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Improving coordination of data and actors for disaster-responsive housing and safer communities

From the AHURI Inquiry: Inquiry into housing policy and disasters: better co-ordinating actors, responses and data

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https://www.ahuri.edu.au/research-in-progress/inquiry-into-housing-policy-and-disasters-better-co-ordinating-actors-responses-and-data

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Acronyms and abbreviations used in this report

ABCB	Australian Building Codes Board
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AFRIP	Australian Flood Risk Information Portal
AHURI	Australian Housing and Urban Research Institute Limited
AIDR	Australian Institute for Disaster Resilience
APRA	Australian Prudential Regulation Authority
AS	Australian Standard
AS/NZS	Australian and New Zealand Standards
ASIC	Australian Securities and Investments Commission
BAL	Bushfire attack level
BCA	Building Code of Australia
BMO	Bushfire Management Overlay
BoM	Bureau of Meteorology
BPA	Bushfire-prone areas
CHP	Community housing provider
COAG	Council of Australian Governments
DA	Development applications
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DELWP	Department of Environment, Land, Water and Planning
DFES	Department of Fire and Emergency Services
DPLH	Department of Planning, Land and Heritage
DRR	Disaster risk reduction
DTA	Digital Transformation Agency
DTP	Department of Transport and Planning
DWER	Department of Water and Environmental Regulation
EM-DAT	Emergency Events Database
EMV	Emergency Management Victoria
EU	European Union
FD	Foundational data
FRM	Flood risk management
FSDF LINK	Spatial Data Framework Location Information Knowledge Platform
G-NAF	Geocoded national address file
GA	Geoscience Australia
GIS	Geographic information system
HD	Hazard data
ID	Impact data
IDT	Insurance data transformation

LG	Local government
LGA	Local government authority
LR	Literature review
NCC	National Construction Codes
NEMA	National Emergency Management Agency
NPCP	National Partnership for Climate Projections
NSW	New South Wales
NSW RFS	New South Wales Rural Fire Service
NSWSS	New South Wales Spatial Services
OECD	Organisation for Economic Cooperation and Development
QLD	Queensland
SA	South Australia
SBO	Special building overlays
SDI	Spatial data infrastructure
SDTs	Spatial digital twins
SPP	State planning policy
TAS	Tasmania
TCHA	Tropical Cyclone Hazard Assessment
UN	United Nations
UNDRO	United Nations Disaster Relief Organization
UNDRR	United Nations Office for Disaster Risk Reduction
VGI	Volunteered geographic information
VIC	Victoria
VPP	Victoria Planning Provisions
WA	Western Australia

Glossary

A list of definitions for terms commonly used by AHURI is available on the AHURI website ahuri.edu.au/glossary.

Executive summary

Key points

- This research project examines how key actors involved in the housing planning and delivery process in New South Wales, Victoria and Western Australia use data to assess disaster risk associated with flooding, bushfires and cyclones.
- Assuming a users' perspective, the research discusses how data could be better used and shared for the planning and delivery of new housing to reduce the impact of disaster events.
- Australia has a complex data landscape. It is unorganised and characterised by data fragmentation and duplication.
- Flood hazard data are the most inconsistent data in terms of accuracy, data coverage, accessibility and availability.
- While overall data availability and accessibility have improved over time, access to spatialised data identifying potential and actual impacts associated with natural disasters is lagging behind.
- In the survey conducted as part of the research, key actors involved in housing planning and delivery identified state and local government policies as playing an essential role in disaster risk assessment, second only to hazard data.
- Planning processes are not agile enough to keep up with the fast pace of information and available data.

- **There is a siloed approach to policy development. This limits information flow between agencies, and results in a disconnect between planning and housing policies at the strategic level.**
- **The three priority areas to improve in decision-making processes were identified as: improved data collection and sharing practices, use of decision-supporting tools for risk assessment, and risk disclosure and communication.**
- **Applying digital solutions to urban development will require advancement in the institutional capacity of the agencies involved in setting, managing and using these platforms.**

Key findings

What is the current data landscape relative to disaster risk reduction in Australia?

According to the recent mid-interim report on Australian progress in the implementation of the *Sendai Framework for Disaster Risk Reduction 2015–2030*, Australia is not performing well in terms of disaster-related data availability, quality and accessibility due to a *'fragmented and complex data ecosystem'* (National Emergency Management Agency [NEMA] 2022: 39). This finding is supported by the comprehensive review of disaster data conducted as part of this research.

This research shows that although data that can be used to inform disaster risk reduction and prevention is currently available at all levels of government, it is located within different government agencies and private enterprises—often in incompatible formats. Most of the data are shared across a range of platforms, which are not integrated. Moreover, the analysis of the data highlights how the degree of standardisation and the quality of datasets change according to the hazard considered—for this research: cyclones, floods and bushfires—and depend on jurisdictional institutional arrangements, policies and practices.

What data is needed for better disaster risk assessment for housing planning and delivery?

Effectively addressing natural-hazard-related risks requires assessments that consider the combination of all risk dimensions: hazard, exposure and vulnerability. This research has identified different issues related to data for these three dimensions.

Hazard: In spite of their differences, all data users who engaged with this research project agreed that flood hazard data needs immediate attention, and expressed their concerns about data quality and currency. Flood hazard data are currently the most inconsistent data in terms of their quality, level of accuracy, and extent of data coverage across states and across local jurisdictions.

Exposure: Impact data contribute to assessing implications associated with exposure to natural hazards. However, the data mapping reveals that impact data held by emergency management agencies and insurance companies are mostly not accessible due to privacy or commercial issues. Improved data accessibility is required.

Vulnerability: Socio-economic factors determining vulnerability are not embedded in the risk assessment for disaster prevention. In the assessment of the delivery of new developments, the social component of housing vulnerability is limited to the logistics of evacuation plans, assuming a risk preparedness rather than a mitigation approach. Planning for safe evacuation does not consider the implications of dealing with the long-term consequences of natural disaster events. Risk assessment needs to take into account the socio-economic component of housing.

What informs decision-making in policy development and the delivery of housing?

Land use planning policies play a critical role in the delivery of safe and resilient dwellings. Policy makers at state and local government levels consider a variety of data and sources in shaping their policy responses, including hazard data and best practices. Policy makers rely on the technical support provided by other government departments and agencies, as well as private consultancies, to translate hazard data and information into legislative requirements. Research participants identified the lack of valid and consistent data about flooding as restricting the ability of the planning system to effectively mitigate risk in new housing.

The current planning system is struggling to effectively harness data to support decision-making. There is a siloed approach to policy development, which causes a lack of information flow between government agencies. As a result, planning and housing policies are disconnected at the strategic level. Urban planning processes are not agile enough to keep up with the fast pace of information and data availability. This generates a general lack of trust in policy tools, with some proponents leveraging the misalignment between the accuracy of data and policy to challenge established mitigation parameters—especially regarding flood hazards in Victoria and New South Wales.

On the delivery side, state and local government planning policies, together with building codes and standards, play a critical role in guiding decision-making for housing delivery. Generally, during the project feasibility and the pre-planning approval stage, developers assess and account for disaster risk in relation to conditions and constraints defined by planning policies. Once a project is submitted for approval, all decisions made by the relevant authorities are grounded on the adherence of proposals to local government (LG) and state planning policies and development controls.

Insurance also plays a critical role in the development processes. Insurance underpins lending and investment activities, and acts as a vehicle to communicate to households the level of risk a dwelling is exposed to.

How can digital technologies support better use of data to inform the decision-making process?

The planners, housing providers and emergency management representatives who contributed to this research agreed that effectively addressing the risk posed by natural hazards in urban development depends on the coordination, aggregation, sharing and effective dissemination of information in the context of a clear legislative framework. They voiced the need for the introduction of digital solutions in the existing decision-making process that:

1. support data collection and information-sharing practices
2. efficiently operationalise data through the use of decision-supporting tools
3. facilitate risk communication and disclosure.

Spatial digital twins (SDTs) are digital tools that can be leveraged to integrate datasets. This facilitates data sharing and improves efficiencies in the operationalisation of data in decision-making across the range of stages in the housing development process.

As a digital representation of a physical area or place, SDTs provide a platform for data to be captured, stored, analysed and then visualised for use. SDTs also provide collaborative platforms with a point of reference for data sourcing, given their capacity to host other applications that are used in the context of urban planning decision-making, such as decision-support tools. In particular, scenario-planning tools support evidence-based planning decisions, primarily around the long-term strategic planning of urban development, by enabling the exploration of alternative framings to address uncertainty in anticipating future conditions (Engin, Van Dijk et al. 2020).

Policy development options

The three main areas of intervention that need to be addressed to improve data-driven decision-making are data governance, risk assessment, and digital technology capacity and maturity.

Data governance

- **Establish an overarching governance system that is responsible for clearly mapping and quantifying data quality and availability.** Support this by successfully establishing protocols for intervention and setting parameters for data administration to guarantee long-term management of the issues.
- **Provide financial and technical support to individual government agencies to revise and improve** data management, security and privacy policies that address the requirement of established protocols for data, managing duplication and fragmentation, and facilitating sharing protocols.
- **Co-design of processes to enable the sharing and use of data** across different government agencies—and between government agencies and external players—based on a shared established role of the data-sharing process in relation to disaster risk reduction (DRR).
- **Strengthen individual agencies' data governance** by addressing data management, security and privacy policies.

Risk assessment

- **Implement legal and regulatory reforms aimed at streamlining policy amendments and review processes** to increase the agility of planning tools. This would allow for quicker responses to changing circumstances—such as the availability of new or improved data—by simplifying procedural requirements for policy updates.
- **Amend development process approvals** to create specific and streamlined approval pathways for proposed developments located in areas identified as at-risk.
- **Establish uniform processes of risk assessment** across government agencies and between the government and the insurance industry, including standardised approaches to data used for risk assessment.

Digital technology capacity and maturity

- **Provide funding for the acquisition of technological resources** to guarantee that all parties involved have adequate hard and soft infrastructure to support the use of new technologies.
- **Plan for and invest in continued digital education.** Provide adequate and ongoing allocation of funding directed at initiatives aimed at increasing and improving current staff digital skills (upskilling).
- **Collaboratively set and implement necessary new protocols linked to changes in decision-making processes** and strengthening collaboration between and within the agencies involved.
- **Appoint a dedicated intra-agencies unit in charge of overseeing the transition.** The main task of this operational unit is to support the setting of digital technologies and oversee their implementation.

The study

This research project is part of a wider AHURI *Inquiry into housing policy and disasters: better co-ordinating actors, responses and data,* exploring how the coordination of institutional systems, processes and information can contribute to Australia's housing policy to better respond to the risk posed by increasing exposure to natural hazards. This supporting research project addresses the Inquiry research question:

> *How can the coordination of data and actors involved in the housing supply process be improved to support and drive the delivery of safer and disaster-responsive housing and communities?*

There is a growing body of literature highlighting the importance of data-driven decision-making for risk assessment of natural hazards. This research project contributes to:

1. understanding how data are operationalised (or not) in the housing delivery decision-making process by the key actors involved
2. identifying the data needs of the key actors, and providing critical information that can help build more effective and targeted data-sharing platforms for risk assessment—including risk disclosure.

The research establishes the context for the study by mapping current data availability in Australia for the three identified natural hazards, including standardisation, ownership, management and sharing systems (desktop analysis).

It then explores how the current decision-making processes relative to housing development planning and delivery use such data and systems for disaster risk assessment, focussing on New South Wales, Victoria and Western Australia. An initial data and actor mapping of the decision-making process was created using data collected via a desktop review of policies and grey literature. This mapping was then completed and complemented by information collected in interviews with key actors: government agency representatives, housing providers, developers and financial institutions. A questionnaire was also developed to extend the knowledge base. The questionnaire was designed to capture the level of importance respondents place on significant elements relating to risk assessment for bushfires, flooding and cyclones across all stages of the planning and development of housing, including the quality of data accessed.

Following the mapping of data and key actors, the research focusses on identifying the needs of these key actors and, applying a forward-oriented approach, outlining a framework for an improved decision-making process for future housing development planning and delivery that embraces the use of data sharing and forecasting tools. To identify how to better respond to the needs and current challenges that emerged through the workshops, the research identifies:

- national and international best practices
- case studies that demonstrate the effective use of data and information systems in natural hazard risk assessment and forecasting.

1. Introduction

- **The increasing severity and frequency of climate-related disaster events challenge existing intervention models, especially those that assess the exposure and vulnerability of communities and assets to natural hazards.**
- **Australia's first National Climate Risk Assessment identifies 11 risks that will need further analysis. This includes the risk to communities from legacy-and-future planning and decision-making that increases the vulnerability of settlements.**
- **Literature investigating how data and assessment risk tools are operationalised in the decision-making process relative to housing planning and delivery mainly considers the needs of individual users.**
- **This research project examines how all key actors involved in the housing planning and delivery process in New South Wales, Victoria and Western Australia use data to assess disaster risk associated with flooding, bushfires and cyclones.**
- **Assuming a user's perspective, the research discusses how data could be better used and shared during the planning and delivery of new housing to reduce the impact of disaster risk.**

Extreme weather events are increasingly impacting Australia's towns and cities. The consequences of disaster events extend beyond physical destruction, as they have social, psychological and health ramifications (Benevolenza and DeRigne 2019; Krzysztof 2020; Leppold, Gibbs et al. 2022; Zhang, Zhang et al. 2022). The damage caused by disasters also negatively affects the Australian economy, including income and household consumption (Australian Bureau of Statistics [ABS] 2020; 2022). After a disaster, household consumption changes drastically, with housing expenditure directed towards '*activity associated with the replacement of destroyed or damaged assets*' (ABS 2020).

Recognising the need to better prepare Australia to adapt to changing climate conditions and the risks they pose, the Department of Climate Change, Energy, the Environment and Water ([DCCEEW] 2024) is currently developing Australia's first National Climate Risk Assessment (the Risk Assessment), in partnership with Australian Climate Service. This Risk Assessment will:

- measure Australia's current and emerging risks associated with climate change
- identify Australia's climate change exposure and vulnerability over the century (DCCEEW 2024).

In its first stage, the Risk Assessment identified and prioritised the *'risks to communities from legacy-and-future planning and decision-making that increases the vulnerability of settlements'* (DCCEEW 2024: 12) as one of 11 risks for further analysis.

The increasing severity and frequency of climate-related disasters challenge existing intervention models—especially how we assess:

- the exposure and vulnerability of our assets and communities to natural hazards (Cremen, Galasso et al. 2022)
- the measures put in place to reduce and mitigate such risks (Deelstra and Bristow 2023).

A risk assessment is the analysis of exposure and vulnerability to natural hazards; such risk assessments are essential for effective risk-based planning (UN Office for Disaster Risk Reduction [UNDRR] 2015). Research investigating disaster risk associated with natural hazard exposure and housing primarily focusses on the post-recovery phase (Charlesworth and Fien 2023; Patch 2023; Van den Nouwelant and Cibin 2022). Little attention has been paid to how disaster risk mitigation, housing policies, and planning and delivery of new settlements link together. Better disaster-prevention measures require better knowledge, better data and information, and standard-setting coordination across the actors involved—the data users—and jurisdictions.

This research project addresses such knowledge gaps by examining how to improve the coordination of actors, processes, and information for better disaster-risk reduction (DRR) and mitigation strategies. In particular, it maps the current decision-making processes of actors involved at various stages of the housing delivery process and focuses on the use, access and sharing of data and other information among these actors. Assuming a user's perspective, the research discusses how data could be better applied and shared to inform the planning and delivery of new housing to reduce the impact of disasters associated with the exposure of dwellings to natural hazards. This chapter provides an overview of the project. It opens by discussing the policy context. It then outlines the key research questions, objectives and methodologies.

1.1 Policy context

Recommendations for better data gathering and information-sharing have been a part of national disaster risk reduction policy since the turn of the millennia. The *Hyogo Framework for Action 2005–2015* (UN 2005) included the collaborative exchange of consistent data among its principles. The use and sharing of data continued as a central element of the Sendai Framework 2015–2030 (UNDRR 2015). One of the guiding principles of the Sendai Framework is that disaster risk reduction requires:

> *a multi-hazard approach and inclusive risk-informed decision-making based on the open exchange and dissemination of disaggregated data, including by sex, age and disability, as well as on easily accessible, up-to-date, comprehensible, science-based, non-sensitive risk information, complemented by traditional knowledge. (UNDRR 2015: 13)*

Australia's disaster-risk-reduction policies and interventions respond to the country's international commitment as a signatory of the Sendai Framework (UN 2015). The Sendai Framework emphasises a stronger cross-sectoral approach to DRR by setting out guiding principles for government and non-government actors. To improve risk assessment, the Sendai Framework (UN 2015: 15) encourages the promotion of real-time access to reliable data *'to enhance measurement tools and the collection, analysis and dissemination of data'.* This is reflected at the national level. The National Strategy for Disaster Resilience (Council of Australian Governments [COAG] 2011) set out actions relating to data and information, according to principles of consistency, availability, data sharing and strong networks.

The *National Disaster Risk Reduction Framework 2019–2020* (National Resilience Taskforce [NRT] 2018) was established to implement the Sendai Framework with the aim of enhancing DRR efforts, with a time horizon to 2030. It aimed to bolster informed and transparent decision-making in DRR by emphasising data sharing, integration, accessibility, utilisation and disclosure to reach the established priority of understanding disaster risk and providing accountable decisions.

As per the DRR Framework, these measures were to facilitate the development of national capabilities for generating, capturing and disseminating data related to disasters. Strategies to reach these objectives included:

- improving public awareness
- identifying gaps in data and knowledge regarding risks
- addressing barriers to data sharing and integration
- using scenario planning to inform decision-making regarding future risk
- developing existing capacities of data access and utilisation
- improving disclosure of risk to build participants' capacity to make informed decisions (NRT 2018).

Recommendations for improving data utilisation and coordination have also stemmed from various state-based and national inquiries into natural disasters. In 2020, the Royal Commission into Natural Disaster Arrangements (Royal Commission 2020) identified a range of issues that contributors raised about data, including improved access to information, capacity to share, data capabilities and consistency of data. The inconsistent application of data across local government areas (LGAs) was identified as a significant issue, noting that while some LGAs boast excellent data systems, others do not. The Bushfire and Natural Hazards CRC (n.d.) provides an inquiries and reviews database that emphasises multiple areas where data could be incorporated into risk-reduction decision-making across government and non-government sectors.

The need for a nationally based approach to data management is identified in many of the recommendations from inquiries and reporting. The Royal Commission (2020) recommended that the federal government take a leading role as coordinator and facilitator in setting common standards and data harmonisation[1] to facilitate the use of data in decision-making. It also recommended building capability in modelling and providing better information about vulnerability and exposure risks. Key recommendations raised in inquiries often include the need for increased data quality and the use of data in land-use planning for urban development.

For example, the New South Wales Government's (2022a) inquiry into the 2022 floods identified key issues related to data and information that hindered effective DRR efforts in planning and urban development, including:

- lack of catchment-scale datasets
- inconsistent planning
- fragmented governance.

1 Harmonisation refers to bringing together data in a consistent way, whereas standardisation means data is collected and stored consistently.

Recommendations from various state-led inquiries stress the need for better risk-based calculations, ensuring high-quality data, improving accessibility to risk information, and standardising data across different regions and sectors (Bushfire and Natural Hazards CRC n.d.).

1.2 Research questions

There is a growing body of literature highlighting the importance of data-driven decision-making for risk assessment of natural hazards. However, there is little research exploring what and how data are used in decision-making across the entire housing planning and delivery process. Current literature mainly examines the use and development of assessment risk tools from the perspective of an individual user's needs (Aye, Jaboyedoff et al. 2015; Crawford, Crowley et al. 2018; Giovinazzi, Wenzel et al. 2013; Komendantova, Mrzyglocki et al. 2014; Wood 2000). As Zuccaro, Leone et al. (2020:3) point out:

> *The actual challenge is to improve more and more the coherence and the collaboration across institutions and public bodies, which would lead to improvements in risk modelling, knowledge management and information-sharing, and the development of laws, regulations and responsibilities.*

This research project contributes to addressing this challenge by:

- understanding how data are operationalised (or not) in the housing delivery decision-making process by the key actors involved
- identifying the data needs of the key actors and providing critical information that can help build more effective and targeted data-sharing platforms for risk assessment, including risk disclosure.

The main objectives of the research are to:

1. Provide a clear mapping of resources relative to data availability and key actors' data needs for natural hazards risk assessment and forecasting that considers hazard, exposure and vulnerability.
2. Outline a framework for an improved decision-making process for future housing development planning and delivery that includes effective use of forecasting assessment tools and other supporting technologies.

These objectives fit within the broader context of the AHURI Inquiry that this research supports. The *Inquiry into housing policy and disasters: better co-ordinating actors, responses and data* seeks to explore how the coordination of institutional systems, processes and information can contribute to Australia's housing policy to better respond to the risk posed by increasing exposure to natural hazards. This supporting research project addresses the Inquiry research question:

> *How can the coordination of data and actors involved in the housing supply process be improved to support and drive the delivery of safer and disaster-responsive housing and communities?*

The research is guided by the following four research sub-questions:

1. Who currently keeps and manages data, and what systems, measures and standards are used to share it?
2. How are relevant data currently available used in the different stages of the housing development process by the key actors involved?
3. What data are needed for better decisions relating to disaster risk assessment for housing development planning and delivery?
4. How can risk-assessment tools be integrated into the housing development planning and delivery processes to guide and better inform decisions that support safer and disaster-responsive housing?

