability Assessment.

Communication was primarily in the form of email and online zoom meetings. Phone calls for queries and informal discussions were also encouraged.

Rhiannan Mundana (Spatial Vision) was the primary contact for data provision and queries.

Table 3 below lists the Project Working Group (Assets Representative) members who were the main point of contact for data collection throughout the process, and the AVA Sustainable Representative members who were across all communication.

TABLE 3. COUNCIL CONTACTS FOR SECCCA PROJECT

Council Name	Project Working Group Member (Assets representative)	AVA Sustainability Representative
City of Casey	Jack Fang	Simon King
Morn Penn	Amir Noorbakhsh/Aaron Hunter	Chris Yorke
Cardinia	Craig McLennan	Aruna Dias
Kingston City Council	Brian Trower	Helen Scott
Bass Coast	Simon Harris	Benita Russell
Dandenong	Russell Tait	Darren Wilson
Port Phillip	John Tran	Renae Walton
Bayside	Eugene Stackpole	Julian Donlen
Frankston	Gayani Jayawardena	Rachel Weaver

Dates of Key Communication

The list below and table after (Table 4) identifies, details and dates the key communication conducted with each council in relation to data collection, noting that there were many intermediate communications between each key communication listed.

1. **Email Introduction and Request for Online Meeting:** This email was sent by Rhiannan Mundana to all council Working Group Members for an initial email introduction to the project and Spatial Vision's role in the SECCCA AVA Project. It also identified the data Spatial Vision was requesting, and suggested a follow-up zoom call for a deeper explanation of this data request.
2. **Data Requirements Meeting:** This first online zoom meeting was organised with the asset management (Project Working Group Members) and their teams to further clarify the information and data Spatial Vision requested in the email sent to each project working group member (and Sustainability reps CC'd) on 27/10/2020, named *'AVA Project – Introductions and Initial contact regarding provision of spatial and other data.'* These meetings were highly encouraged and were followed up with by SV, and the majority of councils attended these meetings.
3. **Data Supply:** Following the Data Requirements Meeting (Key Communication #2), data was provided by Councils to SV. Data was generally provided incrementally.

4. **Data Follow up Questions Email Reply:** After the initial provision of data, SV went through it all and sent an email back to each council with specific questions with requests of further data to be provided if required. The dates noted below are the dates that SV received answers to the follow up questions (whether this be only via email, or via a follow-up zoom meeting where these questions were discussed and answered).

TABLE 4. DATES OF KEY DATA COLLECTION COMMUNICATION

Key Communication for Data Provision	Casey	Mornington Peninsula	Cardinia	Kingston	Bass Coast	Dandenong	Port Phillip	Bayside	Frankston
1.Email Introduction and Request for Online Meeting	27/10/2020	27/10/2020	27/10/2020	27/10/2020	27/10/2020	27/10/2020	27/10/2020	27/10/2020	27/10/2020
2. Data Requirements Meeting	29/10/2020	6/11/2020	29/10/2020	-	05/11/2020	04/11/2020	06/11/2020	06/11/2020	06/11/2020
3. Data Supply	9/11/2020; 01/12/2020; 02/12/2020	09/11/2020; 11/11/2020; 09/12/2020; 15/12/2020; 15/12/2020	06/11/2020; 25/11/2020	27/11/2020; 16/12/2020; 18/12/2020; 22/12/2020; 23/12/2020	23/11/2020; 10/12/2020; 10/12/2020	13/11/2020; 16/11/2020; 26/11/2020; 27/11/2020; 30/11/2020; 07/12/2020; 16/03/2021	26/11/2020; 04/12/2020; 23/12/2020; 11/01/2021; 27/01/2021	13/11/2020; 25/11/2020; 13/12/2020	11/11/2020; 10/12/2020
4. Data Follow up Questions Email Reply	01/12/2020	27/11/2020	25/11/2020	18/12/2020	09/12/2020	27/11/2020	22/01/2020	03/12/2020	01/12/2020

APPENDIX 6

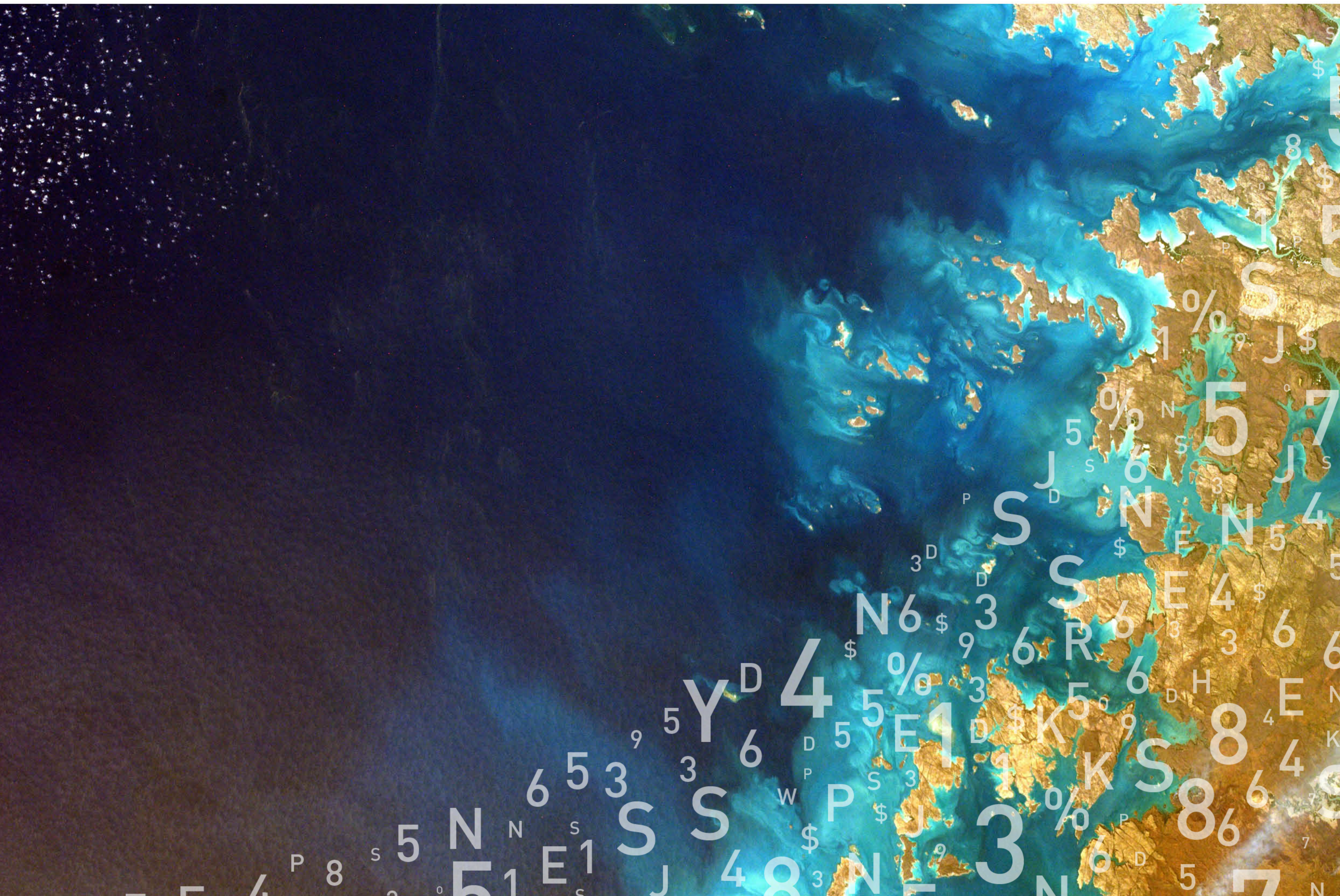
Spatial Vision
Geospatial Intelligent Solutions

Asset Vulnerability Assessment Worked Example User Guide

South East Councils Climate Change Alliance (SECCCA)

5/07/2021

Project Number	SV005891



About This Document

Project Number	SV005891
Project Name	SECCCA Asset Vulnerability Assessment – Worked Example User Guide
File Name	Worked_Examples_V1.0_0.072021docx
Project Client	SECCCA
Date of Issue	05/07/2021
Version Number	1.0
Document Title	Asset Vulnerability Assessment Worked Example User Guide
SV Contact	Rhiannan Mundana
Email	Rhiannan.Mundana@spatialvision.com.au

Disclaimer

Spatial Vision Innovations Pty Ltd

Level 8, 575 Bourke St, Melbourne 3000 VIC

p (03) 9691 3000
e info@spatialvision.com.au
w www.spatialvision.com.au
ABN 28 092 695 951

Table of Contents

1. Purpose of Document

This worked example user guide has been provided to Council to assist in viewing data within a QGIS environment as part of the SECCCA AVA project.