1.3 Research methodology

The project applies a qualitative research approach to answer the guiding sub-questions. In the initial stage, the research addressed the first objective, answering research questions 1, 2 and 3. The project began establishing the context for the study by mapping current data availability in Australia for the three identified natural hazards, including standardisation, ownership, management and sharing systems. It then moved on to explore how the current decision-making processes relative to housing development planning and delivery use such data and systems for disaster risk assessment. Following, the research addressed the second objective, answering research question 4.

1.3.1 Data and actor mapping

An initial data and actor mapping of the decision-making process was created using data collected via a desktop review of policies and grey literature. This mapping was then completed with the support of information collected in interviews. The completed map of data and actors was validated during the workshops.

Interviews

Four main key actors were identified in housing development planning and delivery:

- government planning agencies (state and local government level)
- housing providers (public and not-for-profit/community housing)
- developers and land developers (private and public)
- lenders and insurers.

In-depth semi-structured interviews with representatives of each group were conducted to complete the mapping. The research project identified a case-study approach for mapping the local government (LG) decision-making process. LGs were selected according to the following criteria:

- exposure to different hazards
- having designated growth areas within their boundaries
- representing a mix of regional and urban contexts.

For confidentiality reasons, although we maintained this approach concerning LG representative selection criteria for interviews, the decision mapping is presented from a generic group representation perspective, with no identification of specific LG names.

We conducted 34 semi-structured interviews between August 2023 and January 2024 across the four groups and three states: Western Australia, Victoria and New South Wales.[2] During the interviews, participants were asked to walk the researchers through the decision-making process within their organisation for risk assessment for disasters associated with natural hazard exposure. The focus was on data and information accessed to support such a process, including mitigating and managing future risks. The interviews were conducted online using Teams. Interviews were recorded and then transcribed.

The data recorded were analysed inductively using NVivo software. We performed two types of analysis: a content analysis and a thematic analysis. The content analysis centred around two main key coding areas: 'data' and 'actor relationships'. These main coding categories were then associated with the stages of the decision-making process and cross-referenced across the different actors. The findings of this analysis were used to complete the data mapping and actors' relationship network. The thematic analysis was conducted to complement the mapping of the process with information related to challenges experienced by the research participants in decision-making related to both data and processes.

2 Refer to Appendix 1 Table A1 for an overview of interview distribution across stakeholder groups and relevant jurisdictions.

Questionnaire

A questionnaire was developed to extend the knowledge base established in the interviews. The survey targeted government and private industry representatives of planning and development industries in Western Australia, Victoria and New South Wales. However, through networks, the questionnaire reached beyond the three states and includes responses from Tasmania, Queensland and South Australia. The questionnaire was designed to capture the level of importance respondents place on key elements relating to risk assessment for bushfires, flooding and cyclones across all stages of the planning and development of housing, including the quality of data accessed. Questions were based on themes identified in the interviews. Data was defined in the questionnaire according to Deloitte's (2014: 33) definitions of foundational, hazard and impact data.

The questionnaire was designed and distributed using Qualtrics. It was structured into two main sections:

- The first introductory section included questions aimed at capturing general characteristics of the respondent's area of work and level of experience.
- The second section consisted of three main parts, each addressing one of the natural hazards discussed in this research project.

Each section followed the same structure, and included:

1. Questions to rank the importance of information used to assess disaster risk.
2. Likert-scale questions to capture respondents' perspectives on the quality and accessibility of data, and to measure their level of confidence in the quality of data available.
3. Questions for respondents to evaluate their capacity to effectively use data and information.[3]

The questionnaire received approval from Curtin University Human Ethics Research on 8 September 2023. The questionnaire was distributed via relevant professional and industry representative organisations, including the:

- Planning Institute of Australia (PIA)
- Urban Development Institute of Australia (UDIA)
- Western Australian Local Government Association (WALGA)
- Community Housing Industry Association (CHIA).

These organisations were asked to post an invitation to participate in the research and a link to the questionnaire via social media accounts or newsletters. All LGAs in six states—New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia—were sent the survey and asked to distribute it to a relevant representative in their organisation. The link to the questionnaire was also shared directly via email with the industry representative interviewed, along with the researchers' personal industry network. Receivers were asked to forward the invite to participate in the questionnaire within their industry networks as they judged fit and appropriate. The questionnaire was opened on 17 October 2023, with an initial deadline of 10 November, which was later extended to 21 November 2023.

The survey received 125 valid responses.[4] Over two-thirds (69.6%) of respondents were LG planners, with a further 6.4 per cent working in LG sustainability. The data from the survey were used to complement the insights gained from stakeholder interviews and to contribute to a broad knowledge base that informed the workshops.

3 See Appendix 1 for a copy of the questionnaire with definitions.
4 Refer to Appendix 1, Tables A2 and A3 for responses relating to distribution across stakeholder groups and geographical locations.

Literature review

To identify factors contributing to housing vulnerability, we conducted a literature review (LR) for each hazard subject considered in this study—flood, bushfire and cyclone. The vulnerability components identified in the LR were organised according to the housing vulnerability categories identified by Healey, Lloyd et al. (2022: 3), which are (i) housing structure, (ii) type characteristics and (iii) amenities, and (iv) socio-economic indicators. Healey, Lloyd et al. (2022: 10) explain that each of these proxies plays a different role in determining housing vulnerability according to the hazard considered, and is not equally relevant to all geographies. For example, it emerged from the LR that the category 'amenities' was primarily explored in developing countries, and it referred to the availability of water and sanitation facilities (such as water, sewerage, and wastewater collection). Therefore, this category was omitted from the discussion. Through the LR, we extracted common variables (such as properties or characteristics) that were associated with the natural hazards considered. Resources consulted include academic and grey literature.[5] The identified vulnerability elements were then compared to the data used in risk assessment when delivering and planning for housing to identify possible data gaps (responding to research question 3).

1.3.2 Improved decision-making processes

Following the mapping of data and actors, the research focussed on identifying actors' needs and, applying a forward-oriented approach, outlining a framework for an improved decision-making process for future housing development planning and delivery that embraces the use of data sharing and forecasting tools.

Workshops

The research engaged with the identified actors' groups through workshops. The workshop format was chosen for its capacity to discuss specific issues and *'on the one hand, […] fulfil participants' expectations to achieve something related to their own interests. On the other hand, […] to fulfil a research purpose'* (Ørngreen and Levinsen 2017: 72). Three workshops were planned, one in each of the states, Western Australia, Victoria and New South Wales. Specifically, the workshops had the following aims:

- Map key actors' data needs at different stages of the decision-making processes.
- Design a process for integrating the use of assessment and forecasting tools in the decision-making processes, including identifying opportunities and challenges.

Workshops aimed at engaging six to eight representatives of the identified industries in each state. Selected interviewees were asked to participate in the workshop. As an outcome of the interviews, the interest group was revised, and representatives of emergency services were also invited to participate in the workshops. The workshops were run face-to-face in Western Australia, Victoria and New South Wales. The West Australian workshop was held on 5 February 2024 and had nine participants. The Victorian workshop was held on 19 February 2024; out of the nine participants accepting the invite, only six attended. A workshop was organised in New South Wales for 16 February 2024. Only three people joined on the day out of the seven who had accepted the invite.[6] The workshops were designed to:

- validate the findings and fill information gaps (situational assessment)
- identify knowledge, attitudes and practices that encourage participants to adopt changes or prevent them from making changes (audience analysis)
- collaborate on how data use and processes can be improved to integrate assessment and forecasting tools (process mapping).

5 The outcome of the literature review is included in Appendix 4, Section 4.3, which includes a table summarising the identified factors (Table A11).

6 Refer to Appendix 1, Table A4 for a summary of workshop attendees' expertise.

After introductions, participants were briefed on the findings from interviews and questionnaires. The group was then invited to explore a physical map representing key actors' relationships and information used at each state, as established through the desktop analysis and interviews. The workshop facilitator explained the map, stage by stage, inviting participants to add comments and provide feedback. Participants were prompted to identify current gaps in knowledge, and opportunities to improve the process. Each workshop was recorded, transcribed and analysed. Workshop transcriptions were analysed inductively using NVivo software. The outcome of the analysis was shared with the participants so they could validate the mapping and provide further feedback on current challenges and potential solutions.

Best practices

The research identified national and international best practices that demonstrate effective use of data and information systems in natural hazard risk assessment and forecasting. These best practices were selected through a web-based literature review of academic and grey literature. The scope of selected best practices was limited to the three natural hazards featured in this research, but not restricted to any geographical area. These practices are presented together with the outcome of the workshop.

2. Disaster risk assessment: data quality, availability and sharing

- **Australia has a complex data landscape that is unorganised and characterised by data fragmentation and duplication.**
- **Of all data, flood hazard data are the most inconsistent in terms of accuracy, extent of data coverage, accessibility and availability.**
- **While the majority of data have been increasingly made publicly available over time, access to impact data is lagging behind. Impact data is used to identify potential and actual impacts associated with disaster events linked to natural hazards.**
- **In the survey conducted as part of the research, key actors involved in housing planning and delivery identified state and local government policies as playing an essential role in disaster risk assessment, second only to hazard data.**
- **Planners responding to the survey expressed confidence in their ability to source data to inform their decision-making. They indicated greater concern about data quality and currency than availability.**

Effective disaster risk assessment aimed at disaster risk prevention relies on the availability of relevant datasets, sharing systems and platforms (Davlasheridze and Miao 2021; Sheldon and Zhan 2019; Sunarti, Gunawan et al. 2021). The increase in data availability and the advancement of natural hazard modelling, simulation and forecasting systems create opportunities for better disaster risk reduction and management (Migliorini, Hagen et al. 2019). Data-driven approaches to decision-making aimed at evaluating and reducing disaster risk are applicable at every stage of the housing development cycle, from site selection through design and construction (Carramiñana, Bernardos et al. 2024; Rezvani, Falcão et al. 2023). However, to effectively embed data in the decision-making process, it is essential to have a clear understanding of their availability, quality and level of accessibility (research question 1).

In this chapter we present an overview of current data availability relevant to disaster risk assessment for the planning and delivery of new housing, including an examination of how this information is made available (i.e. format, standards, sharing tools). We examine issues and challenges related to data availability and sharing from a stakeholder's perspective. In particular, we discuss what the respondents to our survey consider valuable information in their decision-making processes and their confidence in data quality and accessibility. This discussion provides context and foundation for Chapter 3, where we map what and how data are used to assess disaster risk by the key actors involved in the planning and delivery of new housing.

2.1 Context

While there have been attempts to better embed natural hazard data in decision-making (Gonzalez-Mathiesen, Ruane et al. 2021) there is also a growing recognition of data limitations (Fahad, Hossain et al. 2023). Barriers that preclude data interoperability include:

- the high number of actors involved
- the lack of standardisation in data collection, processing and distribution
- data availability and quality assessment (Migliorini, Hagen et al. 2019: 804).

Within the Australian context, the main issues identified are the lack of standardisation in:

- flood analysis (Alamdar, Kalantari et al. 2017; Dufty, Dyer et al. 2020; Kelly, Schwarz et al. 2023)
- bushfire hazard datasets (McDonald and McCormack 2022)
- tropical cyclone analysis (Mortlock, Metters et al. 2018).

Lack of standardisation leads to inconsistency in data formats and classification methods, which limits opportunities to compare and exchange datasets and analysis results, and to collaborate across different sectors and diverse geographical regions. The temporal and spatial resolution of disaster datasets is also limited by changes in reporting practices over time, which affect data comparability (Hamidifar and Nones 2023; Nones, Hamidifar et al. 2024). Cuthbertson, Archer et al. (2021) identified discrepancies in disaster definitions and accepted level of error margins between the data in the Australian Disaster Resilience Knowledge Hub and the global disaster-sharing Emergency Events Database (EM-DAT). These inconsistencies impede data aggregation and comparison, and restrict the use of this information for predictive analytics and risk assessment.

The lack of standardisation is also a significant challenge for international large-scale disaster dataset-sharing systems and platforms combining information from multiple sources. Jones, Smith et al. (2020) report that the global disaster-sharing database EM-DAT has recorded an increase in missing data, indicating shortcomings in the current data quality procedures. The missing information includes:

- reporting biases
- inconsistencies in data quality and criteria
- variations in completeness across regions and periods
- lack of comprehensive socio-economic data
- absence of severity metrics for events (Jones, Smith et al. 2020).

The European Commission (2020) report on the natural and manmade disaster risks faced by the region highlights inconsistencies in assessment methods and governance approaches to disaster risk across European countries. To tackle this problem, Zuccaro, Leone et al. (2020) suggest the use of an EU-standardised assessment—including shared datasets—to increase cooperation. However, better standardisation could not be achieved without:

- involvement of relevant users (Moallemi, Zare et al. 2023)
- adherence to legal regulations (Ključanin, Rezo et al. 2021)
- trust in shared datasets (Akter and Wamba 2019; Sarker, Wu et al. 2020).

With the increase in the quantity of public and open datasets, spatial data collected and shared voluntarily by individuals—also known as volunteered geographic information (VGI) data—is increasingly applied in disaster management and analysis research (Granell and Ostermann 2016). Recent case studies on the use of VGI data have exposed a lack of assurance, geolocation credibility, limited scale of participation and privacy concerns (Bayazidy-Hasanabad, Vayghan et al. 2021; Cui, Malleson et al. 2021; Feng, Huang et al. 2022; Wu, Lin et al. 2021). However, the main concern with VGI data is quality assessment and reliability of information shared, as the data is provided by individuals who often lack professional training (Bai, Satarpour et al. 2024).

2.2 Mapping data availability, quality and accessibility

The 2014 Deloitte report *Building an open platform for natural disaster resilience decisions* identifies three critical sets of data required by key actors to make informed decisions on disaster risk associated with natural hazards. These are foundational data, hazard data and impact data (Deloitte 2014). In the context of this research, we adopted these categories and their definitions to organise the mapping of the currently available data. Figure 1 provides an overview of the data type included in each data category, and identifies who is responsible for collecting and managing data (foundational and impact data) and data providers and custodians (hazard data).

In the following sections, the data categories summarised in Figure 1 are discussed in more detail.

Figure 1: Foundational, hazard and impact data mapping overview

Foundational data

Base layers of locational information relevant to all hazards, including exposure data and fundamental geographic data. Used for a broad range of purposes, including but not limited to analysis of natural disasters *(Deloitte 2014: 33)*

Land cover data
provide information on quantity and location of vegetation and waterbodies and are used to examine landscape patterns and characteristics.

Collection and management
- *Federal gov. organisations*

Topographic datasets
information about the shape, elevation and features of the surface of the Earth, both natural and purpose-built. structures.

Collection and management
- *Federal gov. organisations*
- *State gov. departments*

Weather datasets
include current and historical localised information on temperature, humidity, precipitation, wind speed, wind direction, cloud coverage and sea state.

Collection and management
- *Federal gov. organisations*

Climate change datasets
based on modelling of climate observations (reanalysis) and different GHG emissions scenarios (projections).

Providers
- *Federal gov. organisations*
- *State government departments*

Buildings spatial data
information related to building characteristics such as area, height, roof type, and materials.

Collection and management
- *State gov. agencies*
- *Publicly owned company*

Socio-economic datasets
information on demographic characteristics such as individual age and sex, education, marital status, family size, occupation and types of housing.

Collection and management
- *Federal gov. organisations*
- *State government departments*
- *Local governments*

Water datasets
include georeferenced data on water storage, bodies of water, water quality and meteorological monitoring sites.

Collection and management
- *Federal gov. organisation*
- *State gov. environmental and water management dept., agencies and authorities*
- *Local governments*

Hazard data

Hazard-specific information on the risks of different disaster types, providing contextual data about the history of events and the risk profile for Australian locations
(Deloitte 2014: 33)

Flood studies
technical calculations that use historical data and computer models to simulate flood events, including depth, velocity, and extent of flooding.

Custodians
- *Local governments*
- *State gov. environmental and water management dept., agencies and authorities*

Providers
- *Specialised consultancy*
- *State gov. environmental and water management dept., agencies and authorities*

Flood hazard maps
identify areas covered by water during real or potential flood events of a magnitude that has a 1% chance of occurring in any given year (100-years).

Custodians
- *Local governments*
- *State gov. environmental and water management dept., agencies and authorities*

Providers
- *Specialised consultancy*
- *State gov. environmental and water management dept., agencies and authorities*

Bushfire-prone areas maps
identify land that has the potential to be impacted by bushfires. Hazard levels are modelled considering topography, fire fuel type, and weather.

Custodians
- *State government departments*
- *Local governments*
- *Fire emergency departments*

Providers
- *Fire emergency departments*
- *Local governments*

Bushfire attack level assessments
measure the severity of a building's potential exposure to ember attack, radiant heat and direct flame contact.

Custodians
- *Proponents*

Providers
- *Specialised consultancy*

Cyclone hazard recurrence interval 25/500 years map
identifies areas according to the wind speed that would be exceeded, on average, once every 25/500 years.

Providers and custodians
- *Federal gov. organisations*

Wind region classification map
classifies Australian regions based on wind speeds and frequency of extreme weather events these experienced.

Providers and custodians
- *Federal gov. organisations*

Impact data

Data on the potential and actual impacts associated with natural disasters, including information on historical costs and damage and the current and predicted future value at risk
(Deloitte 2014: 33)

Building and infrastructure damage
number and value of dwellings damaged or destroyed by the event and damage to public infrastructure, including roads and public buildings.

Collection and management
- *Local governments*
- *State emergency management agencies*
- *State dept. of finance*
- *Property Insurance companies*

Fatalities and injuries
number of people injured or killed due to natural disaster events.

Collection and management
- *State dept. of health*
- *State emergency management agencies*
- *Health insurance companies*

Evacuation and displacement
number of people evacuated and relocated due to natural disaster events.

Collection and management
- *Local governments*
- *State emergency management agencies*
- *State gov. social and community services dept. and agencies*

Health data
social, psychological and health impacts during and after natural disaster events.

Collection and management
- *State dept. of health*
- *State gov. social and community services dept. and agencies*
- *Research organisations*

Financial assistance
total value of relief payments and financial assistance (state and federal funds) provided to residents of areas impacted by natural disaster events.

Collection and management
- *Nat. emergency management agencies*
- *Nat. dep. of treasury*
- *State dep. of treasury*

Reconstruction and recovery
total value response and recovery programs for recovery and reconstruction (state and federal funds) invested in areas impacted by natural disaster events.

Collection and management
- *Nat. emergency management agencies*
- *State emergency management agencies*
- *Nat. dep. of treasury*
- *State dep. of treasury*

Insurance losses
total amount of money paid out by insurance companies to cover claims for dwelling or building damaged by a natural disaster event.

Collection and management
- *Property Insurance companies*

Total economic cost
sum of the asset losses and the associated financial and social costs incurred due to natural disaster events.

Provider
- *Nat. dep. of treasury*
- *State dep. of treasury*

Source: Authors.

2.2.1 Foundational data

Foundational data (FD) constitute the *'base layers of locational information relevant all hazards'* (Deloitte 2014: 33). They provide descriptive information about current characteristics of identified areas of interest, including:

- physical characteristics—including geology, hydrology, topography and weather
- social and administrative characteristics—such as cadastral, addresses and boundaries.

FD can generally be used for different purposes. However, while they do not explicitly provide information related to natural hazards, they constitute the building blocks of disaster risk identification and analysis (hazard data).[7] In Australia, the majority of FD relevant to hazards are collected and managed by federal agencies. The three leading providers are:

- *Bureau of Meteorology (BoM):* collects and manages current and historic weather (climate change datasets) and water-related data, which are publicly available. BoM also provides specific datasets on a needs basis. It is responsible for collating information gathered from state-based water management agencies.
- *Geoscience Australia (GA):* provides information related to land and landscape characteristics captured via satellite (Landsat), such as the presence of water and vegetation. GA also maintains a national, local wind multiplier dataset used to convert regional wind speeds to local wind speeds.
- *Australian Bureau of Statistics (ABS):* provides socio-economic and asset information through census data, which are publicly available.

Two main types of FD are provided and managed at the local government (LG) and state level:

- water monitoring and reporting datasets: specific data relating to water level, flow, quality and rainfall. The data are part of the information collated by BoM.
- socio-spatial datasets: suites of datasets providing spatial foundation information for mapping.

These datasets are vector data on administrative (cadastral information) and physical (i.e. contours, water tables, etc.) characteristics and are generally freely available via state-managed data-sharing websites.

However, the public-owned company Geoscape Australia is the referring provider of national location data and built datasets. Geoscape derives its data from private and public sources, including state authorities and LGAs, which are continually updated (Geoscape n.d.). These data include geocoded addresses (G-NAF), administrative boundaries, building characteristics, transport and topography, and points of interest. The datasets require a subscription for access.