Section 2 of this user guide provides a schematic representation of the Data Handover structure, with simple explanations for the various folders and the data they contain.

Section 3 provides background notes on the AVA outputs, including links to QGIS video recordings of the Climate Viewer, and definitions of key climate terms used throughout the project.

Section 4 outlines the structure and basic use of the QGIS Climate Viewer.

Section 5 provides step-by-step instructions for four worked examples on key user questions that the QGIS viewers can answer.

Note that Section 5 uses the Bass Coast AVA Viewer as the example (screenshots, etc.). However, the instructions presented in this User Manual are transferrable across all councils and any other QGIS project.

For further information regarding QGIS application, please refer to the provided QGIS training material (training notes, training data and recording), or access additional information here: https://qgis.org/en/docs/index.html.

2. Data Handover File Structure

Figure 1 presents a schematic representation of the data handover file structure. Each of the folders are described in Section 2.1.

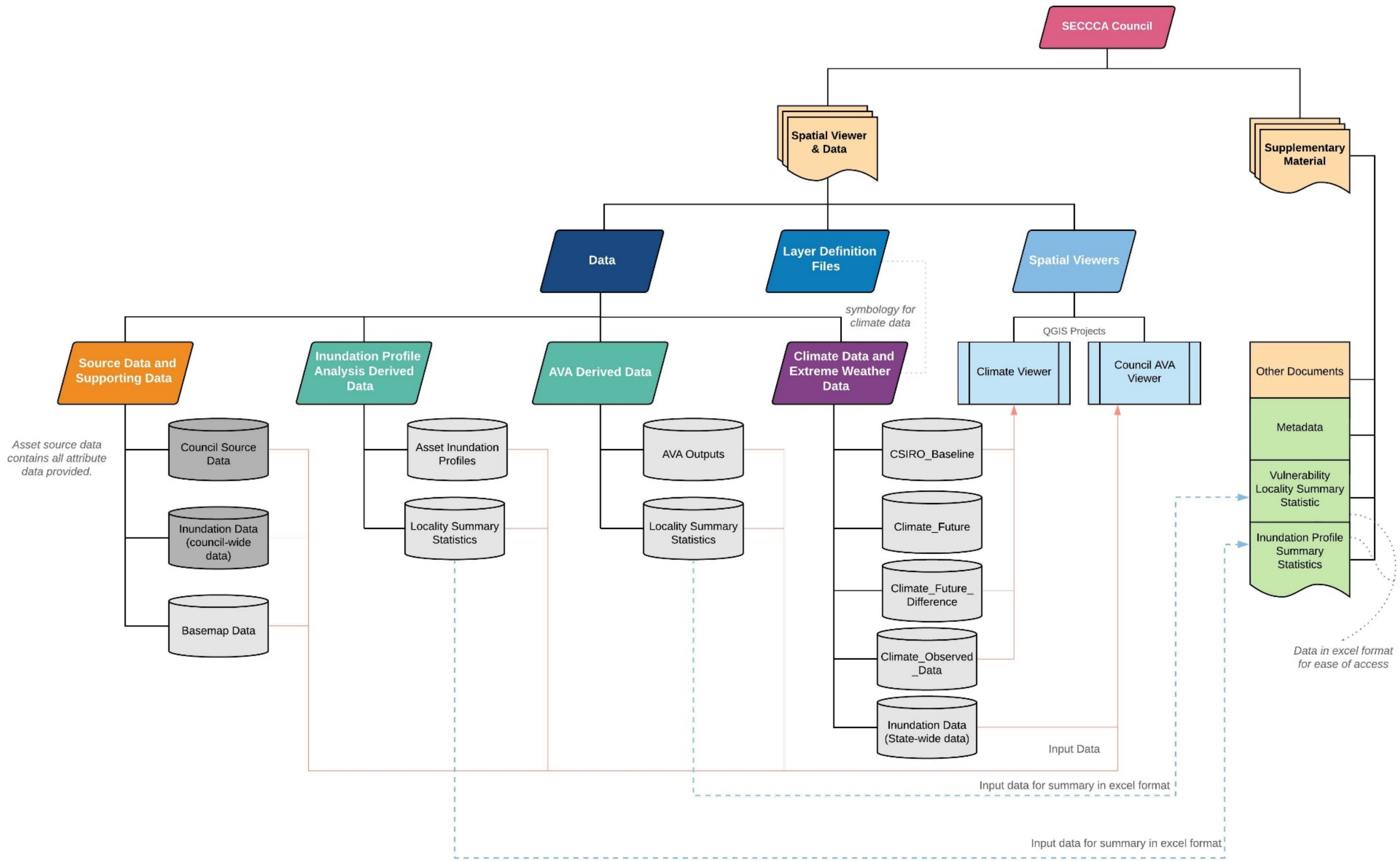


Figure 1. Schematic representation of AVA Part 1 Data Package.

2.1. Handover Structure Folder Explanation

Source Data and Supporting Data

The Source Data and Supporting Data folder contains the un-analysed data provided to Spatial Vision by the Council.

Inundation Profile Analysed Derived Data

This folder contains the outputs of the inundation profile analysis. The *Asset Inundation Profiles* contain the feature classes that identify the assets impacted by the three inundation scenarios:

'_FLD' = 1 in 100 year flooding event

'_SLR' = 82 cm Sea Level Rise

'_STM; = Storm Surge on 82 cm Sea Level Rise

The *Locality Summary Statistics* geodatabase contain geodatabase tables that identify the number of assets (per asset type) in each locality within the LGA impacted by the three inundation scenarios.

AVA Derived Data

This folder contains the outputs of the vulnerability assessment. The *AVA Outputs* geodatabase contains feature classes that identify the vulnerability of the assets (per asset type) to the climate variables. The below table identifies the climate variables for which vulnerability was determined for each asset type.

Asset Type	Climate Variables
Buildings	Extreme Rainfall, Extreme Temperature, Standard Precipitation Index (SPI)
Roads	Extreme Rainfall, Extreme Temperature, Standard Precipitation Index (SPI)
Drainage (Pits and Pipes)	Extreme Rainfall, Standard Precipitation Index (SPI)

The *Locality Summary Statistics* geodatabase contains geodatabase tables that present the 'average asset vulnerability' score for a particularly climate model, RCP future, and time fame (e.g. ACCESS 1.0 RCP 8.5 2050 climate future) (%) for all assets that intersect locality.

Climate and Extreme Weather Data

This folder contains all climate and extreme weather-related data for the case study. The Sub-folders include:

1. CSIRO Baseline Data – 5 km gridded climate data that the projections are based on. The baseline period is from 1981 to 2010.

2. Climate Future Data - 5 km gridded climate projection data (absolute values) for the climate variables. This data is not presented in the QGIS Climate Viewer, but is provided as part of the data package.
3. Climate Future Difference Data - 5 km gridded climate projection data, showing the change in values from the baseline for the climate variables.
4. Historic Climate Data – this contains the 5 km gridded observed climate data (source: SILO) for the same variables mentioned above. These datasets contain observed historical climate data for the decades: 1970, 1980, 1990, 2000, 2010.
5. Inundation Data (state-wide) – this folder contains data of the different inundation scenarios (Flooding Scenarios; storm surge at the different sea level rise increments) from various state-wide sources.

Layer Definition Files

The Layer Definition Files folder contains Layer files that can be brought directly into a QGIS environment, that refers to the data within the *Climate Data and Extreme Weather Data* folder, and has all symbology set.

Spatial Viewers

This folder contains the QGIS Projects that relate to:

1. The Council AVA viewer, with symbolised layers
2. Climate projected and observed polygrids, with symbolise layers

The purpose of these projects with pre-symbolised layers is to allow the user easy viewing of the data.

3. First Pass AVA Project Outputs Background Notes

In delivering the Asset Vulnerability Project, the Spatial Vision team have packaged the data outputs from the first pass assessment process into a spatial data viewer. The viewer used is QGIS.

The data outputs are aimed at assisting asset managers better understand the likely climate change under various climate futures, and the likely impacts.

The data is packaged in two separate viewers:

- one that displays climate information prepared by the CSIRO (and sponsored by the Victorian Department of Environment, Land, Water, and Planning under the Victorian Climate Futures Project (VCF19)); This viewer also includes historical climate observation data. This is referred to as the *Climate Viewer.*
- second that presents the inputs and outputs from the first pass asset vulnerability assessment (AVA) for building, roads and drains. This second viewer includes both the inundation profile for assets under various inundations scenarios, in addition to the full vulnerability assessment for assets based on three different climate models and futures, two carbon emission scenarios, and four different time points. This is referred to as the *AVA Council Viewer.*

3.1. Reference Videos

Reference Videos on AVA Outputs and QGIS which has been used to present the results are as follow:

Note: the reference videos may show the QGIS viewer with slight variances to the final viewer.

Intro to QGIS:
“This video is a brief overview and introduction to the council-specific QGIS viewer that presents the inundation profile and vulnerability analysis outputs.
This video was produced as part of the SECCCA Asset Vulnerability Assessment Project in May 2021.

See: Intro to QGIS: https://youtu.be/NKZ0Z073cuk

Climate Viewer:
“This video presents an exploration of the QGIS climate data viewer (baseline, projected and historic climate data) for the SECCCA region, including how to compare views of different climate future models and timeframes.
This video was produced as part of the SECCCA Asset Vulnerability Assessment Project in May 2021.

See: Climate Viewer: https://youtu.be/IxF9--U7iNk

3.2. Key Climate Data Explanations

Inundation Climate Change Events

The overall first pass Asset Vulnerability Assessment will include consideration of the following three inundation events:

- Sea Level Rise of 82 cm
- Sea Level Rise of 82 cm with 1% Annual Exceedance Probability (AEP) Storm Surge Event
- 1 in 100 year Flood Event based on historical data

General Circulation Models (GCM) selected

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

Representative Concentration Pathway (RCP) emissions scenarios

The carbon emission future scenarios used are RCP 4.5 and RCP 8.5 that represent low and high carbon emissions scenarios.

Time Frames

The time frames selected are those available in the VCP2019 projections and include the years of 2030, 2050, 2070 and 2090. This projection data is based on a baseline climate represented by the period from 1981 to 2010.

Project Climate Change and Climate Change Related Events

The first pass asset vulnerability assessment will include consideration of the following projected climate change variables that will be derived from the most recent climate modelling prepared by CSIRO and made available as part of the Victorian Climate Projections 2019 Project:

- Number of annual hot days (defined as days with a max temp greater than 35°C)
- Degree increase of annual extremely hot days (defined as change that occurs to top 1% of events)
- Number of annual heat waves (defined as three or more consecutive days greater than 35°C)
- Percentage change of annual extremely wet days (defined as change to events that occur top 1%)
- Number of months in a given year in which a dryness index measure falls below a threshold value (based on a Standard Precipitation Index approach)
- Percentage change in annual rainfall

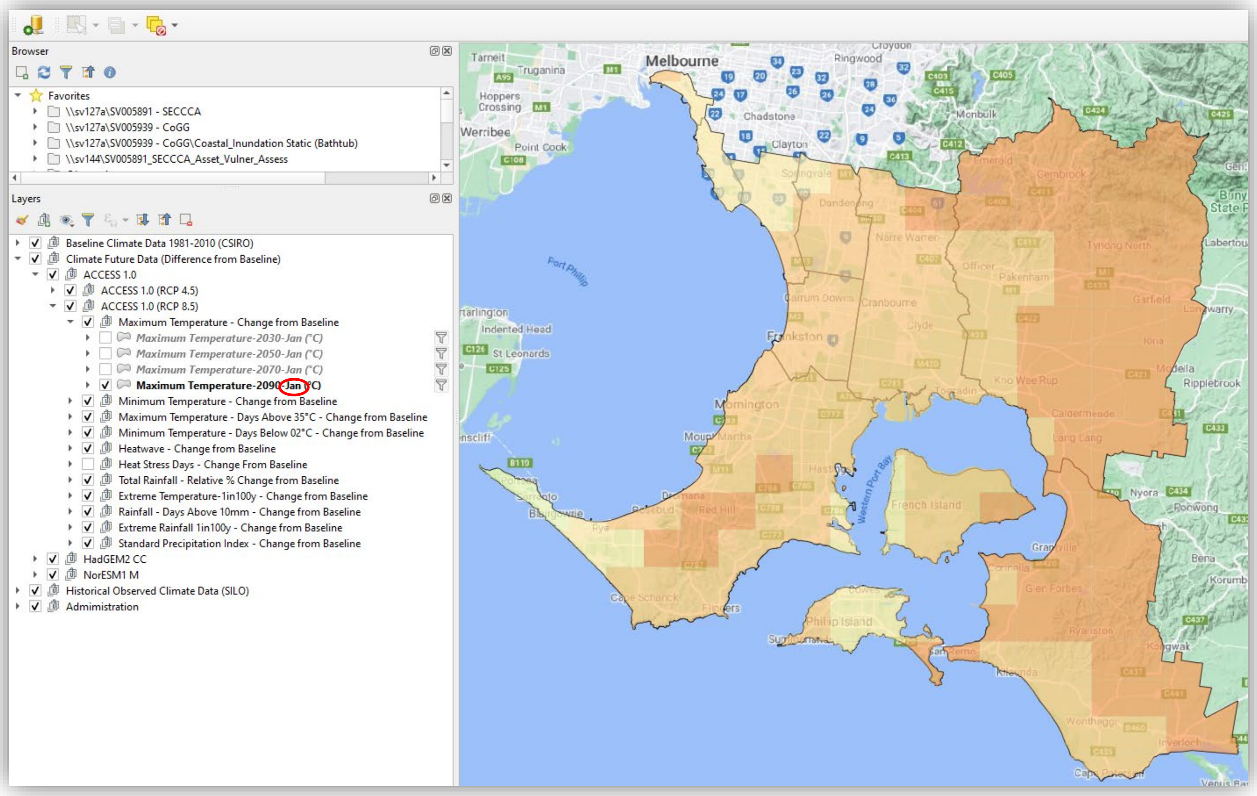
4. Climate Viewer - QGIS Environment

This section provides an understanding on the structure, navigation and use of the Climate Viewer, including instructions on changing the symbology for monthly data variables.

4.1. Structure

The figure below outlines the data presentation structure within the Climate Data QGIS viewer.