Climate projection and scenarios

Climate-change-related datasets are not identified in the Deloitte (2014) report as part of the information relevant to disaster risk and natural hazard exposure in Australia. However, these datasets are increasingly considered when assessing natural hazard risk (Barandiarán, Esquivel et al. 2019; Callaghan and Hughes 2022). These datasets consist of modelled data on climate change observations and scenarios based on future greenhouse gas emissions, which are used to identify possible increases in climate-related hazards (climate projections). These projections can be considered essential building blocks in hazard risk identification and analysis, as they describe how natural hazards are likely to change. As such, their use aligns with the FD definition of 'base data relevant to all hazards' (Deloitte 2014: 33).

7 Refer to Appendix 2, Table A5 for a complete list of foundational data, including type, sources and sharing platforms.

Different climate projections and modelling datasets are available in Australia. These datasets have been developed by federal and state government agencies to reflect their specific needs and jurisdiction—and, therefore, differ in their geographic scope, spatial resolution, choice of emissions futures, and underlying modelling approaches.

As summarised in the *Climate Projections Roadmap for Australia*, the work done so far *'evolved through priority projects and available resourcing, resulting in inconsistent climate information across jurisdictions'* (DCCEEW 2023: 7). However, the federal government and state-based environmental and water management agencies, together with various research institutions, are working together through the National Partnership for Climate Projections (NPCP) group to produce more consistent and up-to-date climate data. Among the initiatives identified are the production of:

- national climate hazard projections for tropical cyclones, fire weather, and heavy rainfall (flooding)
- state-based initiatives to downscale projections for specific regions (DCCEEW 2023).

2.2.2 Hazard data

Unlike foundational data, hazard data (HD) are disaster-specific. Deloitte (2014: 33) defines HD as '*hazard-specific information on the risks of different disaster types, providing contextual data about the history of events and the risk profile for Australian locations'.* HD relating to historical data collection of disaster events is compiled at the national level via the open-source platform Australian Disaster Resilience Knowledge Hub (the 'Knowledge Hub'), while data on risk profiles depend on how the natural hazard is addressed administratively and legislatively.

For example, flooding and bushfires are addressed through planning systems, with responsibilities relating to data shared between state governments and LGAs. Accordingly, HD used in the planning and delivery of housing is produced and administered by agencies and departments within these two levels of government.[8] However, cyclones are addressed at the national level via the National Construction Code (NCC). Because of the complexity and diversity, we will discuss HD relative to flooding, bushfires and cyclones separately.[9]

Flooding

Hazard data related to flooding refers primarily to flood studies and maps. Flood quality, level of accuracy and extent of data coverage vary across states and local jurisdictions.

In *New South Wales*, LGAs are responsible for providing flood studies and maps—and they are responsible for the custodianship of such information. The state offers technical and financial assistance to LGAs on sourcing and using the information, including standards and requirements. Digital datasets for flood hazard data mainly consist of reports and maps, with limited numbers of them being digitalised and available for the geographic information system (GIS). The digitalisation of datasets is challenging, as each council has its own flood programs, risk planning and data interpretation. Moreover, updating this data requires outsourcing—and funding allocation.

In *Victoria*, LGAs lead and co-fund the provision of essential flood hazard data. The Victorian flood data and mapping guidelines provide a reference for flood risk mapping and data collection, including setting standards (Water and Catchments 2023). Flood hazard mapping is included as a layer in the Vicplan tool (flood overlay). Flood information before, during and after floods is available via the FloodZoom web-based tool, which combines hazard data and impact data. However, access to FloodZoom is restricted, and users' access levels differ (Department of Environment, Land, Water and Planning [DELWP] 2016).

8 Refer to Appendix A4.1 for an overview of the legislative requirements and responsibility for bushfire and flood data sourcing and management in New South Wales, Victoria and Western Australia.
9 Refer to Appendix 2, Table A5 for a complete list of Foundational data, including type, sources and sharing platforms.

In *Western Australia*, responsibility for floodplain mapping lies with the state Department of Water and Environmental Regulation (DWER), which provides flood data for all rivers and major watercourses in the state. The flood maps are digitalised and accessible via a GIS mapping tool. This tool is intended for general interest use and as a guide for land-use planning (WA Government, n.d.). However, flood studies are not accessible. Moreover, flood data for some regional areas are not available.

Bushfire

Hazard data related to bushfires is predominantly captured in bushfire-prone areas (BPA) maps, which identify areas that are subject to bushfires, or likely to be subject to bushfires. In Victoria and Western Australia, state agencies are responsible for producing BPA maps:

- Victoria: Department of Transport and Planning (DTP)
- Western Australia: Department of Fire and Emergency Services (DFES).

In New South Wales, LGAs prepare bushfire-prone land maps, following the guide and standards set by the New South Wales Rural Fire Service (NSW RFS), which is also responsible for certifying the maps (NSW RFS 2015).

BPA maps do not directly provide hazard data, but indicate hazard levels established based on modelled FD, including topography, fire-fuel type and weather. Each state considers local conditions to identify hazards and has a different approach to classify risk levels. A BPA map in:

- New South Wales identifies three vegetation categories and one buffer zone.
- Victoria uses three bushfire hazard levels (BHLs) with corresponding risk levels.
- Western Australia identifies two types of bushfire hazards that differentiate densely built areas from the rest of the state. While categories are different, the establishment of these hazard levels responds to the requirements of Australian Standard AS 3959-2009.[10]

BPA maps are revised on a regular basis. In New South Wales, maps are reviewed on a five-year cycle if not required earlier (NSW RFS 2015). In Victoria, these are set to be updated every six months; however, as it is not possible to complete this task for all BPA areas in the state in this time frame, sites are reviewed on a need basis (DELWP 2019). In Western Australia, it is revised annually to capture *'major changes or updates in vegetation extent that are not reflected in the current version of the Map'* (DFES 2021: 15). In all states, BPA maps are freely downloadable via the respective state's data-sharing portals and available in different georeferenced vectorial formats. The maps can also be visualised using the respective states' land-use planning GIS tools: the New South Wales Planning Portal spatial viewer, Vicplan (Bushfire overlays) and PlanWA.

Bushfire attack level (BAL) assessments should also be considered when discussing bushfire-related HD, as they provide information on risk levels. Required under Australian Standard 3959-2009, these assessments establish a property's potential exposure to bushfires and work in conjunction with BPA maps to identify relevant building requirements.

10 This map is linked to the State Planning Policy 3.7 Bushfire (SPP 3.7), which was published on 24 September 2024, and became operational from 18 November 2024, along with the Planning for Bushfire Guidelines (the Guidelines).

Cyclones

Geoscience Australia provides national Recurrence Interval 25 years/ 500 years cyclone maps and tropical cyclone hazard assessments (TCHA).[11] These assessments are used to plan for and reduce the impacts of tropical cyclones during forecasted events. Cyclone risk mitigation is addressed at the building level via construction standards. The federal government—through the Australian Building Codes Board (ABCB)—establishes performance requirements for buildings at risk of exposure to severe winds in the Building Code of Australia (BCA).[12] Underpinning the risk assessment for cyclones is the wind region map classification included in the AS/NZS structural design standard 1170.2:2021.[13] The map identifies four wind regions within which the wind speed is comparable (Cechet, Sanabria et al. 2011). These are used to determine the wind speed to calculate structural loads for buildings located in these regions. Because of this national legislation approach to cyclones, risk assessment is uniform and consistent across the country.

2.2.3 Impact data

Impact data (ID) are defined by Deloitte (2014: 33) as *'data on the potential and actual impacts associated with natural disasters, including information on historical costs and damage and the current and predicted future value at risk'.*

Thus, this type of data includes historical information quantifying damage caused by disaster events that can be used to determine the economic cost of natural hazards and support risk modelling. ID include infrastructure and building (including residential) damage, fatalities and injuries, number of evacuees, government financial assistance and insured losses (Deloitte 2014). These data are held by emergency management agencies at the state and local levels. NEMA collects some of the information from state and local governments and collates it in an interactive map, which includes general data and information on hazard impact and relief and recovery support.

In Victoria, Emergency Management Victoria (EMV) gathers information from various agencies on the extent of damage, immediate threats, loss of life, and persons displaced. In Western Australia, each agency holds relevant data, including LGAs and state government agencies. In New South Wales, the Spatial Services Emergency Information Coordination Unit (EICU) implements and maintains a collaborative data-sharing system for emergency service organisations and the emergency management sector in the state, including the Emergency Services Spatial Information Library (ESSIL). The library combines data relevant to emergency planning, response and recovery that are sourced from over 200 agencies (NSW Government n.d.). Insurance companies also collect and retain important information related to the impact of disaster events, which is collated by the Insurance Council of Australia (ICA).

2.3 Users' perspective on data

The analysis of the survey responses provides a first critical insight into users' decision-making processes and an understanding of their perspectives on data. The questionnaire was designed to capture the level of importance respondents place on key elements relating to risk assessment for bushfires, flooding and cyclones across the planning and development of housing, including the quality of data accessed.

11 Geoscience Australia provides cyclone data through the Recurrence Interval 25 Years Map (Arthur 2018). The data visualised in the map is the outcome of a cyclone hazard assessment developed using the Tropical Cyclone Risk Model (TCRM)): an open-source statistical-parametric model that uses historical data to evaluate cyclones' intensity and event probability (Arthur 2021).

12 BCA forms chapters 1 and 2 of the National Construction Codes (NCC).

13 The standards have been recently revised. In this latest revision, a mandatory climate change multiplier (1.05) was included to reflect the evidence that tropical cyclones will intensify due to global warming (Bell, Dowdy et al. 2022).

The survey was distributed via relevant professional and industry representative organisations. It received 125 responses, with over two-thirds of respondents being local government planners or working in local government. Overall, the survey captured 18.3 per cent of LGAs in the six states surveyed. Therefore, the findings discussed in this section mainly reflect a local government perspective.

In particular, we discuss and compare findings related to flooding and bushfires, as we recorded a very low number of respondents completing the questionnaire section related to cyclones. The low response rate to this section of the survey is associated with the profile of respondents—LGA representatives—and the fact that cyclone hazard mitigation is addressed through the building construction regulations and not via the planning system, as in the case of bushfires and flooding.

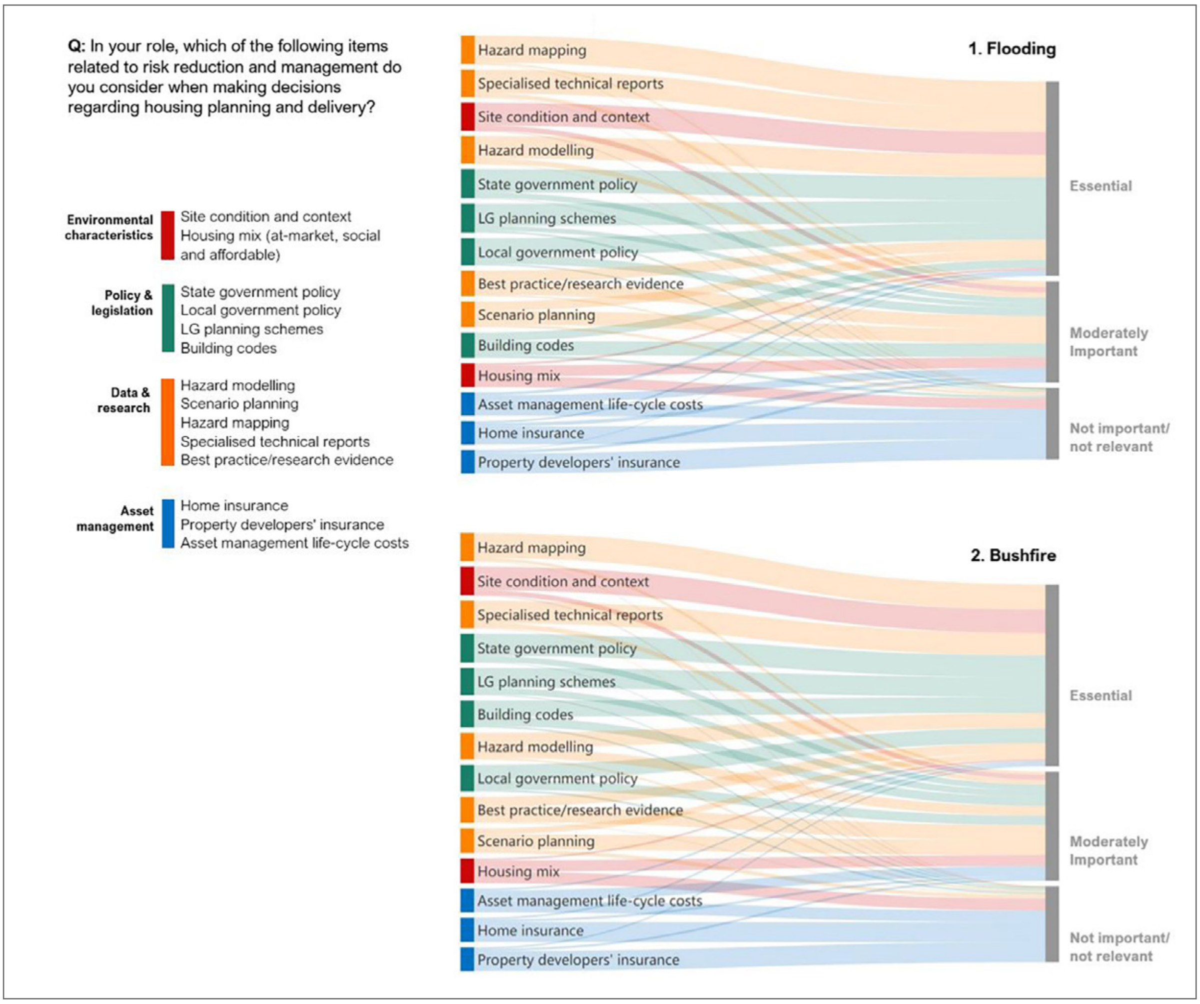
While we do not directly compare responses related to cyclone risk assessment with responses recorded for bushfires and flooding, we refer to them in our discussion, assuming a qualitative approach. The majority of responses to this section of the survey are from planners with a minimum of 10 years of work experience (and over half having more than 20 years of experience) from Western Australia and Queensland, where cyclones are of particular relevance. We also draw on the responses included in the open-ended questions to complement and contextualise the findings.

For the questionnaire, a list of 15 items was compiled, drawing from the literature and the interviews. These can be divided into four main categories: (i) environmental characteristics, (ii) policy and legislation, (iii) specialised data and research, and (iv) asset management (see Figure 2) for the complete list of items). Respondents to the survey were asked to share which information and data they used when assessing DRR and management and categorise them as essential, moderately important, and not relevant. For flooding and bushfires, the respondents regarded hazard information (mapping, modelling and technical reports), site condition and context, and policies as essential information in decision-making (Figure 2).

Specifically, 84 and 81 per cent of respondents identified flood and bushfire-prone land maps as essential, with hazard mapping ranking first in the top five sources of information used by respondents when considering risk reduction and management for flooding and bushfires (Figure 3). However, 20 per cent more respondents considered hazard modelling essential for flooding compared to bushfires. These findings could be explained by the fact that bushfire modelling is more standardised and hazard data are produced with the support of state fire emergency agencies and managed at a state level, while flood hazard data are more fragmented and inconsistent as they are managed at the local government level.

Almost two-thirds of respondents (n=81) included state policies and site conditions and context as essential information for risk assessment for flooding and bushfires. However, when looking at this information in relation to the placed importance, respondents who were not from local government ranked site condition and context higher than hazard mapping for bushfires (Figure 3).

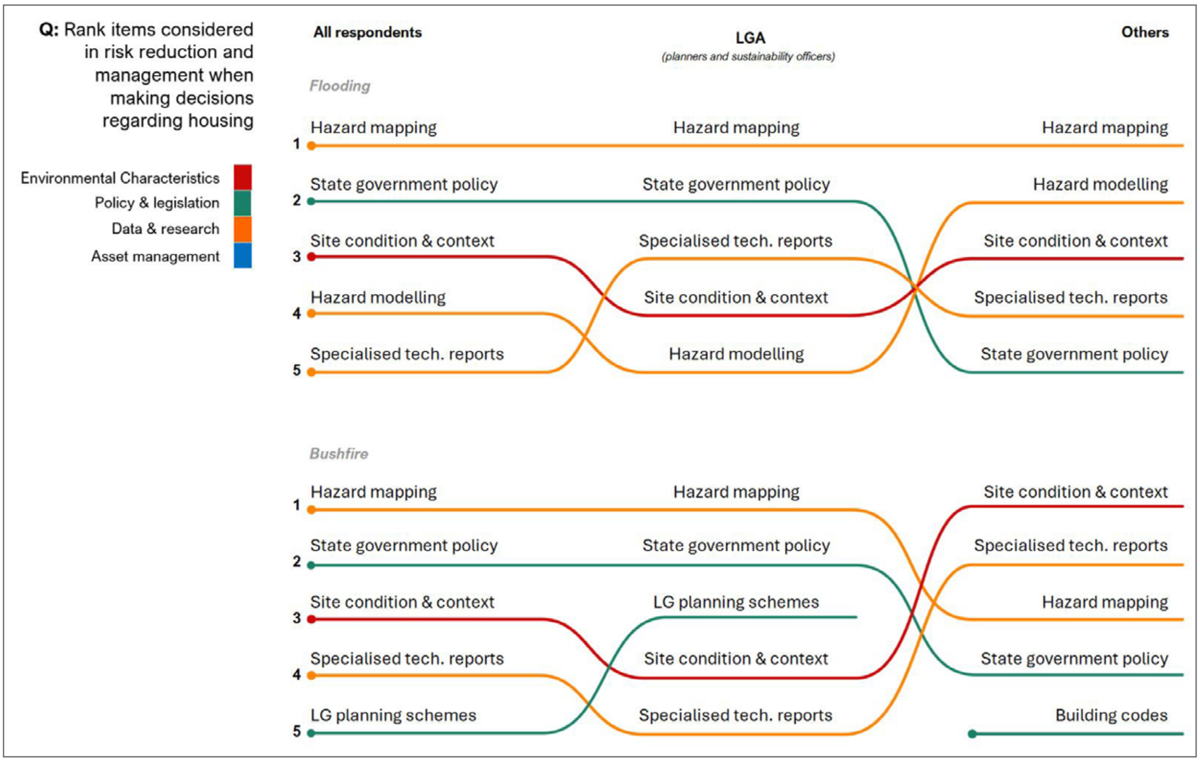
Figure 2: Sankey diagram: information used for flood and bushfire risk reduction and management in decision-making relative to housing delivery



Source: Authors.

However, respondents from local government ranked state policies in second place for both bushfires and flooding. Policies at the local level, including local government schemes, were listed under the 'essential' category by more than half the respondents (flooding (69%) and bushfires (64%)). Building codes were also identified as essential for bushfires by over half (52%) of respondents. This outcome in ranking from planners reflects the role played by land-use planning policies and national building legislation in DRR compared to urban development. Decisions on development approvals are made in consideration of requirements dictated by statutory frameworks. In the open-ended section of the questionnaire, respondents pointed out that there is an 'overconfidence' in AS 3959:2018 Construction in Bushfire-prone Areas. A New South Wales respondent identified a lack of knowledge about risk in the unrealistic perceptions and expectations held by developers and homebuyers that if building codes were met and legislated procedures were followed, then the risk of bushfires would be removed. The respondents also extended this false sense of security and overconfidence in the legislative framework to the planning system, asking, *'how far the planning system can be applied to assess risk'.*

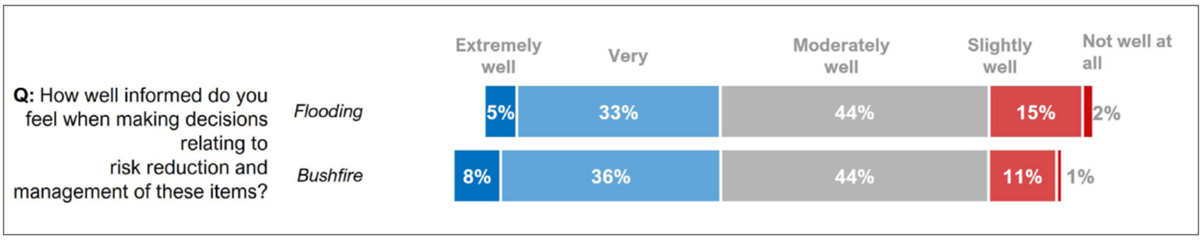
Figure 3: Top-5 information considered essential in decision-making for risk reduction and management by respondent type (All, LGA, others) for flooding and bushfire



Source: Authors.

Overall, respondents said they felt adequately informed when making decisions about flood and bushfire disaster risk reduction and management. More than a third expressed high confidence (extremely and very well informed) (flooding (38%) and bushfires (44%)). Almost half (44%) felt sufficiently informed (moderately well) (Figure 4).