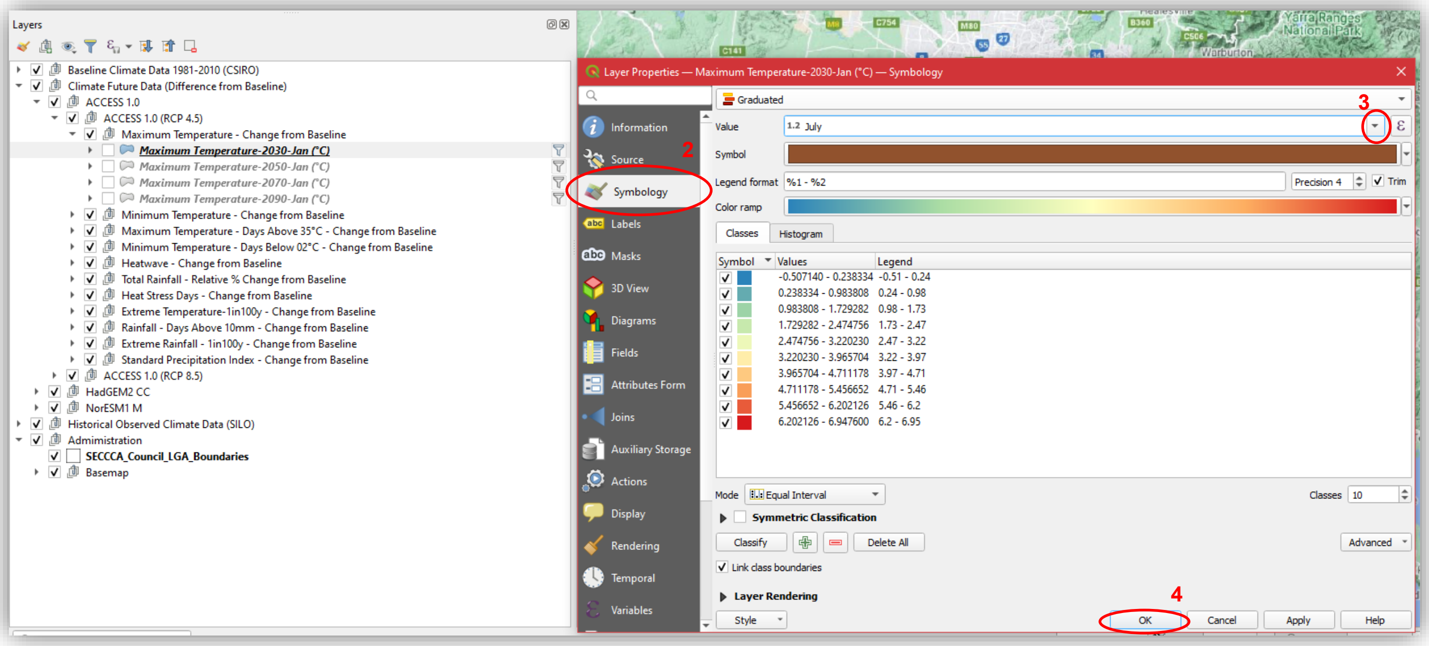
- The climate variables (e.g. “Maximum Temperature”, “Rainfall – Days above 10mm”, etc.) are presented and symbolised for the baseline data, the projected data (for all models, RCP 4.5 and RCP 8.5, and all timeframes) and the historical data.
- For consistency, the Climate Viewer defaults monthly data to ‘January’ (see red circle in figure below). This can be changed by the user to any other month.
- For the climate future data, symbology for each climate variable is consistent across all climate future models, RCPs and timeframes. This allows for visual comparison of these different factors to assist decision making.



4.2. Changing Symbology for Monthly Data

Monthly climate variables are presented for January as the default, but can be altered to another month. Follow the instructions below on how this is done.

1. Identify the climate variable of interest, and right click to access ‘Properties’
2. Navigate to the ‘Symbology’ tab in the pop-up Layer Properties box that appears
3. Change the month by navigating to the ‘Value’ dropdown and selecting the appropriate month.
4. Click ‘OK’ to reflect the change on the map view.



Note: The layer name in the Layers tree will not automatically change from ‘Jan’ to the correct month, despite the change being reflected on the map view. Ensure you manually change the layer name to the correct month to avoid confusion.

Note: The attribute tables have all data in the attribute table for quick reference.

5. Worked Examples

It is suggested that viewers familiarise themselves to the Asset Vulnerability Assessment Project First Pass Methods Report prior to applying these worked examples to ensure they understand the concepts, definitions and data underpinning the examples.

Note: These worked examples are using a specific asset or focus area in Bass Coast to demonstrate the process involved, however the methodologies can be applied across any other asset or focus area.

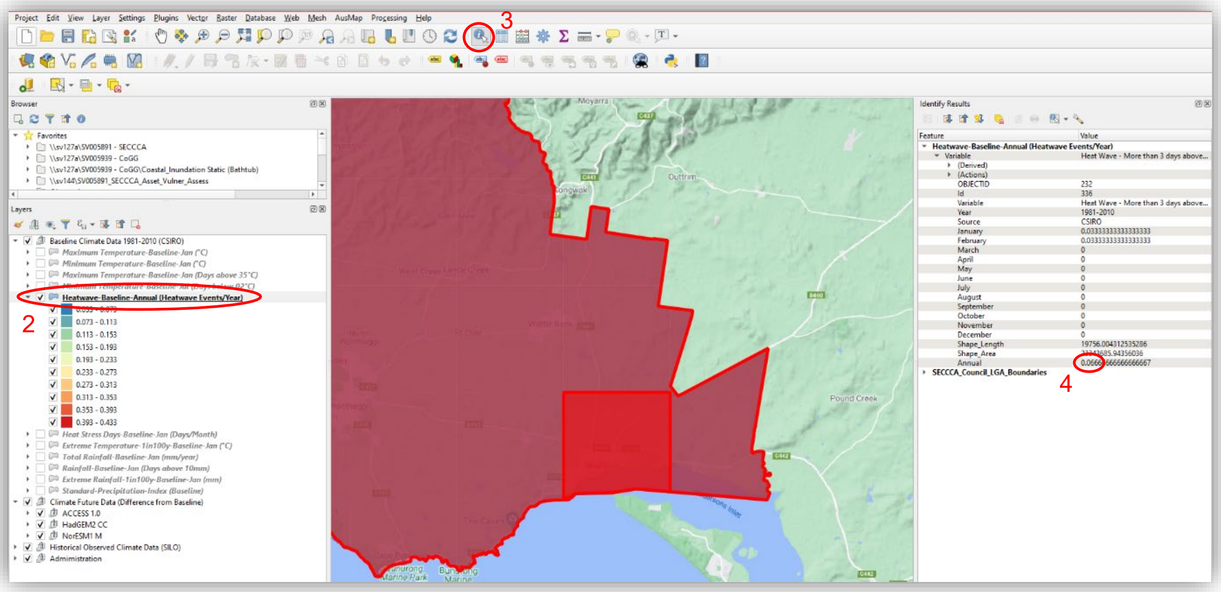
5.1. Climate Viewer – Worked Example #1

Worked Example Question

"What's the relative change in the number of heatwaves per year in Inverloch expected to be over time?"

Steps

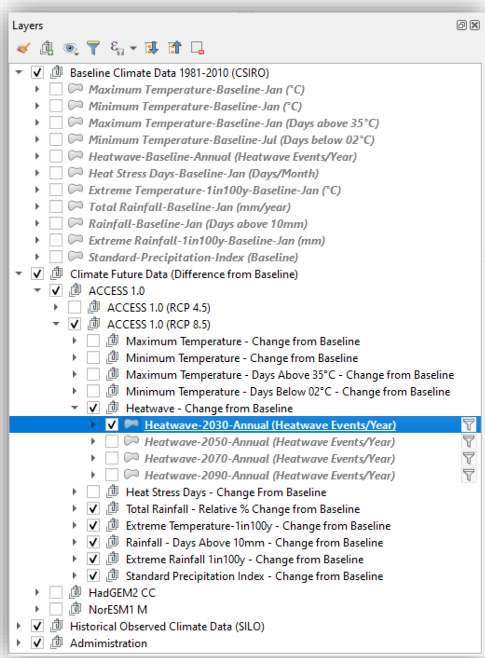
1. Navigate to the area of interest (in this example, Inverloch) in the map view.
2. Turn on the Heatwave layer in the Baseline grouping to determine what the current number of annual heatwaves are in the focus area.
3. Use the identify tool and click the area of interest to get the attribute information pop-up box ('identified' objects will be highlighted in red).
4. From the pop-up box that appears, note down the annual heatwave value. In this example, it is ~0.07 heatwaves per year.



5. Decide which climate model and RCP scenario you will initially look into. In this worked example, the Maximum Consensus Model (ACCESS 1.0) will be used, for an RCP scenario of 8.5.

6. Navigate to the appropriate layer grouping in the Layers tree, and turn on the layer for 2030 heatwaves. Use the identify tool again to click the area of interest and note down the annual heatwaves (change from baseline) from the pop-up box that appears.

Hint: make sure that you're noting down the value from the correct layer in the identify pop-up box that appears. The identify pop-up box will show results for all layers that are currently turned on in the Layers tree.



7. Repeat Step 6 for the other timeframes (2050, 2070 and 2090) to see how the number of annual heatwaves is expected to change over time from the baseline for the focus area.

Note: This worked example can also be repeated for the other climate models and RCP scenarios to see how the outputs vary.

The outputs for this worked example would be:

Timeframe	Annual Heatwaves (ACCESS 1.0 RCP 8.5) (change from baseline)
Baseline (1981-2010)	0.07 heatwave events
2030	+0.13
2050	+0.2
2070	+0.67
2090	+1.27

5.2. Council AVA Viewer - Worked Example #1

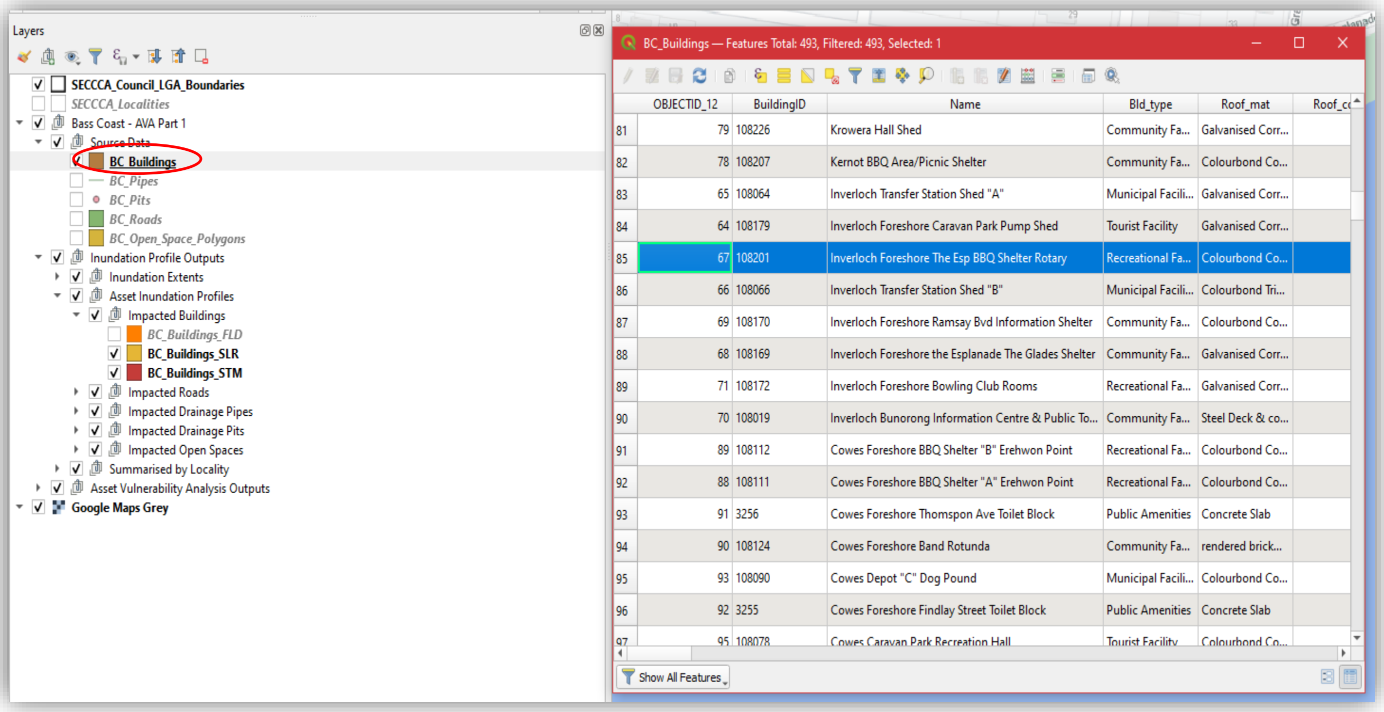
Worked Example Question

"Will Building 'X' be impacted by different inundation scenarios?"

Note: This worked example will use the Inverloch Foreshore The Glades BBQ Shelter building in Inverloch, Bass Coast, but the method can be applied to any building or individual asset.

Steps

1. Open the attribute table for 'Buildings' in the Source Data to find and identify the building of interest (in this example – "*Inverloch Foreshore The Glades BBQ Shelter*"). Note down the BuildingID key (or AssetID/etc.).

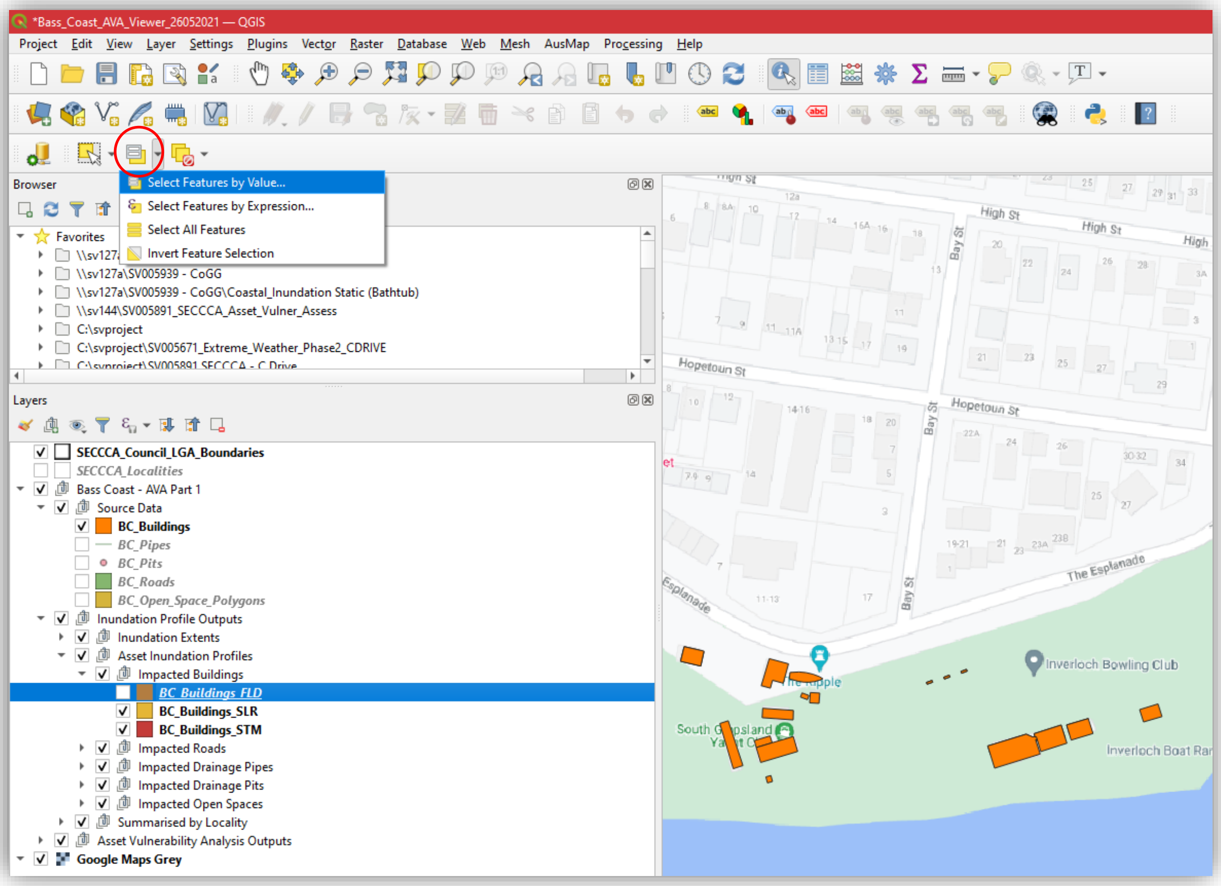


Hint: right click feature in attribute table and select "zoom to feature" to navigate to the building on the map view.