Figure 4: Respondents' level of confidence in feeling informed in taking decisions related to hazard risk reduction and management for floods and bushfires (%)

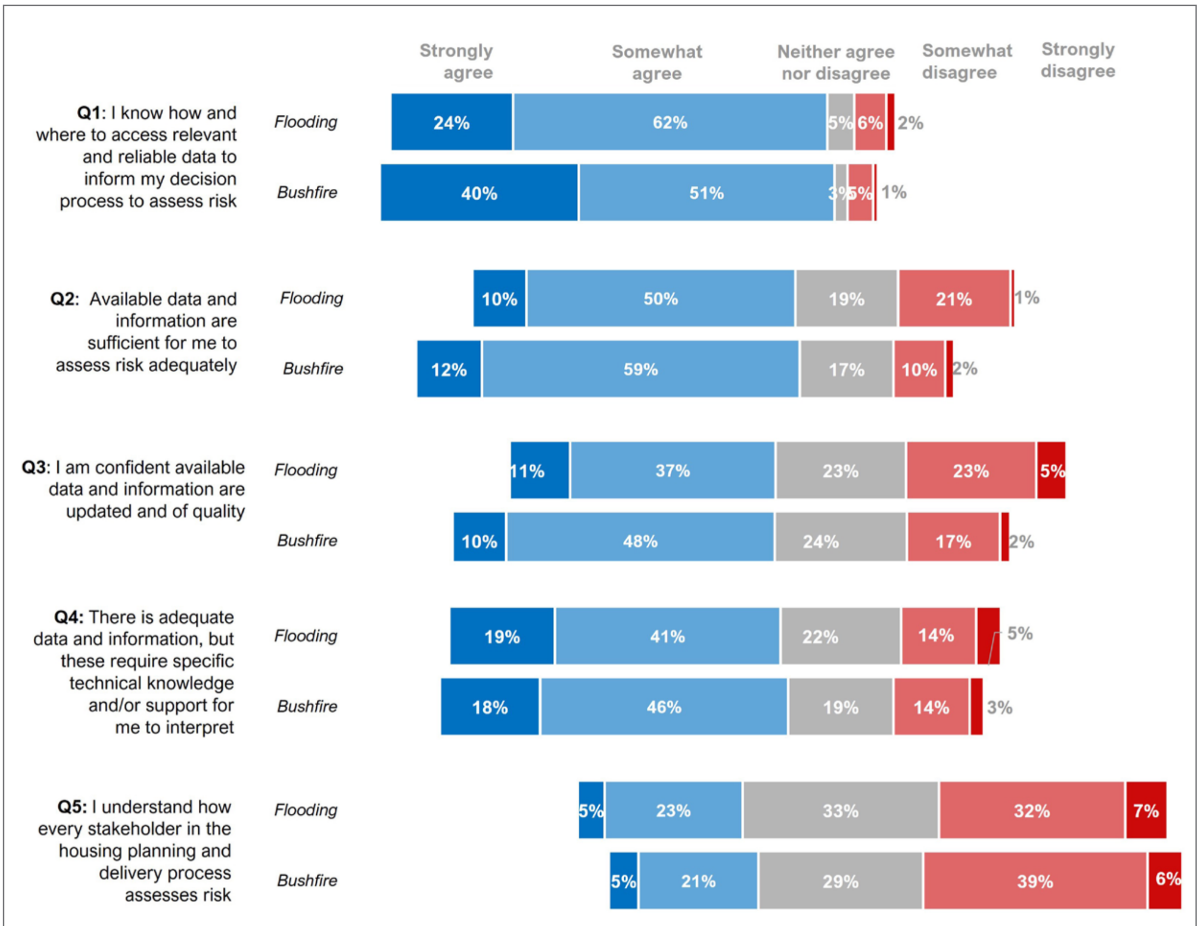


Source: Authors.

While the numbers of responses cannot be compared, it is worth noting that for cyclones, the confidence level is similar in percentage to the other two natural hazards (bushfires and flooding) and does not show significant differences between the two states (Western Australia and Queensland) or planning roles (state, LG, or private) or respondents' level of expertise.

When asked to express their agreement to the statement '*I know how and where to access relevant and reliable data to inform my decision process to assess risk',* respondents expressed overwhelming confidence in their ability to source data to inform their decision-making. Ninety-one per cent agreed with the statements in relation to bushfires, and a comparable figure of 86 per cent expressed similar confidence in flood data (Q1, Figure 5). Only a marginal percentage of respondents expressed a neutral position. These are very low percentages when compared to the average 20 per cent neutrality recorded in the questions related to quality, currency, availability and accessibility of data (respectively, Q2, Q3 and Q4, Figure 5). Over half the respondents consider available data sufficient to inform risk assessment: 71 per cent for bushfires and 60 per cent for flooding. The remaining respondents were split between neutral position and disagreement. Note that the disagreement recorded on flood data (22%) is almost double that of bushfire data (12%) (Q2, Figure 5).

Figure 5: Respondents' level of confidence in data accessibility, quality and quantity for floods and bushfires (%)



Source: Authors.

Responses to the statement *'I am confident available data and information are updated and of quality'* (Q3 Figure 5) were divided reasonably evenly between agreement and neutral/disagreement positions. On the agreement side, around 10 per cent of respondents expressed solid confidence (strongly agreeing). Just over a third (37%) of respondents did not feel confident in flood data quality. Overall, they expressed greater concerns in relation to quality and currency of data (Q3) than data availability (Q2). It is interesting to note that such a lack of confidence in data quality and currency was mostly expressed by Western Australia-based state and LG planners (37%) and New South Wales LG planners (30%). Only a quarter of respondents (flooding (28%) and bushfires (26%)) indicated that they 'somewhat' understood how all key actors are involved in the housing planning and delivery assessment of flood and bushfire risk. The disagreement expressed with this statement is the highest among all questions asked.

2.4 Conclusions

The comprehensive review of data and research in Australia conducted by Deloitte (2014: 4) 10 years ago found that disaster-related data were *'difficult to access, often incomplete or out of date and frequently duplicated across sources'* and *'often single-purpose and the needs of multiple actors have not been considered'*.

According to the more recent mid-interim report on Australian progress in the implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030 compiled by NEMA (2022: 39), Australia is still not performing well regarding disaster-related data availability, quality and accessibility due to a '*fragmented and complex data ecosystem'.* This is proved by the comprehensive review of disaster data conducted as part of this research.

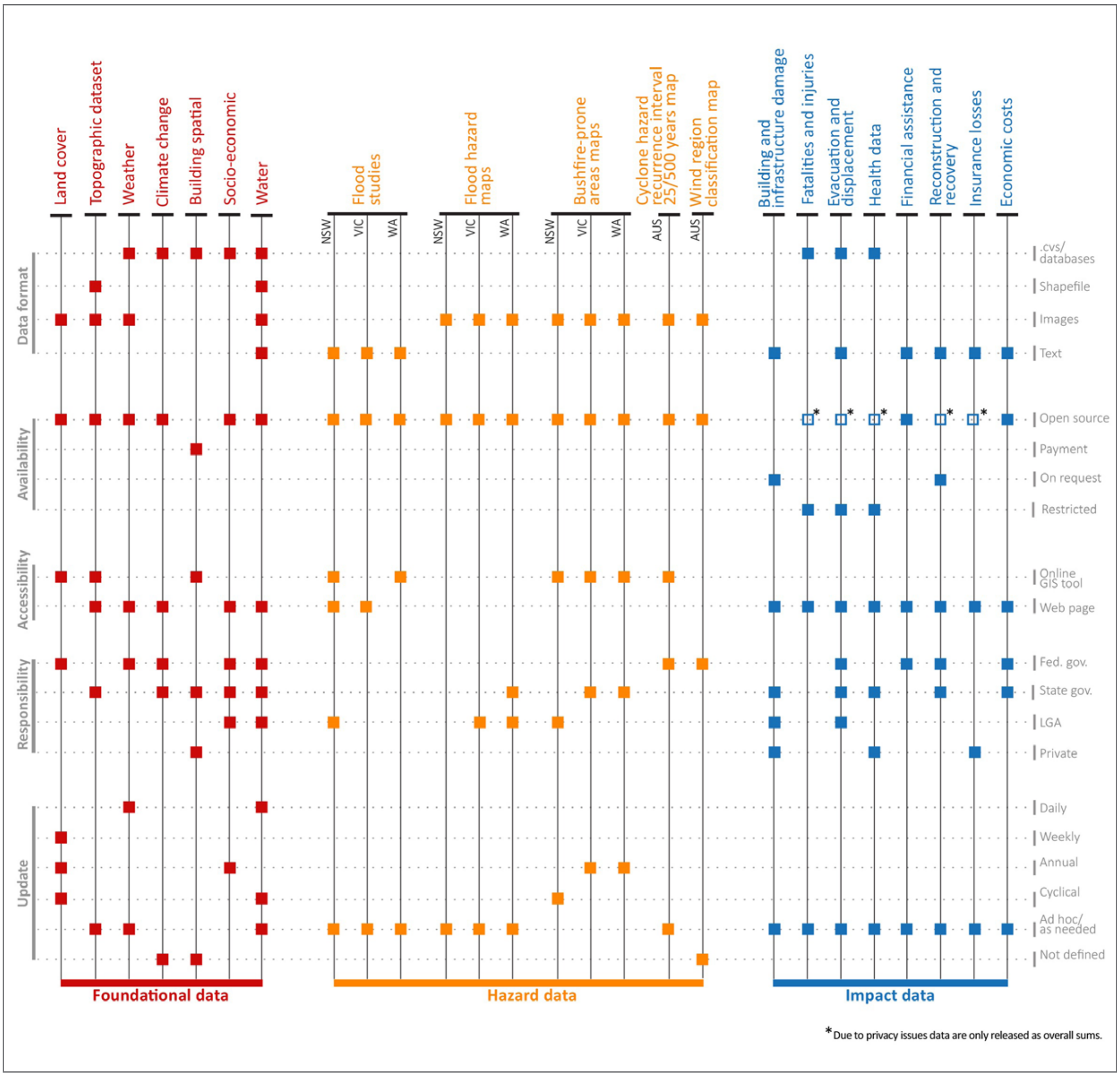
Figure 6 summarises the data discussed in the first part of this chapter, and maps the specific information related to the data format, availability, accessibility, the agency responsible, and frequency of updates as fully detailed in the tables included in Appendix 2. Figure 6 shows which data can be used to inform DRR and prevention is currently available at all levels of government, within different agencies, and private enterprises, disjointly organised and presented, with most of the data shared using different platforms.

The data mapping highlights that standardisation and quality of datasets change according to the hazard considered, and depend on jurisdictional institutional arrangements, policies and practices. Lack of standardisation:

- leads to inconsistency in data formats and classification methods
- limits opportunities to compare and exchange datasets and analysis results
- hinders collaboration across different sectors and diverse geographical regions, which results in fragmentation of information and decisions.

In particular, for flood data, although state and national flood standards are established, these are utilised and contextualised locally. Issues are more evident and pronounced in states where flood data are produced and managed at the LG level, such as New South Wales and Victoria. However, even in Western Australia, where floodplain mapping falls under the state's responsibility, there are some areas where these data are not available—such as in the regions and remote areas. Moreover, these data are often provided by external consultants, which makes them expensive to source and update regularly. External sourcing and limited LG budgets also create problems of data accessibility as the intellectual property is retained by the consultants undertaking the flood study. In the questionnaire's open-section responses, the data quality emerged as a recurring theme around flooding

Figure 6: Data mapping overview of data format, availability, accessibility, responsibility and frequency of updates



Source: Authors.

One New South Wales LG planner contextualised the lack of data quality with how the responsibility around data sourcing is shared and managed, pointing out that:

> *Unlike bushfire, flooding data in New South Wales is not managed by a central authority. Local government is required to follow a guideline, but oversight is lacking, and methodology is left to consultants. It can also be more locally political, given that local government is largely responsible for the modelling and reporting of data.*

Data relating to flood risk assessment is described by a planner from Queensland as *'patchy, of varying quality and currency and not always open source'.* The availability of relevant and accurate hazard modelling is essential to decision-making. As shown by the survey, these are the data that planners use the most in decision-making regarding risk assessment and management.

The data mapping also reveals that impact data held by emergency management agencies, local government and insurance companies are mostly not openly accessible because of privacy or commercial issues. These data should be made accessible, as they contribute to assessing exposure to natural hazards. All research participants involved recognised the importance of the accessibility of this data in order to inform effective risk reduction strategies. Much energy and financial commitment has been invested in recent years to improve data sharing among government agencies, between government agencies and the private, and to explore how these data can also be made available to the general public. In particular, the insurance industry is increasingly consulted and involved in the disaster risk conversation, including data sharing issues. As the outcome of the research conducted by Box, Kostanski et al. (2021: 12) points out:

> *There is mutual industry and government desire for data sharing to support improved DRR decision-making. Data sharing initiatives exist, but scaling is hindered by a lack of agreement on the scope and use of data, and insufficient data sharing frameworks (standards, protocols).*

At the end of 2023, the Australian Prudential Regulation Authority (APRA) and the Australian Securities and Investments Commission (ASIC) released two joint discussion papers to seek feedback on their proposals for the Insurance Data Transformation (IDT) project aimed at addressing data sharing issues such as regulatory burdens and data availability (APRA and ASIC 2023).

2.4.1 Policy development

ISSUE

Australia has a complex data landscape that is unorganised and characterised by data fragmentation and duplication.

There are two main priorities that need addressing to help simplify and better navigate the current data landscape:

- **Reduce data fragmentation.** Data fragmentation is linked to the different ways in which information is produced based on standards and parameters established within state and local government legislation and policies. This is particularly evident in hazard data related to flooding.
- **Eliminate duplication of information** associated with the sharing of the same data across multiple platforms, which are managed by different government agencies. Duplication contributes to increasing data inconsistency and inaccuracy. Inconsistencies and inaccuracies impact risk assessment, and lead to poor decision-making.

Policy development opportunities that will contribute to addressing these issues are as follows:

- Establish an overarching governance system that is responsible for clearly mapping and quantifying data quality and availability, successfully establishing protocols for intervention, and setting parameters for data management to guarantee long-term management of the issues.
- The Digital Transformation Agency (DTA) could be the leading agency in the establishment and implementation of this governance system.
- Establish a working group comprising state and local level representatives to support the work of the DTA, whose representatives are responsible for leading and facilitating the implementation of the framework within the government agencies in their state.
- Provide financial and technical support to individual government agencies to revise and improve data management, security and privacy policies that address the requirement of established protocols for data, managing duplication and fragmentation and facilitating sharing protocols.

ISSUE

Flood hazard data are currently the most inconsistent data in terms of their quality, level of accuracy and extent of data coverage.

Achieving better flood hazard data requires intervention and the development of consistent flood hazard data and support strategies to maintain the relevance and accuracy of flood hazard data. These objectives can be achieved through interventions addressing (i) standardisation, (ii) water governance structures, and (iii) supporting capacity-building. Recommended policy interventions and actions to address these objectives are as follows:

- **Establish and enforce national protocols for flood data modelling**. The protocols will provide a legislative framework that establishes roles and responsibilities, as well as a data management plan that includes data-review time frames. The protocol can be paired with data modelling guidelines. The use of guidelines linked to the protocol—rather than embedded in the legislative framework—is to enable easier review of the calculation model endorsed as new or improved models are available.
- **In Victoria and New South Wales, a single state-based agency or department in charge of water management should be appointed,** which is also responsible for producing and managing catchment-level flood data. The appointment of a state-based agency is essential to overcome issues of data quality brought forward by fragmentation of jurisdictional responsibilities and support for water/flood management at the catchment level.
- **Develop financial models aimed at providing ongoing funding for regular flood hazard data review and maintenance** to guarantee the accuracy and consistency of data across catchments.
- **Build and maintain technical skills within the state agencies in charge of state water management.** These agencies can work in coordination with national research institutions such as Geoscience Australia and CSIRO to produce the modelling. 'In-house' production of modelling based on government data will limit the reliance on external private consultants and address issues posed by data intellectual properties.

ISSUE

While overall data availability and accessibility have improved over time, access to data—which identifies potential and actual impacts associated with natural disasters—is lagging behind.

The discussion and consultation generated by the discussion paper on the IDT proposal is the first step toward the essential policy action needed for improved data sharing relative that entails:

- **Co-designing processes** to enable the sharing and use of data across different government agencies, and between government agencies and external players, based on a shared established vision and goal of the role of the data-sharing process in relation to DRR.

The creation of protocols for data exchange outside of the individual government agency requires each of these agencies to:

- **strengthen individual agencies' data governance** by addressing data management, security and privacy policies.
- **improve the safety and security of digital environments** to facilitate the sharing of data in line with the Intergovernmental Agreement on Data Sharing (IGA).

These actions will also contribute to addressing the fragmentation and duplication of data linked to the lack of data accessibility across all data providers and users—including government and private industries, not just emergency management agencies—benefitting the data-sharing process overall.

3. Planning and delivery of housing: use of data for natural hazard risk assessment

- **Policies and development controls play a crucial role in the housing delivery process, as they are used by other actors, such as developers and lenders, to inform their decisions.**
- **The lack of quality, accurate and consistent flood data is a weak point in the planning system. These issues lead to disputes during policy community consultation and development assessment processes.**
- **Planning processes are not agile enough to keep up with the fast pace of information and available data.**
- **Participants identified a siloed approach to policy development as limiting the flow of information between agencies, resulting in planning and housing policies being disconnected at the strategic level.**
- **Insurance plays a critical role in the development process, as it underpins access to mortgages. The availability of insurance acts as a vehicle to communicate to households the level of risk the dwelling is exposed to.**

There are many different actors in the housing development process engaging at various stages, and each plays a critical role in ensuring the delivery of safe housing. Within this research, we have engaged with representatives from the following four main groups: government planning agencies, social housing providers, developers and financial providers. Furthermore, for the scope of this research, the housing planning and development process was conceptualised into five stages:

- Land-use planning strategic and statutory frameworks
- Development feasibility and appraisal
- Planning approval
- Building approvals and construction
- Disposal.

For each stage, we examined what data are used by the key actors to guide their decision-making around natural-hazard risk assessment and identification of mitigation measures. This chapter charts this process, and highlights the issues related to quality, accessibility and use of data—and how they impact decision-making.

The chapter is divided into two main sections, discussing the planning process and housing delivery. Alongside the data issues, each section also examines the relationship between actors. The decision-making process mapping was developed using data gathered via desktop analysis, literature, and evidence collected during the interviews with the key actors. This information was summarised in five diagrams: one diagram for each identified stage of the process (figures 7–11). These diagrams were used as a base for discussion in the three stakeholder workshops held in Victoria, Western Australia and New South Wales. Workshop attendees were asked to confirm the accuracy of the diagrams, which were then revised to include participants' considerations. The revised diagrams and a summary of the workshop findings were shared with the attendees to give them the opportunity to offer final remarks. In the final section, we evaluate the overarching risk assessment process to identify data issues.

3.1 Planning for safer communities

States and territories play a leading role in reducing disaster risk through the regulatory planning system. In this research, we have considered the process of developing statutory and strategic land use policies at the state and LG levels. Each of the three states considered in this research has a different suite of policies addressing disaster risk assessment and management. Policy approaches vary according to the natural hazards considered.[14] It is worth recalling that for the three natural hazards studied in this research, only floods and bushfires are addressed via the planning system. In this section, we discuss what informs the decision-making for the development of policy at the state and LG levels.

3.1.1 State planning policies

Statutory frameworks

The role of statutory planning policies is to establish statewide frameworks and standards. The consideration of natural hazards at the state level is not site-specific, but relates to the understanding of the possible impact of the hazards. These policies establish acceptable, tolerable or unacceptable levels of risk, and provide parameters for mitigation and risk reduction intervention through specific development controls. Such controls are then applied and contextualised at the site level through the local planning schemes. Further, building requirements (construction standards) are either nested within the state planning considerations or layered over land-use planning requirements as part of the hazard mitigation efforts. While there are differences in planning systems and policies across the three states, our interviews revealed commonalities in how and what information and data are used for policy development.