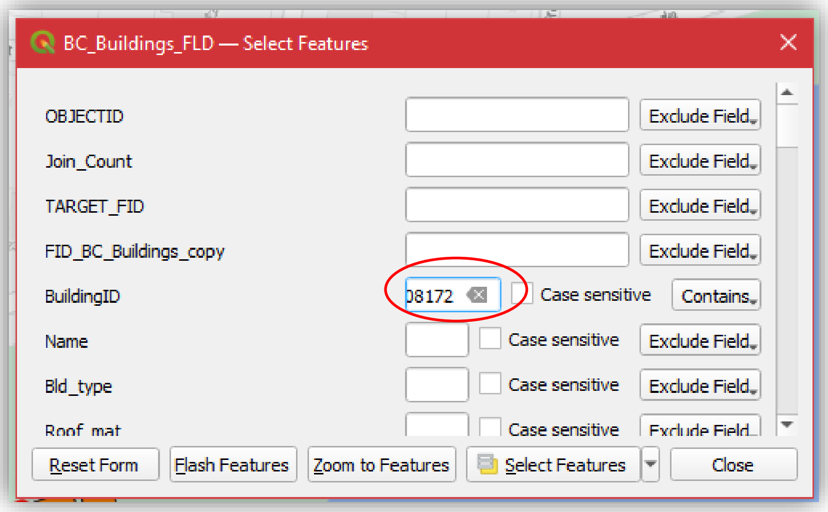
Hint: Turn on the BC_Building_FLD layer to visually see whether the building is impacted by a 1 in 100 year flood event.

Note: Assets within these Inundation Profile Output layers are those that ARE impacted by the inundation scenario. If the asset is not in the layer, then it is not impacted by the inundation scenario.

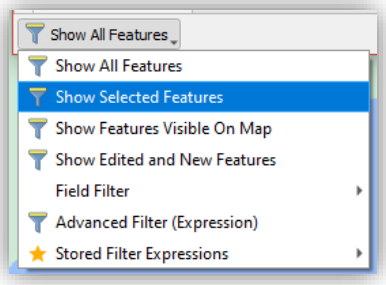
2. Ensure the *BC_Building_BC* layer is highlighted in the Layers tree, then click the 'Select Features by Value' symbol in the main toolbar.



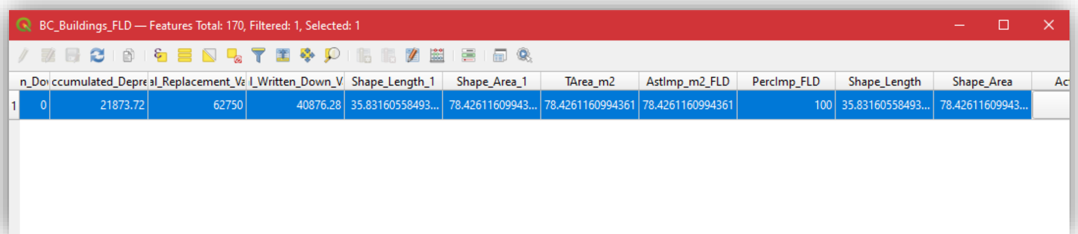
3. In the popup box that appears, input the BuildingID number of the focus building, then click 'Select Features'.



4. Open the *BC_Building_FLD* attribute table and select the 'Show All Features' drop-down box in the bottom left corner to then select 'Show Selected Features'. This will change the attribute table to only present the selected asset.

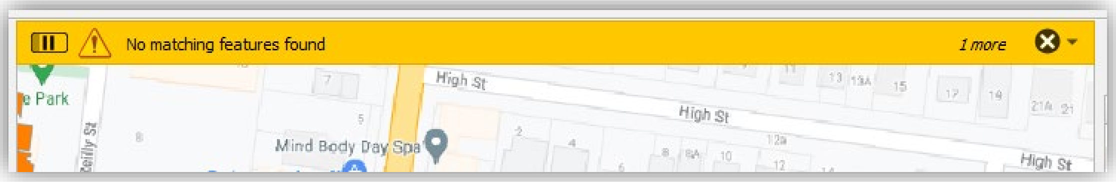


Hint: the information in the attribute table includes usefuls statistics such as the total absolute area of the asset impacted, and the percentage of the total asset impacted.



5. Repeat this step for the other two inundation scenarios (82cm Sea Level Rise = SLR; Storm Surge on 82cm Sea Level Rise = STM) to see whether the asset is impacted.

   Hint: If the asset is not impacted by an inundation scenario, an error like the screenshot below will appear when doing the 'Select Feature by Value' step (Step 4).



5.3. Council AVA Viewer - Worked Example #2

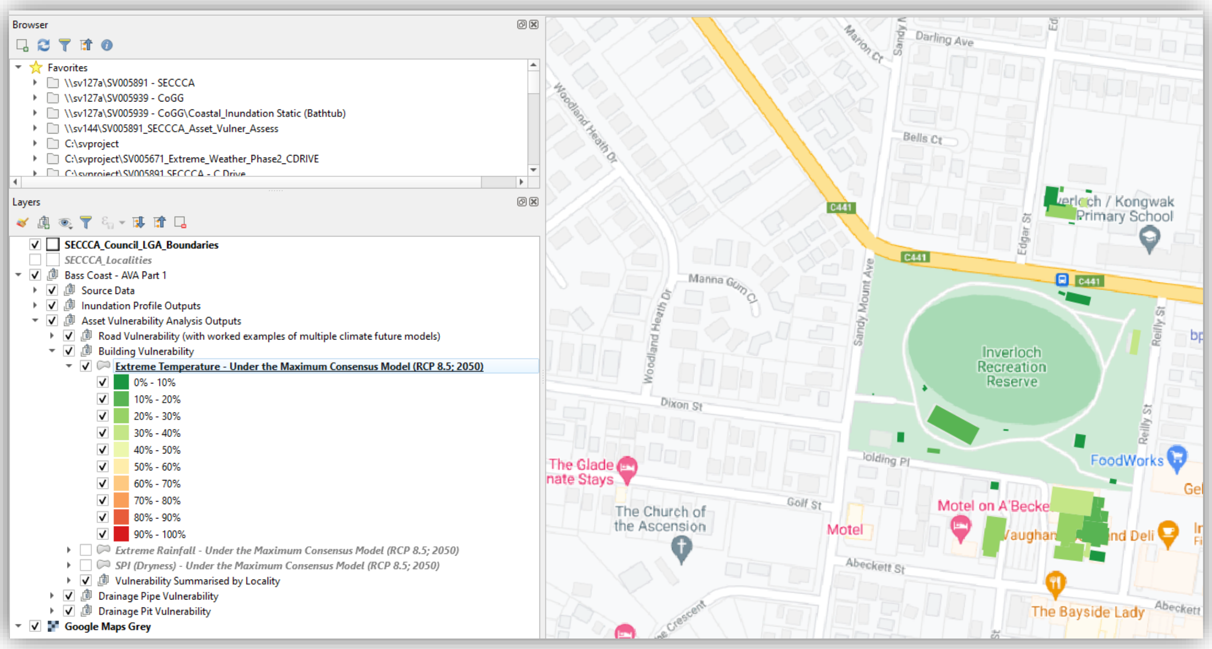
Worked Example Question

"Which building assets are the most vulnerable to extreme temperature in my LGA?"

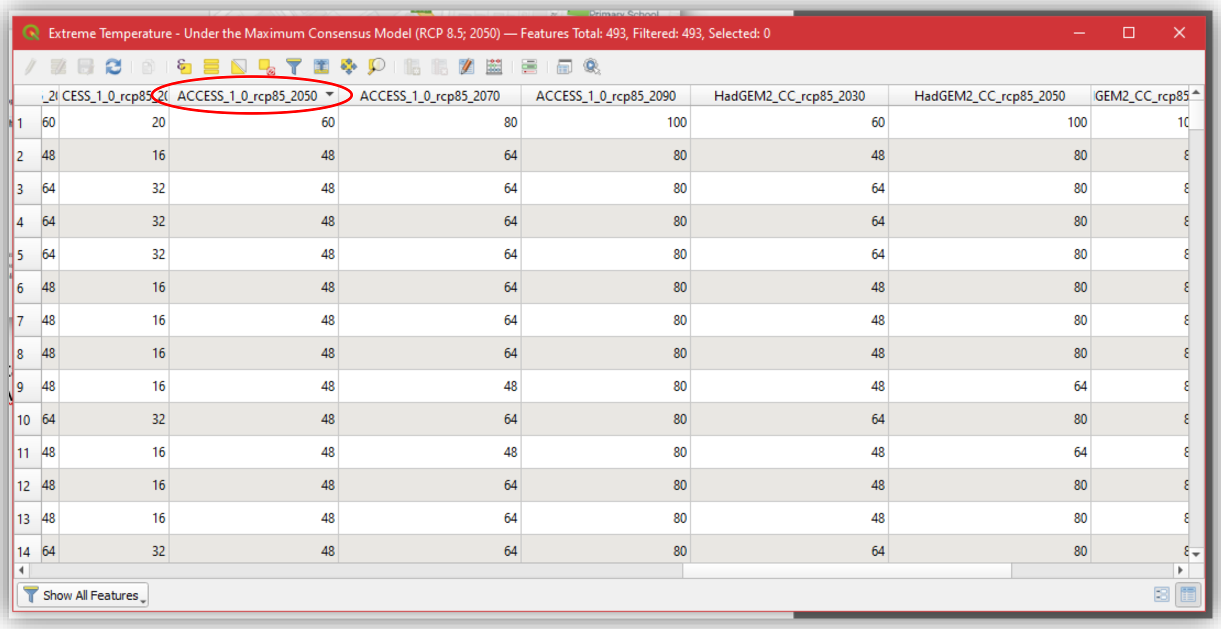
Steps

1. Locate the outputs for building vulnerability to extreme temperature in the Layers tree and tick the box to view in the map area.

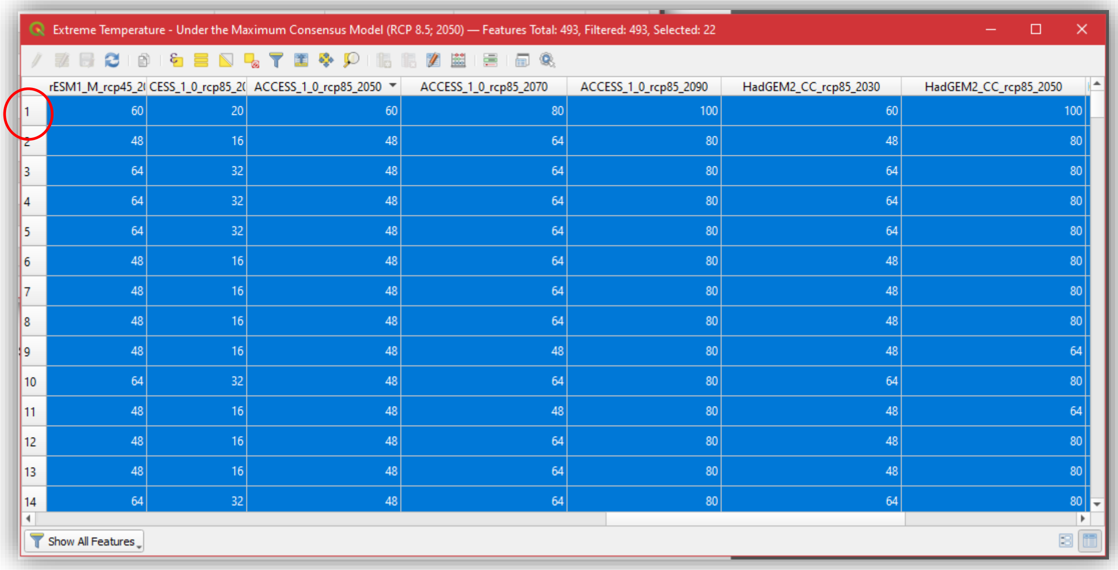
   Note: the default future scenario in the QGIS viewer is set at the Maximum Consensus Model (ACCESS 1.0) RCP 8.5 for 2050.



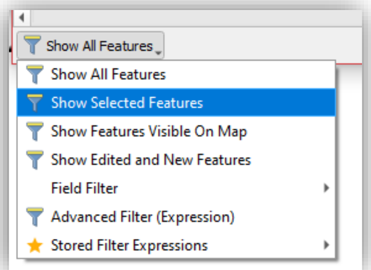
2. Open the attribute table of this layer and navigate to the future scenario field you are interested in. Click the field name twice to automatically sort from high-low.



3. Highlight the assets with the highest vulnerability by clicking the row ‘1’ and dragging down to desired number.



4. Click the ‘Show All Features’ drop-down option and select the ‘Show Selected Features’ to only view these selected high-vulnerability assets in the attribute table



5. Scroll back to the left in the attribute table to view asset information for each highly-vulnerable asset (i.e. Building ID, Building name, etc).

Note: This information can be copied across to an excel/text document by selecting the 'Copy selected rows to clipboard' option in the toolbar

Extreme Temperature - Under the Maximum Consensus Model (RCP 8.5; 2050) — Features Total: 493, Filtered: 22, Selected: 22

	OBJECTID_12	BuildingID	Name	Shape_Length	Shape_Area	Exposure	Sensitivity	Adaptive_Capacity
9	224	108281	Rhyll Foreshore Jetty Shed	19.95855880733...	24.64982844094...	1, 1, 2, 3, 3, 2, 3,...	Field: SuperStru...	Field: Walls_co...
10	228	108174	Inverloch Foreshore Bowling Club Shelters	23.88481137735...	8.8875739398531	1, 1, 2, 3, 3, 3, 5,...	Field: Roof_Typ...	Field: Walls_co...
11	198	108127	Dalyston Rec Reserve Caretakers House	41.98627286146...	105.0111534201...	1, 1, 2, 3, 3, 2, 4,...	Field: SubStruct...	Field: SuperStru...
12	182	108237	Newhaven CP Washing up Shelter	16.78571284846...	16.88044138264...	1, 1, 2, 3, 3, 3, 4,...	Field: Walls_ma...	Field: Roof_Con...
13	353	CT059	Wonthaggi Mitchell House Community Centre Sand Pit Cover	17.16056814509...	18.37512829006...	1, 1, 2, 3, 3, 3, 4,...	Field: SubStruct...	Field: Roof_Con...
14	335	3273	Inverloch Foreshore "A" Toilet Block - Boat Ramp	32.40348660798...	63.26606052191...	1, 1, 2, 3, 3, 3, 5,...	Field: Walls_ma...	Field: Walls_co...
15	303	108286	San Remo Foreshore Marine Pde BBQ & Shelter 2	22.01980962103...	34.98205110697...	1, 1, 2, 3, 3, 3, 4,...	Field: Roof_mat...	Field: Roof_con...
16	313	108368	Wonthaggi Rec Reserve Table Tennis Pavilion	73.72614274745...	306.1707545806...	1, 1, 2, 3, 3, 3, 5,...	Field: SuperStru...	Field: Walls_co...
17	315	108366	Wonthaggi Rec Reserve Store Shed Oval 2	24.04687298700...	36.1397837760171	1, 1, 2, 3, 3, 3, 5,...	Field: SubStruct...	Field: Roof_con...
18	457	CW080	Bass Recreation Reserve Old Scoreboard and Coaches Box	24.06525907221...	23.23648421899...	1, 1, 2, 3, 3, 3, 4,...	Field: SubStruct...	Field: Roof_Con...
19	452	CW075	Bass Recreation Reserve Netball Rooms	77.82054332793...	293.1029175718...	1, 1, 2, 3, 3, 3, 4,...	Field: SubStruct...	Field: Roof_Con...
20	441	CW056	Bass Community Hall	84.34202096773...	299.6924151776...	1, 1, 2, 3, 3, 3, 4,...	Field: SubStruct...	Field: SuperStru...
21	106	BLDG10336	Cowes Blue Tonge Common Picnic Shelter	39.82745002242...	71.55094350684...	1, 1, 2, 2, 2, 2, 3,...	Field: SuperStru...	Field: Asset_Typ...
22	76	108301	Pound Creek Tennis Toilets	22.60592441233...	31.58068086811...	1, 1, 2, 3, 3, 3, 5,...	Field: Walls_ma...	Field: Roof_Con...

You have now identified the buildings with the highest vulnerability to extreme temperature for the future scenario of 'ACCESS 1.0 RCP 8.5, for 2050'. These steps can be repeated for any other climate future model, RCP scenario, or timeframe.