14 Refer to Appendix 4, Section 4.1 'Natural-hazards state-planning policy overview'.

The policy development process considers and assesses risk in line with the framework provided in Land Use Planning for Disaster Resilient Communities (Australian Institute for Disaster Resilience [AIDR] 2020) and the ISO 31000 Risk Management—Principles and Guidelines (AS/NZS 2009). The process overall consists of two main stages: understanding the hazard and responding to it. The first stage sees policy developers acquiring a more in-depth understanding of the natural hazard and its associated risk. To inform this phase, state planners in charge of developing such policies access specific hazard data, such as bushfire and flood maps. Hazard data are used to gauge the extent of the areas affected by natural hazards. While they do not carry out a formal assessment of the extent of areas impacted, policy makers use the expertise of other government agencies to understand the implications of the different levels of risk and what these might mean for future development. This technical support is provided mainly by state fire departments, water and environmental management departments, and private consultancies (Figure 7). One state planner in Victoria explained: *'We're very reliant on the expertise across the sector. […] we don't do this alone',* then added:

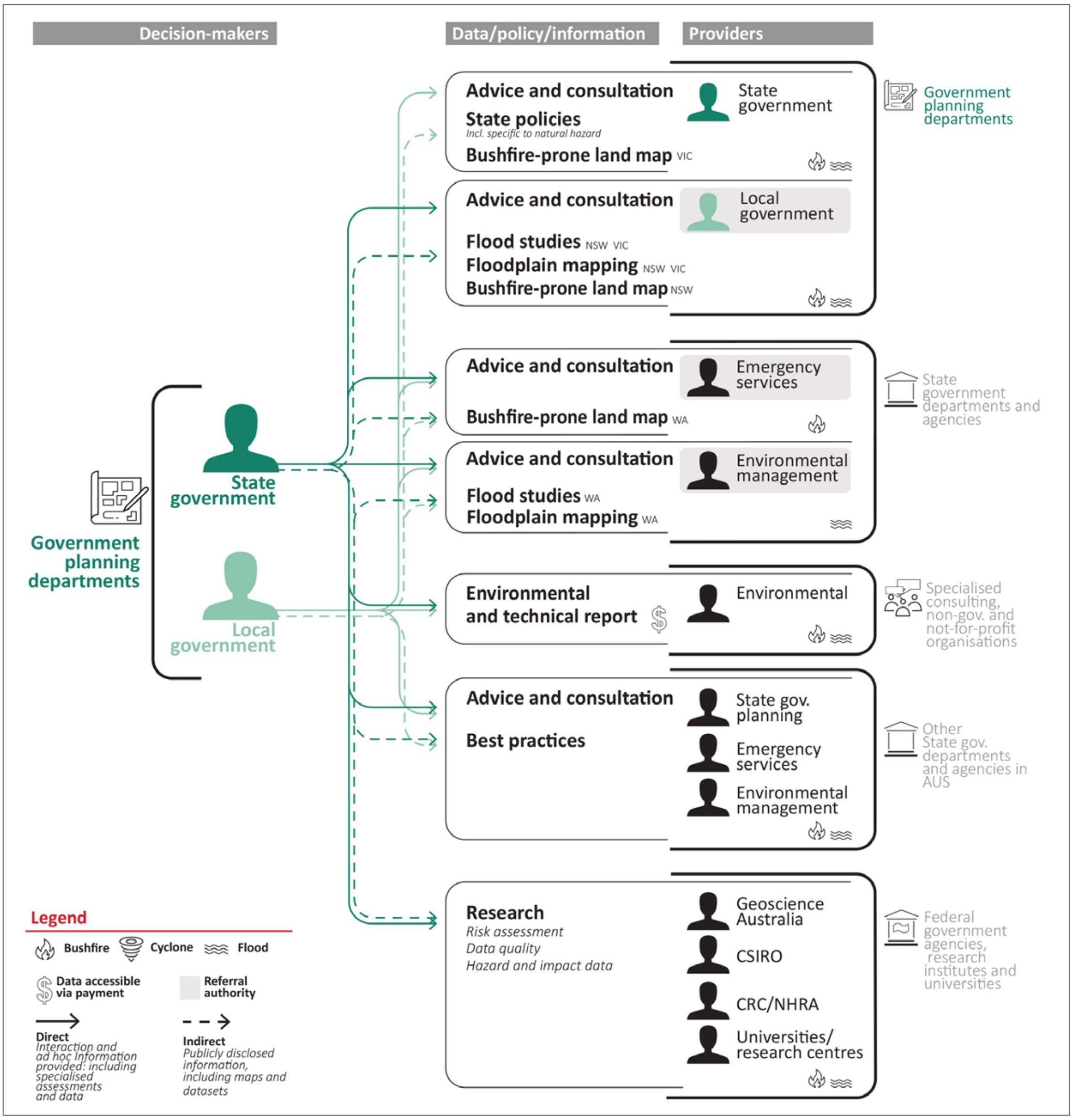
> *Often the experts do a bit of data dump on us and say, 'Well, we've done the data in the research. Now, you implement it.' But there are often gaps in that data in terms of understanding how the built environment needs to respond (VICSG1).*

This is a sentiment shared by other planners that we interviewed. In particular, it was pointed out that data are provided without clear information on how they could be translated into actionable measures. So, this technical information, even if scientifically accurate, is inadequate as it cannot be made operational in a policy context.

Apart from hazard data, no other specific dataset pertaining to DRR is used during policy development. A West Australian planner explained: *'We [are] actually probably not responding to data as such, as responding to international best practice, [to] what is happening in terms of research'* (WASG2). Information for policy development is drawn from a variety of sources, mainly studies conducted in Australia by institutions such as CSIRO, Cooperative Research Centres (CRC), Natural Hazards Research Australia (NHRA) and universities. International research is also consulted. Policies and practices implemented in other settings in Australia and overseas are analysed and evaluated to assess their effectiveness in the local context. Information is also drawn from a direct exchange of experiences with other state government agencies across Australia (Figure 7). This is done using informal channels, but also more formally through established interstate working groups and associations. The scope of this exchange and research work is to inform *'what the policy [approach] should be to manage the risk'* (WASG3). The information is then woven together to develop the policy response. So, again, the evaluation process to identify the best approach is not done in isolation but with the support and consultation of referral authorities, including those that have provided hazard data, emergency management services, and state-level departments and agencies responsible for transport and infrastructure delivery, and LGAs.

Disaster events—as well as official inquiries and associated recommendations—are the main trigger for the development and revision of natural hazard-related policies. State planners in Victoria noted that *'Change […] it's often very reactionary'.* They explained, *'That drives a lot of our work in terms of improving the [planning] system'* (VICSG2). Their West Australian counterpart also echoed this sentiment; they gave the example of the recent review of the West Australian bushfire policy, which was scrutinised and questioned only after 18 months post-approval, explaining: *'Feedback at a political level was part of the trigger for the government when they were in opposition to say we will look at that, and then when they got in […] fought for review'* (WASG3).

Figure 7: Data and information exchange and access: planning policy development



Source: Authors.

During the interviews and workshops, state planners from all three states highlighted that even if data were considered sufficient to instigate policy development and revision, the development controls and approach to natural hazard risk level definitions proposed in the policy need to reflect a position endorsed by the government. Without political support, planners do not have the authority to say that a change needs to be implemented through the planning system—or even what this change entails. A Victorian state planner expressed frustration, claiming that their *'role is to design tools to respond to the agenda set by the government, as opposed to identifying issues'* (VICSG1). These issues include improvements in hazard data availability and quality, increased knowledge of the hazards and their impact, or opportunities for the development of better mitigation strategies.

State planners engaged during the research identified a lag between the time frame in which policy operates (long-term process) and the fast-paced response required when addressing risk related to exposure to natural hazards. They noted that policy review could not keep pace with the quickly evolving panorama of disaster risk data, associating the cause of the lag with the complexity of the policy development process—particularly its engagement and consensus-building components. Engagement with relevant interested parties takes place throughout the policy development cycle, from the initial stages when seeking advice from experts and testing options to building community consensus to political endorsement needed for approval. During the West Australian workshop, one of the planners stated:

> *The process of producing a policy can take around five years due to the need for analysing data and applying it to the local level [context], and then consultation, by which time the policy will likely be out of date as new data will have been produced. (WASP3)*

Moreover, as another West Australian planner pointed out, data can be a source of contention during community consultation as, 'it doesn't matter how strong your data is; there's always a group [that] it is going to say it is faulty for a particular reason'. The planner went on to explain:

> *We can't just rely on the data. We really have to look at many different issues around how that data interacts with the land use system, [and] the communities that we are trying to protect. (WASP2)*

Land use planning strategic frameworks and housing policies

Land use plans are used to set long-term visions aimed at coordinating the delivery of physical, social and economic infrastructure. These tools identify future land uses, including areas for new developments and growth, looking strategically at future housing demand and where this could be allocated. Growth areas are determined by a need to meet housing targets—and in determining such needs, it is unclear how much weight in the process should be given to environmental considerations (Maund, Maund et al. 2022).

The research participants in the three states identified a lack of consideration of natural hazard risk assessment and broader environmental issues when identifying areas for new development at the strategic planning level. According to the interviewees responsible for developing planning policies, it is unclear how housing policies link to land-use planning strategic tools. During the workshop in Victoria, planners pointed out that housing policies indicate aspirational housing targets. However, it is uncertain how and if these targets are established in consideration of the effective capacity to deliver. In particular, they questioned how natural hazard risk is considered in the housing policy context, noting: *'We have a lag in terms of what Plan Victoria might say about where we should deliver and where we can deliver'* (VICW3). State and LG planners in Victoria referred to the siloed approach to policy development: *'We perform in silos. We do our patch; they do their patch. Then [we] try to connect the dots […] I don't know many government departments that are not siloed'* (VICW5). While a whole-of-government decision-making process was seen as ideal, participants working in government agencies highlighted how hard it is to translate this into practice. They claimed that 'advances' in institutional knowledge and information-sharing are made by individuals reaching out to other departments, rather than being facilitated by how the system works. The siloed approach was identified as a barrier to the flow of information between agencies, resulting in urban planning and housing policies being disconnected at the strategic level.

State planners in all three states also noted that identifying areas for new development in the urban fringes is mostly driven by developers' requests for rezoning. During the West Australian workshop, one state planner noted:

> *We always have people who come outside those [identified] areas [for development] and say, 'But we want to rezone this area' […] The proponents are saying we can make this safe within the context of the state government policies when putting forward the rezoning. (WAW2)*

Planners from New South Wales and Victoria recounted similar situations. The West Australian planners stated that it is hard to push back requests and make developers understand that even if *'the risk can be managed, it doesn't mean that it's acceptable'* (WAW2). A New South Wales state planner who attended the Sydney workshop pointed out that the definition of what is *'acceptable risk'* is a critical point when contextualised within the current housing crisis, clarifying that the conundrum in planning and approval of development is:

> *Where, and if, you want to take a housing-crisis point of view, or do you want to take a setting where [you] want to keep-people-safe point of view—and that […] comes to what is tolerable risk. (NSWW1)*

3.1.2 Local government planning policies

The role of LGAs is to identify risks and inform where building and planning response interventions are required. LG-level planning schemes (Western Australia and Victoria) and environmental plans (New South Wales) are tools that set up strategic and statutory provisions to coordinate infrastructure and development within the LG areas. At the LG level, the decision-making relative to land use allocation is informed by a more in-depth consideration of exposure to natural hazards and the level of risk.

Hazard data plays a crucial role in establishing development controls—which include prohibiting development. In the case of assessing and responding to flood risk, LGAs rely on flood studies and associated flood mapping. The information on flood behaviour and constraints (including flood hazard) is used to form the basis for setting flood planning levels and is convened in flood-prone land mapping. These flood mappings translate flood event simulations and calculation of the probability of flood events occurring (hazard data) into policy frameworks aimed at guiding future development in at-risk areas in alignment with state policies.

Similarly to the process used for state policies, advice and consultation with identified state-level agencies provide the required expertise and support to complete the process of translating hazard data into policy (Figure 7). A New South Wales LG planner, with extensive experience working in Victoria and Queensland, echoed the explanation from the West Australian state planners:

> *Flood studies to determine flooding risk in any area, once you decide to do it, […] can take three to five years to be done because of the process required to engage, establish our flood risk, [our] flood-plain-management committees, assess the risk, and properly consult with people and prepare the data. (NSWLG1)*

In Victoria, a planner working in a regional LGA subject to riverine flood stated: *'[For] two of our townships, […] we actually have flood studies completed for both in 2017, and none of those studies have actually gone into a planning scheme yet'* (VICLG3). The issues experienced at the LG level reflect the issues recorded for state-level policies regarding the extensive time frames required by the planning process to implement changes—which is primarily linked to the community engagement and political consensus-building processes. Regarding local government, planners pointed out that it is not only a question of timing but also the quality of information shared and embedded in the planning system. They noticed that the technical information is manipulated in the consultation phase. A sustainability officer supporting local planners in regional Victoria pointed out that the local government council *'feels the community's pressure'*, which impacts their decision regarding endorsing a flood map: *'Now it's not a technical decision anymore. That's [a] political one'* (VICLG1). As a consequence, changes are made to maps. Therefore, the final flood map used in LG schemes—and then in state planning overlays—is a governing tool, and should not be confused with technical hazard data.

Similar to flooding, bushfire-prone maps guide decisions relative to development at the local level. For consideration of bushfires in all three states, fire emergency services provide guidance to local and state governments for the development of hazard data (Bushfire land mapping), and function as a referral and consultative authority in the policy context—as well as later in the process—in the development approval phase. For bushfires, planners across the three states stated that the process is more *'straightforward'*, thanks to national legislation and state government playing a more prominent role in providing direction and guidance for data and risk assessment that is cohesive overall.

3.2 Delivering disaster-responsive housing

3.2.1 Feasibility and pre-approval stages

There is limited research in Australia on how relevant hazard and impact data are used as part of the risk assessment and evaluation process conducted at this stage of the development process and, in general, throughout the entire process. A recent study on the decision-making practices of property developers in Australia and New Zealand conducted by Moorhead, Armitage et al. (2023: 100) exposed *'a heavy reliance on intuition and rules of thumb'* in feasibility practices. During the early stages of the development process, evaluation of site-specific aspects is dominated by consideration of land (relative to cost and amenity), economic characteristics and legal documentation (Preller 2009). Accordingly, during the pre-planning approval stage, disaster risk is assessed and accounted for in relation to conditions and constraints imposed within planning policies. Risks related to the site are identified during the 'due diligence' process—the review of existing planning tools aimed at determining the development controls applying to the considered site. Private planning consultants provide such information for smaller developers who do not have an in-house capacity to carry out this task. This due diligence process is also crucial for developers seeking external funding to support development from lending institutions.

Representatives of a national lending institution providing finance for land subdivision, new housing stock and new apartment stock, interviewed as part of the research, explained that lending institutions have a *'low-level appetite to accept planning risk'* (NALEN3). Therefore, providing evidence that the development is meeting *'prerequisite approval'* is crucial to access funding. Lenders expect developers to demonstrate that *'elements of risk assessment [have been] taken into consideration, and it's been deemed acceptable that you can develop land lots'* (NALEN3). The documents provided by developers are only a starting point for lenders. Banks rely on third parties—such as quantity surveyors, valuers and sometimes project managers—to measure and inform their decision to finance certain development activities.

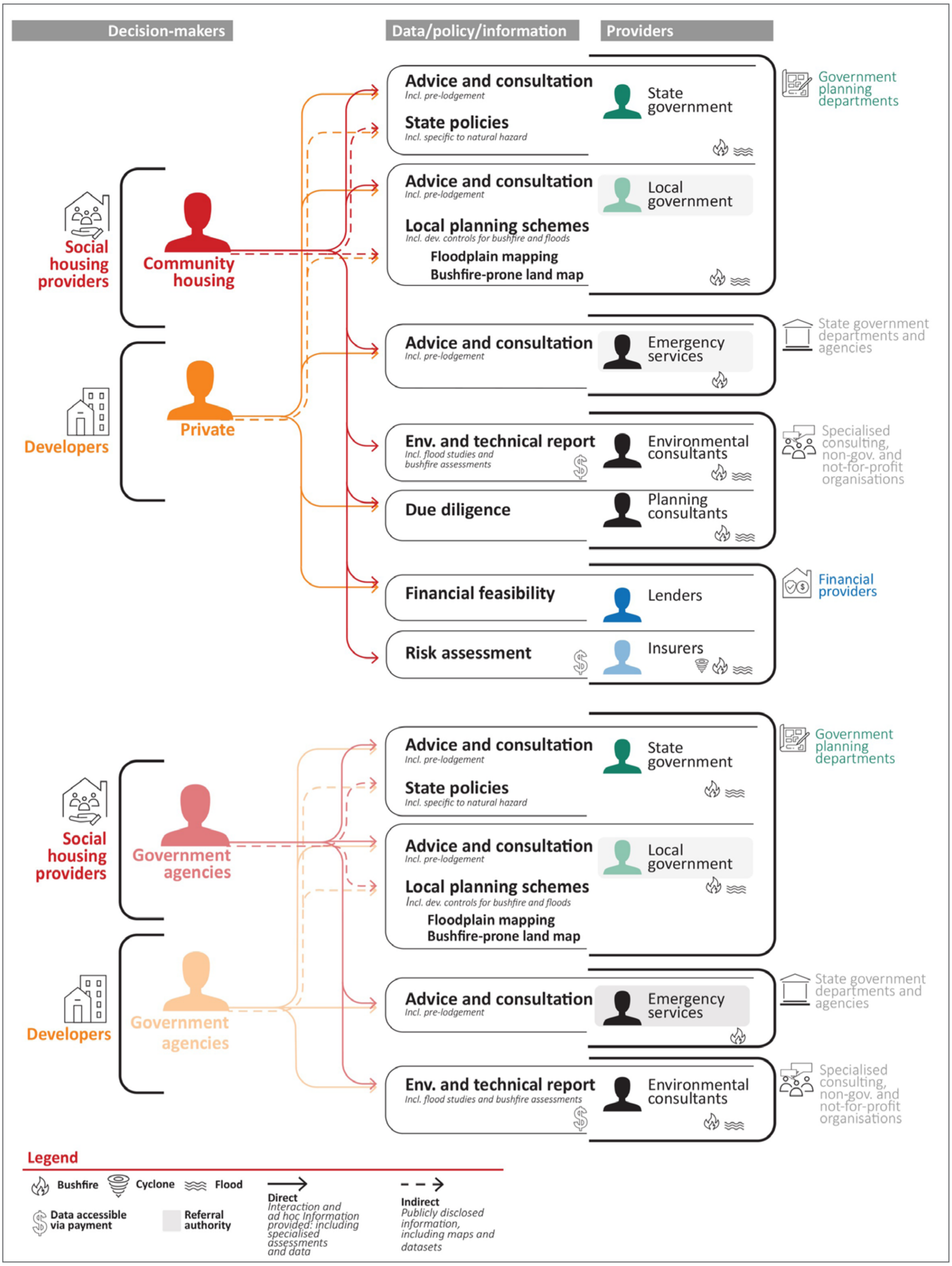
Insurance is an important consideration in the risk-assessment stage. A representative from a lending institution explained: *'If you can obtain insurance, then it's reasonable to assume that it mitigates that risk for us'* (NALEN4). When carried on with the assessment, lenders use both qualitative and quantitative parameters. The lenders we interviewed use around 15 criteria, of which some are metricated, such as *'value ratios line to total development cost',* and others are based on the *'expert judgement of the assessor'* and other elements such as client profile, quality of sponsor and contractors. Lenders also consider the impact of mitigation measures on project costs and knowing the clients are aware of these costs before delivery, *'because if you had a building contract for X, it turns into Y, and they can't fund that differential. It really puts a lot of stress on the project'* (NALEN3).

Residential developers consider the cost of the mitigation measures as an essential factor in assessing the feasibility of a project.

However, community housing providers (CHPs) assume a longer-term approach in their decision-making—when compared to residential developers targeting the private market—because they retain rather than dispose of the asset(s). CHPs consider the life cycle of the dwellings. For example, the CEO of a West Australian CHP told us that they are reassessing the overall risk for their business in continuing to invest in regional and remote areas. This is due to an upfront increased cost to meet the cyclone-rating requirement, paired with an increased cost of asset maintenance due to harsher, hotter weather conditions in these regions—which results in faster deterioration of construction materials. He explained:

> *We are essentially providing social and affordable housing for people on very-low, low, low-to-moderate incomes […] the rent commensurate with the costs to maintain the property; we actually see now that the cost of maintaining the property is almost exceeding the rent. (WAH1)*

Figure 8: Data and information exchange and access: pre-planning approval stage



Source: Authors.

However, larger CHPs we spoke to are accessing comprehensive data to guide them in this long-term risk-assessment approach for future investment. An asset manager from a CHP operating across multiple states told us they have invested in a subscription to a platform that allows multi-hazard climate-risk analytics at the property level. They use this system to evaluate current assets and future investments:

> *For new development, while we get the initial snapshot, we then have a look at what the long-term climate change is […] We're calling this the portfolio optimisation strategy, as we can say: 'We need to get out of this area because the risk profile is getting bigger.' (NAH2)*

They also explained that *'having data-driven evidence-based decision-making'* has helped reduce the 'personal biases and opinions' in managing assets and making decisions for future investments. They expressed concern for CHPs that have a much smaller portfolio and *'just can't do this'* (NAH2). The two CHPs attending the Victorian workshop also consider the cost of insurance in risk assessment at the early stage of decision-making around future housing investments. Both CHPs indicated that insurance plays a part in decisions about where to locate community housing. If the land is *'at risk'*, insurance would be more expensive or unavailable, as well as the consideration for tenants' safety:

> *We choose not to take that risk with the tenants and place them in harm, either by way of not having access to their property or potentially, you know, losing their home. (VICW6)*

Both private and public developers use the same approach to site assessment and access similar types of data to inform their decisions. Once the feasibility is assessed—and before a planning application is submitted—developers rely on consultants to produce bushfire assessment reports and more detailed flood studies for them (Figure 8). However, while private developers produce flood modelling or bushfire risk assessment mainly in response to government policy, government development agencies produce, source and utilise data in their risk assessment to inform design responses at a level that goes above the minimum requirements, with the aim of demonstrating best practices to the industry. In the case of Landcom in New South Wales, consultants produce the data. This information is then shared with private developers to whom the land is sold. These developers are held accountable for complying with the responses to disaster risk.

3.2.2 Planning approvals

Proponents are required to prepare applications that address the provisions and conditions applicable to the site where development is proposed. In areas identified as being at risk of natural hazards, proponents are required to undertake detailed flood or bushfire studies and economic and environmental studies. The studies are to demonstrate that the development proposal has no adverse environmental effects and meets expected performance standards. The relevant planning authorities assess development applications (DAs) on the basis of the information submitted by proponents. Decisions on DAs are grounded on the adherence of proposals to local government and state planning policies and development controls. These same parameters are used by public housing departments and state development agencies when, according to legislation, these agencies act as approval authority (including self-assessment) for the delivery of affordable and public housing (see notes in Figure 9).

For more significant developments, and when the proposals are non-compliant, the approval authority considers the planning and building consent aspects of the application on its merits. As part of the risk assessment of the development proposal, significant attention is placed on the proposal's consideration of efficient and effective evacuation, the burden placed on emergency services, and possible damage to public assets. This process involves consultation with the relevant referral authorities, which provide advice on these issues (Figure 9). Representatives of approval authorities interviewed as part of the research pointed out that technical data and information are the centre of the merit-based risk assessment—and also in case of disputes.

Delays in embedding more accurate data in planning schemes can be an issue when assessing proposals. According to a Victorian Emergency manager who often, in his daily work with LGAs, talks to planners who complain of feeling stuck: *'Because at the moment if we say, 'Yes, go and build', because legally we have to say yes, and that's what the planning scheme says, but then, we know, that they're going to be at higher risk'* (VICW2).

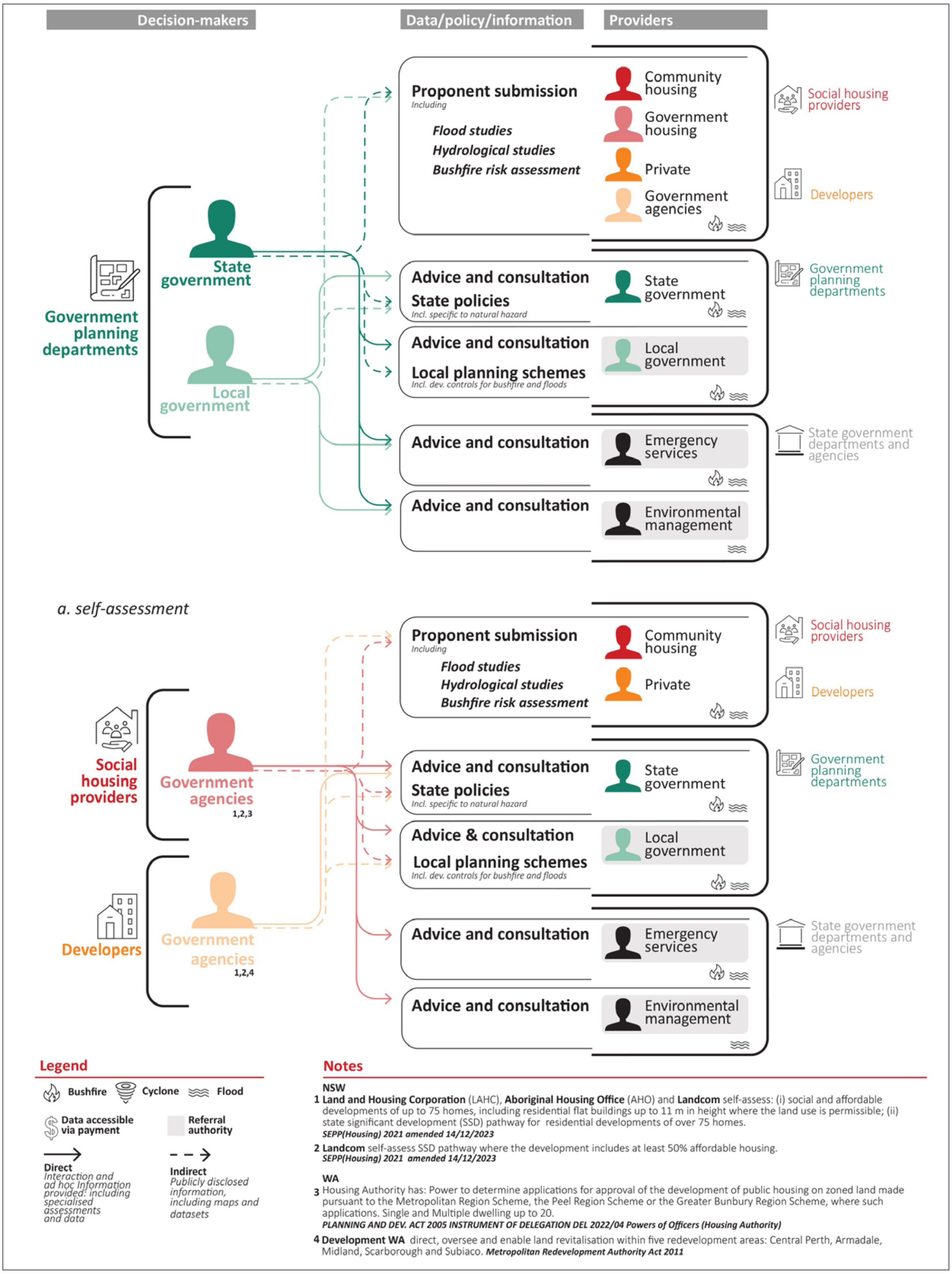
One LG planner based in regional Victoria described the lack of up-to-date information embedded in planning tools as *'leaving the door ajar a little bit where people think, 'Oh, well, hang on, I've got this mapping, but I might be able to disprove because it hasn't been tested for so long.'* (VICL3).

In some cases, where the relevant authority has not granted planning consent, applicants seek an alternative determination through legal appeals or political pressure. Courts and other legal institutions, such as administrative appeals tribunals, play a significant role in settling disputes between developers, councils and other opposing parties regarding applications for development in floodplains or BPAs. Interviewees listed many cases in their respective jurisdictions where developers have sought legal resolutions. The planners at the Victorian stakeholder workshop pointed out that the decision taken in a tribunal can be *'inconsistent because it's supposedly each case on its merits. What really happens is that those who can afford the best bowlers and the most expensive experts win'* (VICW3). West Australian state planners also noted that proponents are persistent in challenging decisions at each stage of development, from rezoning applications to subdivisions all the way to the final stage of approval to build the individual dwellings. They noted that at each stage, new data and information are put forward, *'the risk profile changes,'* and a case is made as to how the proponent can mitigate the risk differently. They lamented:

> *It's unrealistic to think that just because the government has said, 'You can, under certain parameters', that there is an argument to change those parameters going forward at every single stage (WAW2)*

They also observed that these subsequent amendments to approval might reduce the effectiveness of mitigation strategies required—and therefore increase risk. They noted that, in the case of bushfires, some of the measures proposed to reduce risk rely on actions implemented by future individual homeowners. Therefore, the level of risk of the dwelling could be different from that assessed. It could also increase over time if, for example, the residents do not keep the asset protection zone or remove bushfire roller shutters for aesthetic reasons.

Figure 9: Data and information exchange and access: development approval

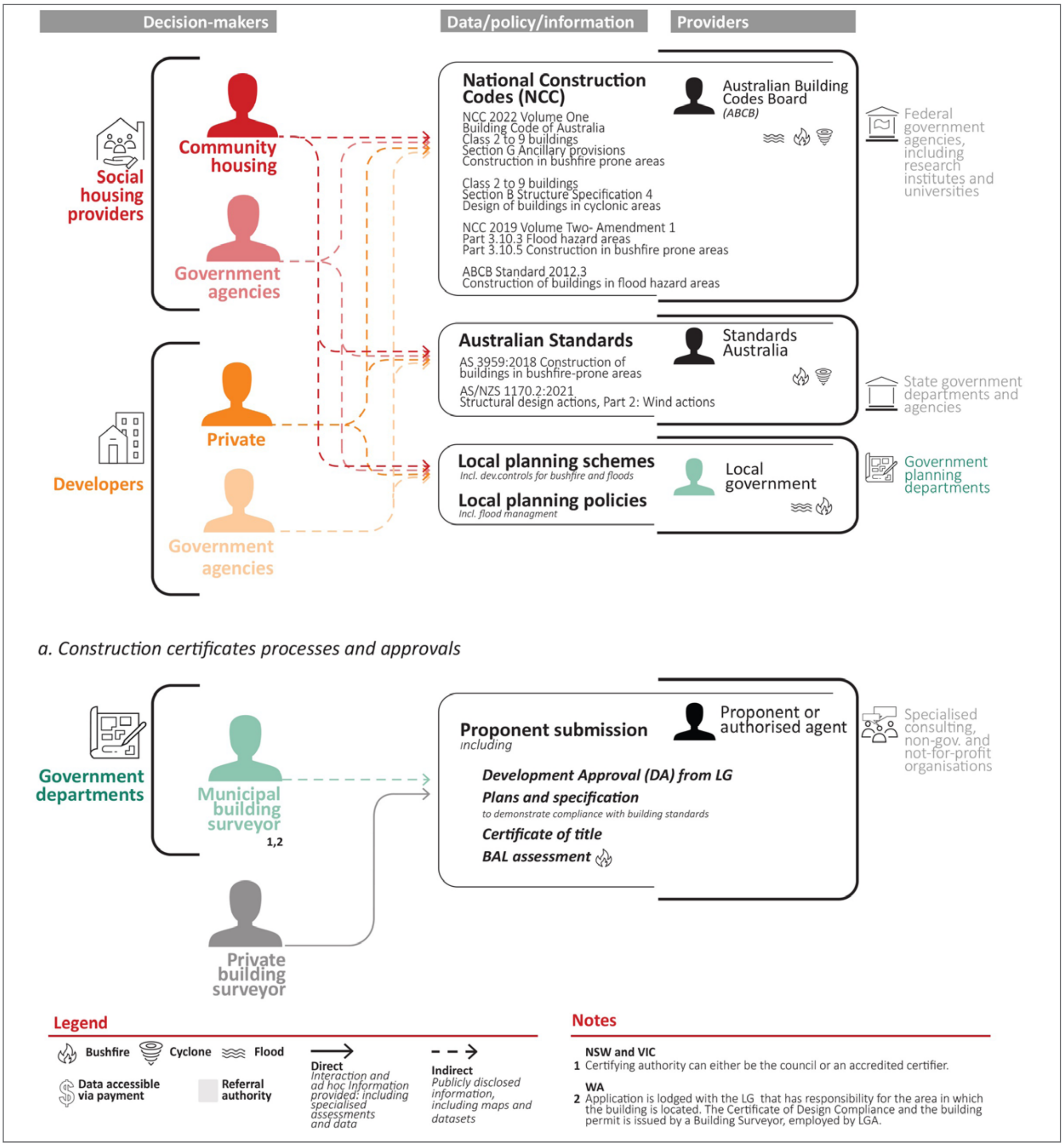


Source: Authors.

3.2.3 Building approval and construction

In parallel with land-use planning processes, building codes determine design and materials requirements for built structures in order to achieve pre-established levels of safety and health for the building—and thus for its occupants. The BCA sets out specific structural minimums for resilience for all building categories, including residential buildings. The ABCB is responsible for setting these statewide standards for the design and construction of new buildings. Building codes get improved at various times on the basis of damage data from disasters or other building performance data, such as structural failures and fires.

Figure 10: Data and information exchange and access: building approvals



Source: Authors.

However, Building Codes are implemented and regulated at state and territory levels. In particular, local government play a critical role in enforcing the BCA and matching zoning with development applications to ensure appropriate resilience measures are incorporated into new buildings and additions. However, the building approval process has been privatised in many states and territories. LGAs have minimal input in the approval or inspection process, and when they do offer these services, they compete with the private market. At this stage of the development process, no other critical information or data are used to inform the delivery of housing, and the building standards requirements are considered the only point of reference (Figure 10). Assuming building permits and planning consents are granted, the management of the construction primarily rests with the builder to ensure that the construction complies with approved DAs and building permits, BCA requirements and any specific design aspects.

Participants raised concerns about building quality and current building inspection and surveying processes:

> *[it] is about the quality of construction and that might seem that it's covered by building regulations, […] and generally speaking, the building surveyor [is] in the pocket of the builder […] so you have to trust, but I think in any context, no matter the regulation, there's still the chance for peace of work to be done at a high quality or at a low quality. And when it comes to hazard to risk, reducing the quality of the construction is key to everything (VICW2).*

Participants in the research observed that there is a whole range of data and information included in building permits and building design documentation related to building material and dwelling design that can be used to inform research for improved dwelling resilience. However, LGAs lack the capacity to collect these data systematically, and privacy issues around data sharing due to privacy also hinder the use of this information. An emergency management authority representative also mentioned that important data collected after disasters could inform the future improvement of building codes and how quality control is delivered throughout the life of the dwelling:

> *Damage to the properties and assets [data collection post disaster] that's held at the council level. So then you have to have agreements with each Council that might be impacted at a state level to be able to access that data. They deal with that data very differently from one council to another, so you know, you are not comparing apples and apples. […] That's a big, big challenge in its own right, but that's also another gold mine. Is this kind of what's called the secondary impact assessment data, which also provides you with an idea of the level of impact for that particular asset, which then can help to map and plan assessments and response assessments […] including informing building standards (VICW2).*

3.2.4 Markets

Households are responsible for safeguarding their property and assets from natural hazards by identifying risks and implementing mitigation measures, including purchasing adequate property and contents insurance. The time of dwelling purchase is the moment when households can determine if their future dwelling is subject to natural hazard risks. Disclosure statements are required by vendors in Victoria and New South Wales when marketing their houses or land for sale. In Victoria, section 32C of the *Sale of Land Act 1962* requires a vendor statement to include information related to planning and building prohibitions when buying or selling property. In New South Wales, the *Conveyancing (Sale of Land) Regulation 2005* (NSW) requires the seller to disclose that the land is not subject to *'any adverse affectation'* (Christensen, Duncan et al. 2007). There is no mandatory disclosure in Western Australia. However, title checks included in contract conditions can capture natural hazard risks through the notification and covenants included in the documents; a notification on the title records states whether the land is within a BPA and may be subject to specific requirements. When mandatory disclosure is not in place, buyers of residential property can also rely on publicly available information, such as a search of state and local government registers and websites (Figure 11).

Insurance is the main instrument to manage disaster risks and fund post-disaster activities. Insurance is also important because obtaining insurance for the dwelling is critical to the successful approval of the mortgage for most homebuyers. As explained for the commercial loans sought by developers, lenders' decisions are strictly tied to the insurance to offset investment risk. As a lender explained to us:

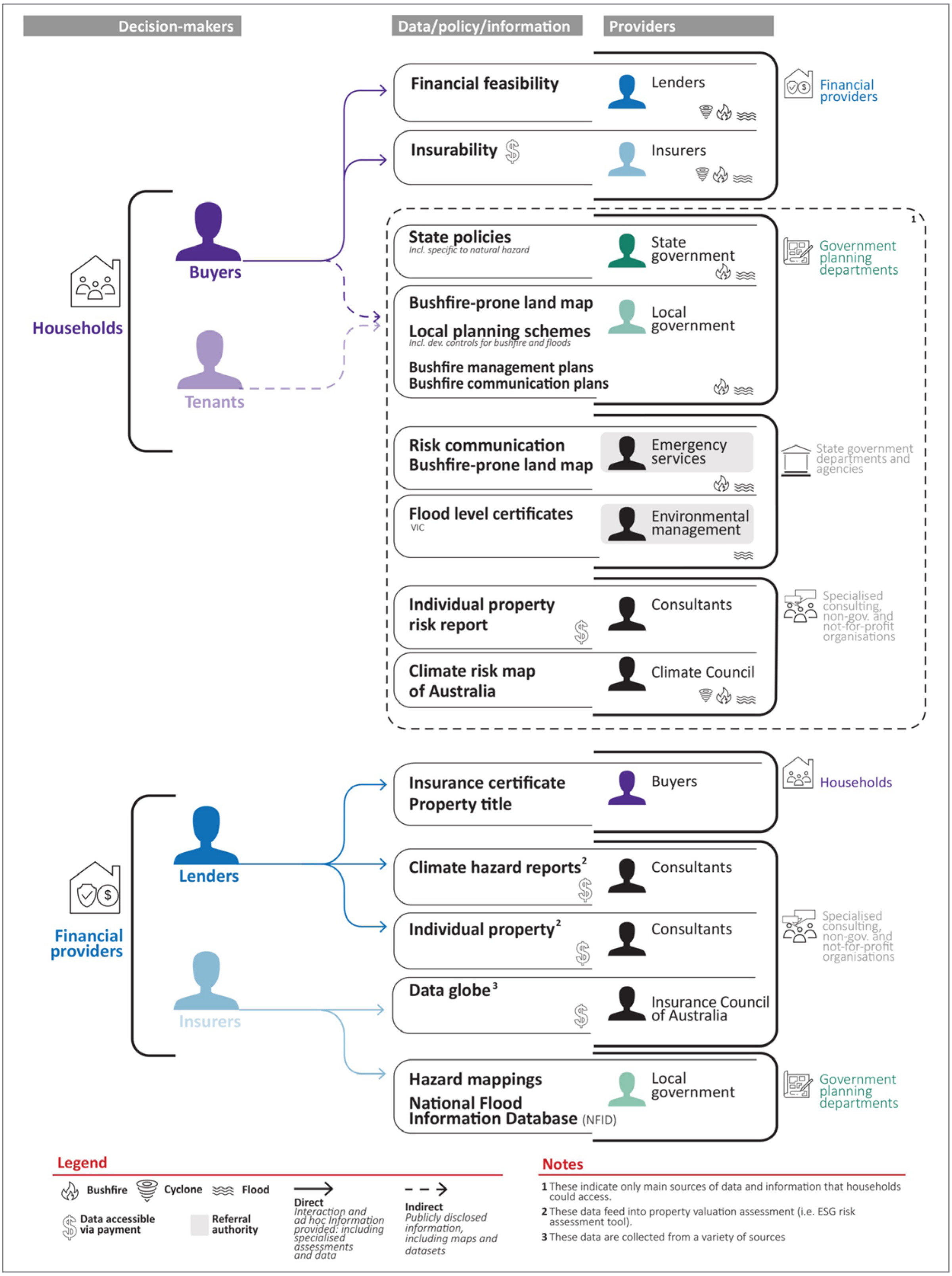
> *So [a] customer chooses their home, and the responsibility to do the research and understand what risks they're getting into sits with the customer when they choose their home […] Then the bank has a decision as to whether to approve that loan or not […] Our approach guidance requires us to check that the customer has insurance at the point of origination on the loan […] and then it requires us to ensure that customers have ongoing insurance via our terms and conditions (NALEN2).*

There is no guarantee that the owner will stay insured during the entire term of the loan. The lenders we spoke to have identified this as an issue and are working to establish processes to monitor home insurance across their investments.

However, insurance is only one piece of the decision-making process in approving mortgages. The final decision on lending is tied to automated client-creditworthiness tests and benchmarking of the cost of the dwelling against the bank valuation assessment. There is still a manual decision component related to *'geographic business rules. But the maturity of climate in those is very, very low'* (NALEN2). Currently, a state-level indicator is used to track the exposure of particular areas. The person making the call on the mortgage evaluates that they are not *'taking too much or too little of the market share in any one state'* (NALEN2). These lenders are currently working to develop climate-based key-risk indicators and credit monitoring metrics aimed at identifying the estimated total dollar exposure of the property they are purchasing.

While the Lender we interviewed is working on developing indicators for risk assessment for new investments, they have also invested in buying access to climate risk data from the actuarial and insurance consultant, Finity, *'in order to monitor the number of customers that we have in high-risk [groups]'* (NALEN2). This includes the number of customers, the value of properties, and the loan-to-value ratio (LVR). As part of the research, we interviewed two major data providers who sell data to insurers, banks, developers, private companies, and the government. Both provide data on climate change, flooding and bushfires to allow the calculation of risk on property.

Figure 11: Data and information exchange and access: housing markets



Source: Authors.

As home insurance in Australia uses risk pricing—which means that higher risk equals higher price for insurance—insurers require numerous data points to make decisions on pricing. These generally include historical data, third-party data on hazards and risks, and exposure data. However, these actuaries notice that some information about a building's characteristics is not readily available for all properties in Australia, and this is collected by insurance companies directly from homeowners—for example, what is the roof made of? What is the age and condition of the house? In particular, insurers rely on homeowners for exposure data (if the dwelling has been affected during a disaster event in the past) as there is no data available at the property level. The age of the house is important data for insurers, as it indicates the construction codes and building requirements at the time of building. Generally, the older the house, the more expensive its insurance is as, in many cases, there is no way to track improvement and renovation done to the buildings. Moreover, these data providers offer information on disasters under different climate scenarios, such as flooding and sea-level rise.