5.4. Council AVA Viewer – Worked Example #3

Worked Example Question

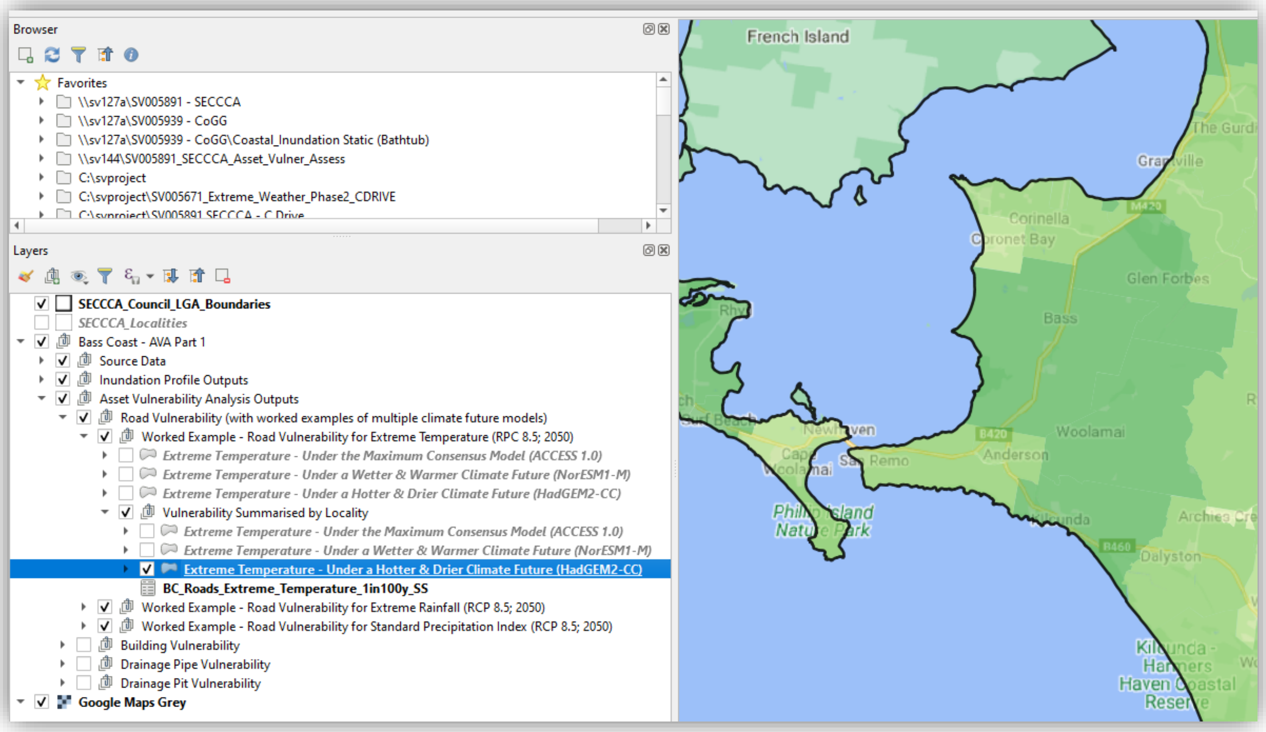
"Which localities in my LGA should I be most concerned about in regards to the vulnerability of roads to extreme temperature?"

Note: This question can also be answered by referring to the Vulnerability Locality Summary MS excel document.

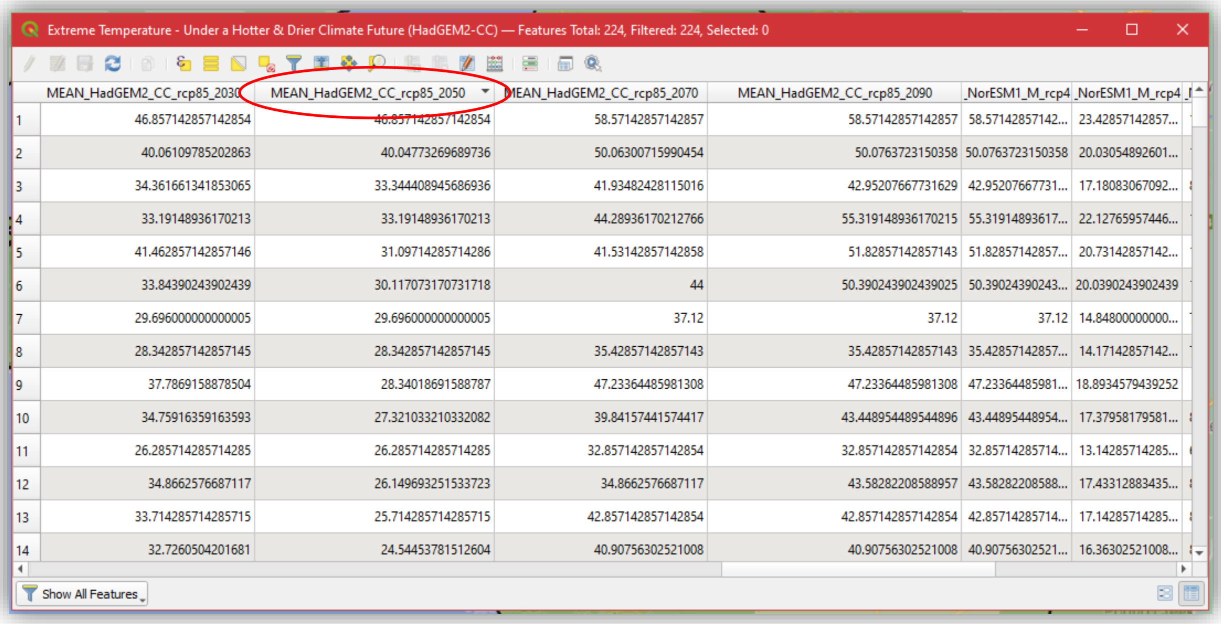
Steps

1. Locate the outputs for road vulnerability (summarised by locality) to extreme temperature in the Layers tree and tick the box to view in the map area. Decide which model you want to view the results for.

   This worked example will focus on the HadGEM2-CC Climate Future Model, RCP 8.5 for 2050.



2. Open the attribute table and use the scroll bar to navigate to the desired climate future scenario (in this case – "MEAN_HadGEM2_CC_rcp85_2050"). Click the field name twice to automatically sort from high-low.



Extreme Temperature - Under a Hotter & Drier Climate Future (HadGEM2-CC) — Features Total: 224, Filtered: 224, Selected: 0

	MEAN_HadGEM2_CC_rcp85_2030	MEAN_HadGEM2_CC_rcp85_2050	MEAN_HadGEM2_CC_rcp85_2070	MEAN_HadGEM2_CC_rcp85_2090	_NorESM1_M_rcp4	_NorESM1_M_rcp4
1	46.857142857142854	46.857142857142854	58.57142857142857	58.57142857142857	58.57142857142...	23.42857142857...
2	40.06109785202863	40.04773269689736	50.06300715990454	50.0763723150358	50.0763723150358	20.03054892601...
3	34.361661341853065	33.344408945686936	41.93482428115016	42.95207667731629	42.95207667731...	17.18083067092...
4	33.19148936170213	33.19148936170213	44.28936170212766	55.319148936170215	55.31914893617...	22.12765957446...
5	41.462857142857146	31.09714285714286	41.53142857142858	51.82857142857143	51.82857142857...	20.73142857142...
6	33.84390243902439	30.117073170731718	44	50.390243902439025	50.39024390243...	20.0390243902439
7	29.696000000000005	29.696000000000005	37.12	37.12	37.12	14.84800000000...
8	28.342857142857145	28.342857142857145	35.42857142857143	35.42857142857143	35.42857142857...	14.17142857142...
9	37.7869158878504	28.34018691588787	47.23364485981308	47.23364485981308	47.23364485981...	18.8934579439252
10	34.75916359163593	27.321033210332082	39.84157441574417	43.448954489544896	43.44895448954...	17.37958179581...
11	26.285714285714285	26.285714285714285	32.857142857142854	32.857142857142854	32.85714285714...	13.14285714285...
12	34.8662576687117	26.149693251533723	34.8662576687117	43.58282208588957	43.58282208588...	17.43312883435...
13	33.714285714285715	25.714285714285715	42.857142857142854	42.857142857142854	42.85714285714...	17.14285714285...
14	32.7260504201681	24.54453781512604	40.90756302521008	40.90756302521008	40.90756302521...	16.36302521008...

Show All Features

3. Repeat steps 3 to 5 from Worked Example #2 above to highlight required assets and copy out into excel/text format.

Spatial Vision