These companies do not consider publicly available data on flooding to be of good quality, but a respondent from an insurance company praised the quality of the freely accessible datasets related to bushfires:

> *The [flooding] data is out of date, it's not appropriate, and it's far too conservative; it just blanket-covers everything to be 'at-risk' because the councils don't want any exposure. […] There's some really great data out there in terms of bushfires. Each state will publish its own bushfire-prone vegetation and dataset for free online, and then you can go in and find out whether you know you have to build a certain fire standard or not. That's one of the layers that we include within our analysis. (NAINS2)*

3.3 Conclusions

Effectively addressing natural-hazard-related risks requires assessments that consider the combination of all risk dimensions: hazard, exposure and vulnerability.

- **Hazard** is correlated to the possibility of a natural event (bushfire, flood or cyclone) impacting settlement areas.
- **Exposure** is defined by the extent of damage caused by a natural hazard. The level of exposure is linked directly to the hazard level and impact—increased exposure causes more damage.
- **Vulnerability**, when applied to disaster risk, is concerned with future and potential harm and captures the capacity of a system to respond to the possible impacts of the disaster event (Wisner 2004).

Risk is associated with settlements' exposure to hazards caused by natural events and the characteristics of the dwellings and households, which describe their vulnerabilities. Two issues emerge from the analysis of the decision-making across planning and delivery of new housing presented in this chapter: the first concerns data issues impacting risk assessment (answering research question 3), and the second concerns risk management.

Data issues

Effectively addressing natural hazard-related risks requires assessments that consider the combination of all risk dimensions: hazard, exposure and vulnerability. This research has identified different issues related to data for all three dimensions.

Hazard: Across the process of planning and delivering new housing, each decision-maker harnesses data for informed decision-making differently to reflect their role, mandates, priorities and expertise. However, in spite of their differences, all data users—including state and local government representatives, developers, housing providers and financial institutions—that engaged in this research project agreed that flood hazard data needs immediate attention, and expressed their concern about the quality and currency of available data. Flood hazard data are currently the most inconsistent in terms of their quality, level of accuracy and extent of data coverage across both states and within local jurisdictions.[15]

Exposure: Impact data contribute to assessing implications associated with exposure to natural hazards. However, the data mapping reveals that impact data held by emergency management agencies and insurance companies are rarely openly accessible.[16] Improved data accessibility is required.

Vulnerability: Most often, when referring to housing vulnerability in the context of natural hazards, vulnerability is framed through the lens of the physical domain of housing and described in relation to the capacity of the dwelling to endure the risk linked to hazard exposure (Zhu, Holden et al. 2021). However, Healey, Lloyd et al. (2022:3) identified four components of housing vulnerability: (i) housing structure and (ii) type characteristics, (iii) amenities, and (iv) socio-economic indicators.

The current approach to risk assessment focusses on establishing the level of exposure (which includes a consideration of contextual factors), addresses vulnerability related to housing structural characteristics, and calculates the possible economic impact of the natural event, mainly linked to the cost of reconstruction.

However, socio-economic factors that determine vulnerability are not embedded in the risk assessment for disaster prevention. In the assessment of the delivery of new developments, the social component of housing vulnerability is limited to the logistics of evacuation plans, assuming a risk preparedness rather than a mitigation approach. Planning for safe evacuation does not consider the implications of dealing with the long-term consequences of a natural disaster event. Risk assessment needs to take into account the socio-economic component of housing.

Risk management

From the reconstruction of the decision-making process across the planning and delivery of housing, two main actors bear the greatest responsibility in assessing natural disaster risk, and their decisions influence the choices made by the other actors involved in the process. These are: planning authorities and insurance providers.

Planning authorities

State and local government planning authorities carry numerous responsibilities that play a crucial role in risk assessment and management of natural disasters. These responsibilities include identifying hazard areas through mapping and policy development that provide statutory provisions aimed at integrating disaster risk assessment into land-use planning. These legislative frameworks, together with national legislation (such as building codes and standards), guide the decision-making regarding housing delivery.

Generally, during the project feasibility stage and the pre-planning approval stage, developers assess and account for disaster risk in relation to conditions and constraints imposed within planning policies. Once a project is submitted for approval, all decisions made by the relevant authorities are grounded on the adherence of proposals to local government and state planning policies and development controls.

15 Refer to Chapter 2 for a more detailed discussion on hazard data quality issues.
16 Refer to Chapter 2 for a more detailed discussion on hazard data accessibility issues.

In carrying these responsibilities, planning authorities—especially at the local government level—are called to balance and manage the conflicting interests of the actors involved in the planning and delivery of housing. In doing so, planners encounter numerous challenges. In particular, the need to:

- reconcile the need for an increase in housing supply (aimed at addressing housing shortages) with the definition of acceptable, tolerable and intolerable risk levels
- integrate the perspectives of stakeholders and affected communities
- ensure that decisions over land-use allocation and decisions on development approval (especially when contentious) are robust and defensible.

These challenges are exacerbated by the struggle of the current planning system to effectively harness data to support decision-making. Planning processes are not agile enough to keep up with the fast pace of information and data availability. This generates a general lack of trust in policy tools, with some proponents using the misalignment between the accuracy of data and policy to challenge established mitigation parameters by providing their 'own' data—especially regarding flood hazards in Victoria and New South Wales. Planners also noticed an increased tendency of developers to seek alternative development approval pathways to overcome the development process or to challenge decisions taken by state and local government planning authorities—for example, by appealing to state tribunals. This approach further weakens the authority of the planning provisions and the agencies responsible for overseeing the development approval process, as well as the overall credibility of the planning system.

Insurance providers

Insurance providers are the second main actors in the risk assessment process. Insurance plays a critical role in the development processes. It underpins lending and investment activities and acts as a vehicle to communicate to households the level of risk to which the dwelling is exposed.

Currently, lenders rely on home insurance to offset possible risks linked to natural disasters when approving mortgages. The Australian Senate Environment and Communications References Committee (2018: 64) explains clearly the link between the risk assessment conducted by these two actors:

> *Both insurers and lenders need to manage risk and prudential requirements successfully. A key point of difference is that property finance is long-term (such as 30-year mortgages), whereas regular property insurance contracts are for 12 months. Therefore, developments in short-term insurance contracts could influence long-term property lending. In particular, rising insurance premiums in areas considered at risk due to climate change will likely affect property values, with consequences for the approach taken by financial institutions to lending in those regions.*

The increase in the occurrence of natural events is currently—and inevitably—pushing more rigorous risk-assessment measures from insurers, which is resulting in an increased number of highly populated locations (and dwellings) across Australia being deemed uninsurable. Due to the decades-long time-frame lag between an insurance contract and mortgage commitment (as explained earlier), lenders are not yet revising their risk-assessment practices. As discussed in subsection 3.2.4, banks are still in the 'monitoring phase'—investing in evaluating the exposure of the current housing stock in their portfolio to inform future actions.

Due to the lack of clear legislative requirements related to risk disclosure at the selling point for buyers of new dwellings, homeowners are often made aware of the risk the dwelling they are purchasing is exposed to when procuring home insurance to support a mortgage application.

It's important to highlight that these two main actors use different datasets to assess risk. As one participant in the Victorian workshop put it:

> *[Insurance companies are] making their own decisions about what they will insure […] Councils are doing listing, meanwhile the insurance industry, they are assessing the risk themselves and making decisions. (VICW3)*

In the participants' view, the current disparity in data access and quality, and the discrepancy in assessment approaches, lead to insurance being framed as an antagonist to the government process of assessing natural disaster risk. Data collected and held by insurance companies, which are used in their assessments, are sought after by governments and lenders alike. In recent years, much effort has been put into facilitating and supporting the exchange of data between government agencies and actuaries to encourage dialogue and address these discrepancies (see Section 2.4).

3.3.1 Policy development

ISSUE

The complexity, length and rigidity of the planning process and related governing structure hinder their responsiveness

To better support planning systems and authorities to more efficiently and effectively address their disaster risk assessment and management responsibilities, policy intervention should aim to support enabling legislation that provides a legal basis for flexible and adaptive planning practices; this requires the following:

- **Implementing legal and regulatory reforms aimed at streamlining policy amendments and review processes** to increase the agility of planning tools, allowing for quicker responses to changing circumstances—such as the availability of new or improved data—through simplifying procedural requirements for policy updates.

To be effective, legislative reforms should be paired with the introduction of nationwide policies and interventions that support a consistent approach to risk assessment during development approval. Policy development options advised are:

- **Amend the development process approvals** to create specific and streamlined approval pathways for proposed developments located in areas identified as at-risk. Pathways could be based on the levels of risk the site is exposed to, such as low, medium and high.
- **Establish uniform processes of risk assessment** across government agencies and between the government and the insurance industry, including standardised approaches to data used for risk assessment.

4. Improving the decision-making process through better data management

- **This research shows that government, industry and community actors often struggle to identify and access critical information or adequate digital tools. This impacts the quality of their decisions.**
- **Workshop participants identified three priority areas where better use of data could improve decision-making processes: improved data collection and sharing practices, use of decision-support tools for risk assessment, and risk disclosure and communication.**
- **The implementation of digital solutions applied to urban development will require advancement in the digital competencies of the agencies involved in the setting, management and use of these platforms.**

The power of data insights has emerged as a crucial tool in natural-hazard risk mitigation and management, enabling authorities to make efficient and informed decisions. Data-driven decision-making offers the potential to inform strategies for mitigating risks, enhancing preparedness, improving response coordination and facilitating post-disaster recovery (Hughes, Giest et al. 2020; Ling and Thomas 2022; Yang, Yu et al. 2018; Thomson, Delaney et al. 2024a; Thomson, Delaney et al. 2024b). Our use of the term 'data-driven decision-making' in this research refers to the use of data and information to align the knowledge of our cities and what can impact them in the future with decision-making regarding the development of land and the provision of housing.

In Chapter 2, we mapped the data and information available in Australia to describe and identify natural hazards, risks and impacts. We also identified the three elements of disaster risk and what contributes to the vulnerability component of the assessment. In Chapter 3, we mapped how data are used in the context of disaster risk assessment across the various stages of the decision-making process related to the planning and delivery of new housing.

In this final analytical chapter, we examine the use of data and digital technologies to better support decision-making related to the planning and delivery of housing in the context of assessing hazard risk. This chapter draws on findings from the workshops conducted in New South Wales, Victoria and Western Australia, which engaged with the key actors involved in the planning and development process: state and local government planners, housing providers, developers and financial providers. During the workshops, participants were asked to identify their data needs in assessing risk in housing development, and to then explore opportunities to address the issues raised. As part of the workshop, we discussed the use of digital technologies and forecasting assessment tools across the various stages of development.

This chapter is organised into three sections reflecting the areas of intervention identified in the thematic analysis of the workshop engagement: data collection and sharing, use of decision-supporting digital tools, and measurement and communication of risk. Case studies are used in this chapter to illustrate possible supporting technologies that address these areas of intervention. The conclusion presents a process framework that considers the use of forecasting assessment tools and other decision-making and data-sharing supporting technologies in the various stages of housing planning and delivery development.

4.1 Data collection and sharing

Effective collection and sharing of data improves efficiency, fosters collaboration, and provides the foundation for implementing evidence-based decisions to address disaster events linked to exposure to natural hazards (EMV 2022). The *Digital Review 2021* conducted by the Digital Transformation Agency (DTA 2021) revealed that the digital technology capacities of government agencies are impacted by the ineffectiveness of the digital platforms currently used to support cross-agency collaborations, including data-sharing and information-sharing, and discrepancies in agencies' protocols and systems for data collection and management. These issues were also highlighted during the engagement with key actors in the workshops. Moreover, all representatives of government agencies and departments (at both state and LG levels) participating in the workshops acknowledged that within their organisations, many datasets are not adequately operationalised. LG representatives highlighted the presence of many datasets that 'sit' unutilised, mostly saved in an *'Excel spreadsheet format'* (WAW4).

Ku and Gil-Garcia (2018: 9) highlight that effective data collection and management in the LG setting depends on *'the operation of organizational, legal and political, and externally contingent elements, coupled with the complex deployment of information technology resources'.* Participants identified factors impacting the effective collection and maintenance of data as being technical issues linked to the volume of data and the financial commitment required to set up and manage digital platforms. Moreover, one participant in the West Australian workshop suggested that acquiring and maintaining data is not seen by the general public *'as a good use of public funds'* (WAW2). Employees of state government agencies participating in the research also pointed out that data sharing[17] across public agencies negatively impacts the integration of information into the decision-making process. They noted that the exchange of data between organizations is difficult due to privacy issues. In some cases, privacy issues affect not only the movement of information between agencies but also internally, where different areas of the same organisation—or even different people within the same team—have distinct levels of access to information.

Overall, workshop participants voiced the need for the introduction of digital solutions that promote data-sharing practices among all actors involved. A CHP in the West Australian workshop stated that over the last 18 months, they had been working on profiling the risk for their asset and found that:

> *One of the biggest challenges is the consistency of the data. It's a quagmire of all the different data sources to try to collate a listing for view. So we ended up going to work with advisory services, and it cost us money. (WAW7)*

This issue resonated with the experience of another CHP in Victoria, who lamented the lack of *'one source of truth',* and advocated for a single point of reference to consult where *'all the information, the data, all the modelling goes in'* (VICW6). They further indicated that such a comprehensive data-sharing tool should be managed at either a federal or state level. The mapping of data presented in Chapter 2 exposed that while there is openly available information collected and shared at all levels of government and within different agencies, these are disjointly organised and presented.

17 Data sharing refers to the process of providing third parties with access to the datasets of others, which are then often used to develop multiple new applications and services (Jussen, Schweihoff et al. 2023).

Here is an example showing the lack of coordination and duplication of information related to flood hazard data. Geoscience Australia collates flood hazard data through the Australian Flood Risk Information Portal (AFRIP). At the same time, the New South Wales government has a state version of the national portal: the New South Wales Flood Data Portal (NSW Government n.d.), which collates the same information but is limited to the New South Wales jurisdiction. However, neither of these two agencies is responsible for the provision of flood studies, and neither can guarantee that the information uploaded and shared in their systems is the most up-to-date version. Therefore, LGAs remain the relevant authority that the public and other agencies should reach out to source such data. LGAs also share this information on their websites. So, overall, the same information could be shared across three different platforms. Moreover, various platforms could also potentially share different flood hazard data relative to the same local government areas, depending on the platform data update protocols.

A state planner in Victoria suggested leveraging currently established platforms to support sharing information, rather than building new ones. Digital Twin[18] Victoria[19] was put forward as a possible option to coordinate data sharing across agencies. The participants in the Victorian workshop also suggested spatial digital twins (SDTs) as a *'valid tool for catchment management authorities (CMAs) and the government to talk to each other'* (VICW1) to address shortcomings in flood-risk data coordination in the state. The literature also supports the use of SDT technology as a solution to the issues of data sharing in natural-disaster planning and management (Fan, Zhang et al. 2021; Ham and Kim 2020; Yu and He 2022). SDTs offer the potential for integrating datasets, facilitating data sharing and improving efficiencies in the operationalisation of data in decision-making across the range of stages in the housing development process.

There are many examples of the use of SDTs for land use management and climate adaptation discussed in the literature, including the New South Wales and Victorian tools. An SDT platform that stands out for its design and the way in which it is used for land management is the one built for the city of Zurich (see Box 1).

Box 1: Zurich Digital Twin, Switzerland (EU)

Zurich Digital Twin, *Switzerland (EU)*

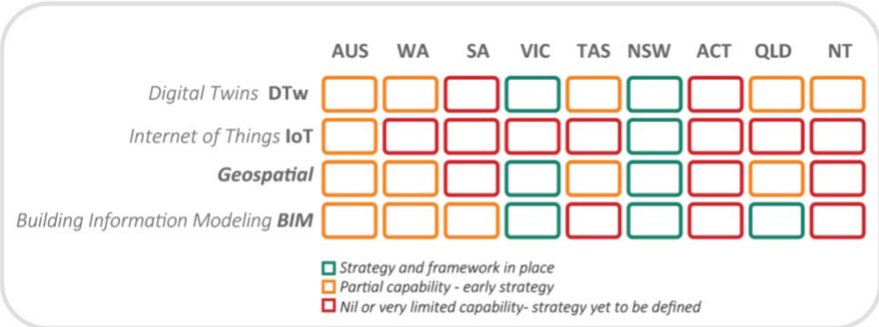
The Zurich digital twin, as it is known today, began almost 20 years ago, when the city identified the need for the coordination of spatial information. The city approved the GIS City of Zurich (GIS Stadt Zürich) in 2009, followed by the 2019 revision of the strategy to allow technological improvement of the urban spatial data infrastructure (SDI).

To support the development and interoperability of the platform, data requirements (spatial data, models, metadata) are set by law—the Federal Act on Geoinformation (Schrotter and Hürzeler 2020). The platform uses open governmental data, and includes several applications that provide collaborative platforms and allow simplification of information. Among these applications, there are several that are used in the context of urban planning decision-making. These include the Municipal Development Plan *(Kommunale Richtplanung)* for comparing urban development scenarios, and the Urban Climate, which helps assess the effect of planned buildings on the city heat-island effect compared with the current development (Schrotter and Hürzeler 2020).

18 Spatial digital twins (SDTs) are digital representations of a physical area or place, providing a platform for data to be captured, stored, analysed and then visualised for use.
19 https://www.land.vic.gov.au/maps-and-spatial/digital-twin-victoria

There is a currently keen interest in SDTs across Australia. Government investment in SDTs is increasing, with state-based digital twin programs being financed in 2024 in Victoria, New South Wales, Western Australia and Queensland. However, the recently released White Paper by Australian Standards, authored by Beck and Cotterill (2023: 18), points out that *'while there have been major steps forward in many jurisdictions, there is a lack of 'joined up' action and investment'*. They note that in the absence of digital policies, programs and funding, projects delivered in the last decade *'have been siloed'* and *'driven from a bottom-up perspective'* (Beck and Cotterill 2023: 18). When analysing the implementation of digital built environment SDT initiatives by state—such as Geospatial and Internet of Things (IoT)—there is a significant disparity across Australia in the level of digital capabilities maturity (see Figure 12).

Figure 12: Snapshot of Australian application of digital built environment initiatives



Source: Authors, adapted from Beck and Cotterill (2023: 19).

Further, the 2021 DTA digital review of Australian government agencies identified that advancement in the digital capability of government agencies is impacted by using *'bespoke single-purpose applications'* and widespread duplication *'across technology capabilities, including delivery platforms'* (DTA 2021: 42).

The implementation of SDT platforms requires advancement in the digital preparation of the agencies involved in the setting, managing and use of these platforms. In the 2023 Digital Government Index (DGI) report released by the Organisation for Economic Cooperation and Development (OECD 2024), Australia ranked in the top 10 countries for data-driven public sector measures (and fifth overall across all measures). This indicator is measured using dimensions such as data-sharing mechanisms, data standards and data interoperability. Australia's high score reflects the country's advancement in setting up mechanisms and legislative frameworks to support data-sharing practices across government agencies as part of the national Data and Digital Government Strategy (Australian Government 2023).

However, as demonstrated by the experiences reported by research participants, setting up such a legislative framework does not guarantee the implementation of effective and consolidated data-sharing practices to support decision-making and day-to-day operations in government settings. Lei, Janssen et al. (2023) note that addressing data ownership in practice requires work and effort in setting up negotiation and collaboration between multiple actors within and outside organisations. In the local government setting, this could be challenging. The resourcing of local government varies between councils, depending on their size and capability (Torabi, Dedekorkut-Howes et al. 2017) and geographical location (McGregor, Parsons et al. 2021).

Further opportunities

While not directly identified by the participants in the workshop, the use of blockchain technologies is put forward as a tool for improved data sharing and support of decision-making processes (Allen, Berg et al. 2020; El Khatib, Al Mulla et al. 2022; Malik, Chadhar et al. 2022). Blockchain represents a record of transactions that are updated continuously across a distributed network. Blockchain has played a role in the development of decentralised energy networks, peer-to-peer sharing systems and logistics. Blockchain has also shown the potential to contribute to the secure sharing and coordination of data in the context of SDTs (Sadri, Yitmen et al. 2022).

One key area where blockchain has been explored as a digital supporting platform for urban development is through information and property exchange. Vannucci, Pagano et al. (2021) highlight the potential for blockchain to contribute to DRR by theorising a framework for procedural checks across financial, regulatory and mitigation measures. While Vannucci, Pagano et al. (2021) conceptualised the use of blockchain in DRR for an application within the insurance sector, their proposed framework has the potential to address the need for secure data sharing and tracking of decision-making for accountability in the urban development context expressed by the workshop participants. However, there has been limited use of blockchain in the planning, development and delivery of housing in Australian cities, given the existence of a robust land-title registration system (Pettit, Liu et al. 2018).

4.2 Decision-supporting tools

Data and information made available through centralised platforms can be enhanced through various decision-support tools to improve risk management in the planning and delivery of new housing. Engin, Van Dijk et al. (2020) highlight that decision-support tools can influence urban management and planning by:

1. providing real-time dynamic data
2. supporting evidence-based planning decisions, primarily around the long-term strategic planning of urban development
3. facilitating alternative framings or scenarios to address uncertainty in anticipating future conditions.

Workshop participants identified scenario-planning tools as the most effective support for land-use planning decisions to assess risk. Data platforms, including SDTs, integrate decision-making tools, such as scenario analysis. In the West Australian workshop, a participant shared how the government has secured funding through the state climate initiative for the Department of Planning Land and Heritage (DPLH) to trial a scenario-planning tool. The tool was developed in 2019 by the University of Adelaide and is named UNHaRMED, which is short for 'unified natural hazard risk mitigation exploratory decision' support system (see Box 2).

Box 2: UNHaRMED: Unified natural hazard risk mitigation exploratory decision support system Australia

UNHaRMED: Unified natural hazard risk mitigation exploratory decision support system Australia

Developed through the Bushfire and Natural Hazards CRC at the University of Adelaide (Van Delden, Riddell et al. 2019), the system models a range of multi-hazard impacts (fire, riverine flooding, coastal inundation, earthquake) across social, spatial and temporal scales. The tool focuses on addressing end-user needs and allows the user to identify different natural hazards, see their impacts on physical property, and calculate the annual cost of the impact (e.g. rebuilding). The model can be run using different climate change scenarios. The model can also be used to look at different adaptation solutions in terms of cost and effectiveness and identify the risks and trade-offs related to locating future urban development.

The strength of UNHaRMED is that it also offers the opportunity to explore changes in structural elements such as policy and legislation, including land-use planning changes and building codes, as well as parameters such as community education, therefore testing different levels of social vulnerability (Holger, Riddell et al. 2019).

This scenario-planning tool has been trialled by different Australian state governments to support the development of DRR and urban planning policies using a case-study approach. In Western Australia, the aim is for DPLH to be the reference agency for the use of this tool, and to support LGAs in their decision-making by running workshops with parties involved in land-use planning and working collaboratively to evaluate the different hazards. A West Australian state planner told the workshop that the trial period is to work on calibrating the tool to agency needs and to *'develop a product so that we can use it in conjunction with local governments, mainly for decision-making'* (WAW2). The planner pointed out that:

> *At the moment, [the tool] is still quite technical, and from a front-end user, not very user-friendly. So, part of the three-year project is looking at how we can empower people to use it more simply. (WAW2)*

During the Victorian workshop, participants identified an example from East Gippsland Shire Council, where an open-source hazard data platform providing multi-hazard information for individual property assets was developed, which also accounts for climate-change projections.

In addition to providing risk information for all property assets, the East Gippsland Shire is proposing to include a risk assessment of all public and privately owned infrastructure. The reasoning is that communities are not just exposed to levels of risk affecting their property—they are also exposed to the weakest links in local infrastructure. The infrastructure will be assessed from a risk exposure and economic perspective to enable cost-benefit decision-making and reduce infrastructure risk. It is proposed that the new multi-hazard risk-exposure data created will also help inform land planning policy.

These multi-hazard assessment risk tools are currently available and are being used. An existing example is the RiskChanges open-source tool developed by the University of Twente in the Netherlands, in collaboration with the Asian Institute of Technology GeoInformatics Centre (see Box 3).

Box 3: RiskChanges, Netherlands/Thailand

RiskChanges, *Netherlands/Thailand*

RiskChanges is an open-source web-based spatial-decision support tool developed through a collaboration between the University of Twente in the Netherlands and the Asian Institute of Technology, GeoInformatics Centre based in Khlong Nueng, Thailand (Twayana 2023). The tool is designed to support local government in assessing future risks linked to multiple hazards—both natural and human-induced—and to help them identify the most effective reduction initiative. Users can compare current and future risk scenarios and plan alternatives. The tool also allows users to analyse risk for different asset types and spatial characteristics (van Westen, Hazarika et al. 2022). It allows users to leverage their own data and facilitate collaboration between different users (Twayana 2023). The tool includes features such as: 'multi-hazard, multiple assets, a vulnerability curve database, multi-user approach, comparison of risk, and spatial analysis' (van Westen, Hazarika et al. 2022).

4.3 Measuring and communicating risk

According to workshop participants, effective risk communication reflects best practice for creating a shared understanding of risk. Risk-assessment tools leverage data to:

- identify high-risk areas
- predict the probable events of a natural disaster
- assess vulnerabilities in critical infrastructure.

These data help to inform intervention plans and actions aimed at safeguarding communities, and enable public authorities and urban planners to better inform infrastructure allocation in cities by uncovering areas that are more vulnerable than others (Krichen, Abdalzaher et al. 2023; Ling and Thomas 2022; Peixoto, Costa et al. 2024).

During the workshops, the communication of risk to households emerged as a recurring issue in all three states. Participants in the Victorian and West Australian workshops commented that data and information about risk are not forthcoming. They noted that in the final stage of the development process, it is up to the individual homeowners to decide what level of risk they are willing to live with and manage. However, participants also pointed out that the level of risk is not clearly communicated to buyers at the time of purchase, or even later during occupancy. As discussed in Chapter 3, some states—including New South Wales and Victoria—have a mandate that a vendor must disclose any history of a dwelling being affected by a disaster event, or any risk linked to natural hazards exposure affecting the property. Still, there is no established mechanism for risk communication for new dwellings. Research participants overwhelmingly indicated the need for a transparent and consistent approach to risk-informing sharing. Legislation implemented over the last 15 years requires the inclusion of risk information in land titles. Planners attending the workshops identified that mechanisms such as notifications on titles are only effective when new titles are issued—which is at the subdivision stage—because *'the problem with the title is [that] it is static'*:

> *[But] houses have a long life, and there are new buyers and new occupants, and risk is constantly changing. So, how is this even considered? How do people get information in time about the changing risk property? (VICW3)*

Participants in both Western Australia and Victoria called for an *'easily accessible, one source of truth, that people can go to'* (VICW6).

It is not only an issue of where to find the information but also how this is communicated. In the case of flood risk, participants noted that communities often lack the necessary tools and access to information, impacting the understanding and awareness required to make well-informed decisions about their flood risk. Presently, 100-year floodplain maps serve as the primary means of communicating risk. Experts easily interpret these maps, but community members often find them challenging due to complex visuals and technical language (Auliagisni, Wilkinson et al. 2019; Dransch, Rotzoll et al. 2010; Hagemeier-Klose and Wagner 2009). Scholarly literature distinguishes between flood maps designed for experts and those for non-expert users. While experts can navigate complex information, the general public benefits from more accessible and intuitive maps (Van Kerkvoorde, Kellens et al. 2018). All participants in the research highlighted that publicly available flood information across the three states is tailored towards experts and does not assist with effectively communicating risk to the general public. An example that reflects effective communication between the data providers and the public is the pilot project for south-east Texas done by the Institute for a Disaster Resilient Texas (2022) through the development of the damage plan map (see Box 4).

Box 4: Flood Risk Visual: The Damage Plain, Southern Texas (US)

Flood Risk Visual: The Damage Plain, *Southern Texas (US)*

The Institute for a Disaster Resilient Texas (2022) experimented with creating a different way to visualise risk for the community through a 'damage plain' map. This proposed map clearly links the larger geographical scale represented in flood-prone area maps with individual risk levels provided per building, using an index identifying the level of risk each property would be exposed to in a flood event. The pilot tested a 'three layers' digital information map that integrates: i) floodplain maps with ii) floodplain risk maps, estimating the likelihood that a location within a specific area will experience a damaging flood event, and iii) a building's exposure rating where information on the individual building risk exposure is evaluated. This approach can reconcile an assessment of risk probability provided for a flood-prone area with individual risk levels provided per building.

The identification of risk levels plays a key role in effective communication—and also in developing risk mitigation and management strategies. The bushfire attack level (BAL) system is a clear example of this. The BAL system was at times criticised by research participants, with issues raised about the quality of bushfire assessments. Still, there was general agreement from participants that the use of a unified rating tool eases the management of risk and facilitates communication with both proponents of new developments and homeowners. Furthermore, one participant observed that the presence of a clear framework has allowed the system of bushfire risk communication and preparation to continue to grow and innovate.

Regarding rating systems, a Victorian participant identified the work led by the Resilient Building Council (RBC) with the development of the Bushfire Resilience Rating system and app. This rating system measures a home's performance in a bushfire event by combining local environmental risk and housing characteristics (Henderson, Bennetts et al. 2022). This system has been developed by the Resilient Building Council team with the support of the Insurance Council of Australia's partnership with the Green Building Council of Australia on The Future Homes initiative. Research participants saw this rating system developed by the RBC as complementary to the BAL system. They indicated that this type of work could be used to break the barrier of communicating risk beyond the approval stages by targeting existing housing stock—and informing and educating the current dwelling occupants. During the Victorian workshop, a CHP observed that insurance premiums have become the vehicle for communicating risk to homeowners:

> *I think the way people are finding out about [risk] now is by their insurance policies going up. That's the market reality. When they get an increase in their insurance policy next year, that will wake them up that they are actually in a high-risk [area]. (WAW6)*

A clear example of how the processes of risk assessment and rating, data sharing and insurance can work together is demonstrated by the US flood-risk system of Flood Insurance Rate Maps (FIRMs). FIRMs combine the flood hazard data—that is, 100-year flood maps—with a risk-rating system. Flood-prone areas are divided into zones, depending on the hazard level to which they are exposed. This ranking is linked to the national insurance program (Federal Emergency Management Agency [FEMA] n.d.). Moreover, across the US, there are many cases in which state and local governments have partnered with FEMA to improve how to communicate such risks to communities. One example of risk communication that could be embedded into the planning system is the flood risk information system (FRIS) from North Carolina, USA (see Box 5).

Box 5: Flood risk information system (FRIS), North Carolina (USA)

Flood risk information system (FRIS), *North Carolina (USA)*

Following the aftermath of Hurricane Floyd in 1999, the state of North Carolina (NC) decided to prioritise the development of more precise flood maps, and partnered with FEMA (Geneva Association 2020). As part of the project, the North Carolina government assumed the lead responsibility for developing flood insurance rate maps (FIRMs) for the entire state as part of the national flood insurance program (NFIP).

As part of this project, the North Carolina government developed a centralised data portal (FRIS), which is also available to the public. Users can enter a property address to find that property's flood-risk information, including flood-risk categories across a low-risk, medium-risk and high-risk scale base flood elevation; the amount of expected damage to their property in dollar terms split by building and contents; the estimated insurance premiums; potential local mitigation options; and information about how many local monitoring gauges exist in the area. Users can also adjust parameters such as type of foundations or number of storeys to examine how flood risk changes under different scenarios.

In the case of flooding, better risk communication could be achieved using mechanisms like the BAL rating system for bushfires, such as implementing a flood rating system that associates various levels of risk with designated actions for risk reduction. Like the BAL system, the building requirements have the potential to be integrated into the regulatory system through the building codes. Furthermore, building exposure information and risk classes can be linked directly to the estimated cost of insurance based on the assessment system (such as l*ow, high*, or *not insurable*). Both voluntary and involuntary (legislated) actions can be considered as part of the assessment.

Furthermore, the risk-rating system's involuntary actions can be linked to the insurance assessment system, which contributes to reducing the insurance premium (insurance bonus schemes[20] by providers) and/or government-subsidised insurance schemes. The implementation of such a system will require national leadership in financing insurance programs such as those seen in the USA (Perugia, Rowley et al. 2023). This type of intervention has the potential to be used to address retrofitting schemes for current housing stock. Participants in the Victorian workshop identified that *'there is little in the system'* (VICW2) to encourage the reduction of risk through ongoing maintenance, except what is included in residential tenancy regulations.

Effective measurement and communication can also be facilitated through the governance of land-use planning for new housing development. A state planner at the New South Wales workshop pointed out that the governance issues related to flood data could be overcome by leveraging the legislative powers of the newly established Reconstruction Authority. The NSW Reconstruction Authority Act (NSW Government 2022b) delegates to this agency the function to 'coordinate the development and implementation of whole-of-government policies for managing the risk of disasters in the State'. Such coordination includes: *'information provision and exchange'* and carrying out *'flood modelling and the determination of flood planning levels, particularly in relation to high-risk catchments to assist with the development of flood plans'* (NSW Government 2022b).

The agency's authority in overseeing policy implementation and provision of data, linked to its independence—as the Reconstruction Authority is a statutory corporation)—was a strength that could be leveraged to implement a unified framework providing consistent and effective flood management, and risk management at large, at the state level.

4.4 Conclusions

The mapping of the use of data and actor relationships across the different stages of the development process has highlighted the difficulty of the current planning system in harnessing data effectively to support decision-making. This has been identified by the workshop participants as caused by:

1. the lack of quality, accuracy and consistency in hazard data
2. the fast pace of data improvement is not being matched by equivalent responsiveness in revising statutory planning frameworks.

Moreover, from the workshops, it emerges that communities, industry and government actors often struggle to identify and access needed information or adequate digital tools, which impacts the understanding or awareness required to support their decisions. To address these shortcomings, workshop participants identified a need for the introduction into the existing decision-making process of digital solutions that:

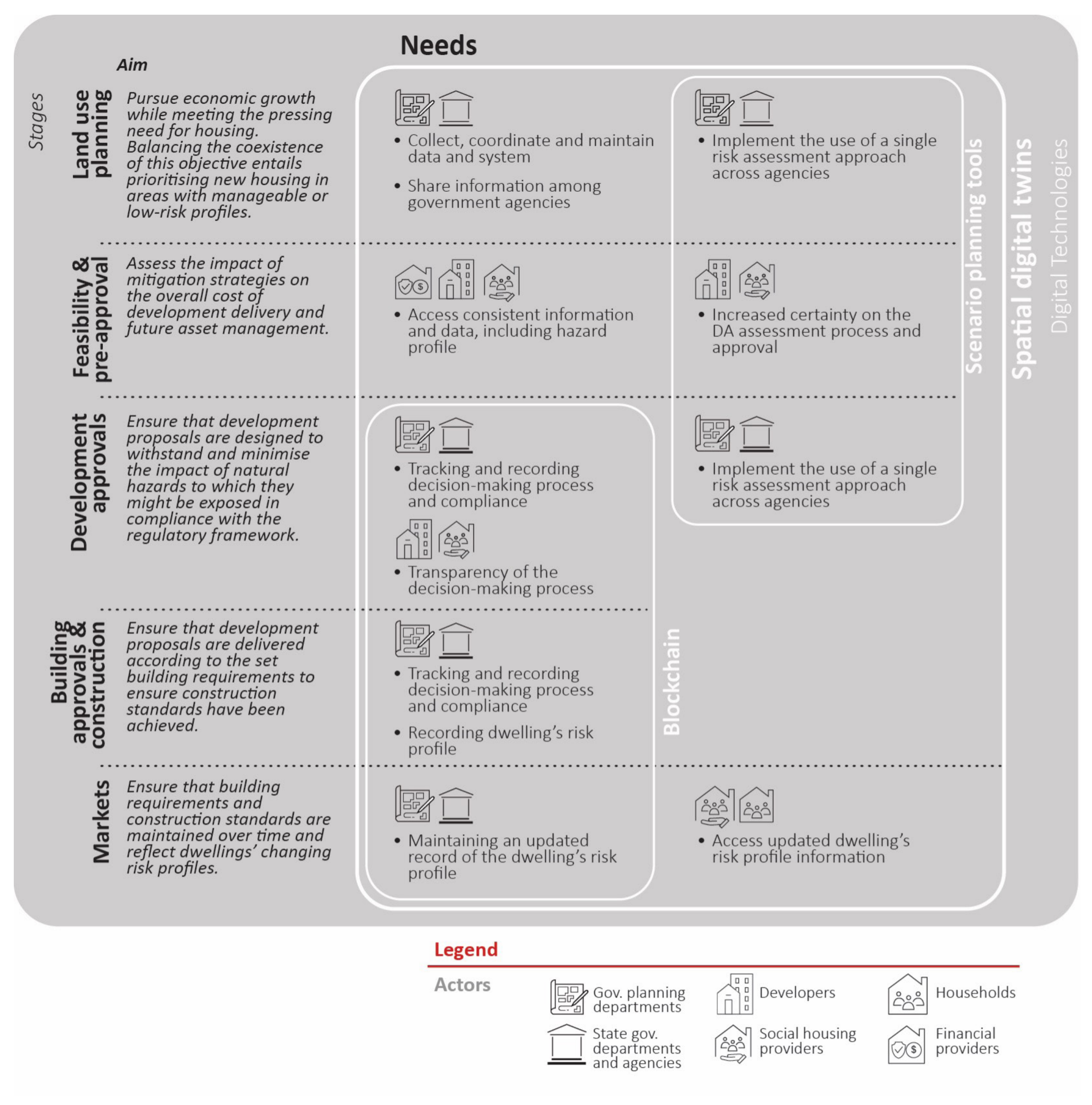
1. support data collection and information-sharing practices
2. efficiently operationalise data through the use of decision-supporting tools
3. facilitate risk communication and disclosure.

20 Discount applied by insurance providers to insurance premiums when certain actions taken to reduce flood risk are implemented.

Participants also identified the need to develop risk-measuring systems for flooding (similar to the BAL system) to support the development assessment process, while also addressing household risk awareness.

Figure 13 summarises the analysis presented in this chapter, and overlays it with a suggested framework for embedding digital technologies in the decision-making related to planning and delivery of housing—including the establishment of housing delivery targets, identification of growth corridors, development assessment and risk disclosure. The diagram identifies the key actors involved at each stage of development (as identified in Chapter 3), links them to their relevant expressed needs, and maps the applicability of proposed digital technologies.

Figure 13: Digital technologies framework



Source: Authors.

The issues of data sharing—the need to have ‘one point access to information’—and the tools to support decision-making and facilitate the planning approval process have been addressed separately.

In particular, data accessibility has been dealt with as a technical issue related to assembling a ‘one-stop shop’ platform for data access. This is true for all types of data-sharing issues and decision-making processes in government settings. Several infrastructures and initiatives have been implemented in a bid to bring data together in different ways. Some initiatives were concerned with the creation of simple data catalogues, and others were based on online georeference visualisation tools that aimed to address user experience, data communication and data accessibility.

Among these initiatives are the Foundation Spatial Data Framework Location INformation Knowledge Platform (FSDF LINK), the Australian Flood Risk Information Portal (AFRIP), or overarching data catalogues such as the Australian Urban Research Infrastructure Network (AURIN) platform and the upcoming Australian Government Data catalogue. However, instead of these initiatives bringing a solution to data accessibility and reducing fragmentation and duplication of information, they have often had the opposite effect, such as the example of flood data discussed in Section 4.2.

In this proposed framework, the use of SDTs is recommended as an overarching spatial data infrastructure (SDI) for the collection and sharing of information across all actors involved in the process, and all stages. This recommendation is made in response to the users’ needs and in consideration of the analysis of the decision-making related to disaster risk assessment and reduction in the development process. SDTs offer the potential for integrating datasets, facilitating data sharing and improving efficiencies in the operationalisation of data in decision-making across the range of stages in the development process (Adade and de Vries 2023).

The Zurich DT platform (see Section 4.1, Box 1) exemplifies the potential of this technological solution—especially the capacity of the platform to be more than just a data storage and visualisation tool. Such a platform provides collaborative digital environments by allowing the embedding of applications aimed at information simplification, and supporting decision-making related to the urban environment, such as apps for scenario-planning tools, development approval processes and urban climate evaluation (Schrotter and Hürzeler 2020).

4.4.1 Policy development

ISSUE

Lack of digital maturity and capacity of the various government agencies involved in land-use planning decisions and development processes

The implementation of the proposed framework (Figure 13) requires that all parties involved have sufficient and comparable digital maturity so that the framework can be fully embedded in the decision-making process effectively and efficiently. Intervention options to overcome the differences in the level of digital maturity among government agencies and professional organisations include the following:

- **Supporting the development of adequate and comparable data governance protocols** to increase data interoperability and operability (refer to Section 2.4).
- **Providing funding for the acquisition of technological resources** to guarantee that all parties involved have adequate hard and soft infrastructure to support the use of the new technology.
- **Planning for and investing in continued digital education.** Provide adequate and ongoing allocation of funding directed at initiatives aimed at increasing and improving current staff digital skills *(upskilling)*. Initiatives aimed at upskilling should prioritise peer-based learning to strengthen collaboration.
- **Plan for talent acquisition and retention** *(capacity building)*.

These interventions aimed at overcoming structural barriers need to be paired with the implementation of **structural strategies**, such as:

- **Collaboratively setting and implementing necessary new protocols** linked to changes in decision-making processes and strengthening collaboration between and within the agencies involved.
- **Appointing a dedicated intra-agencies unit in charge of overseeing the transition.** The main task of this operational unit is to support the setting of digital technologies and oversee their implementation.

5. Policy development options

Australia is increasingly experiencing devastating bushfires, flooding and significant cyclone events. These events have substantial and long-lasting environmental, social and economic impacts on the communities directly affected, as well as a flow-on effect on housing markets. Reducing disaster risk involves addressing vulnerabilities in the existing housing stock linked to natural hazard exposure, and ensuring effective disaster risk assessment in the planning and delivery of future housing stock. This research is concerned with supporting effective disaster risk assessments put in place throughout urban development processes.

Disaster risk reduction starts with better consideration of natural hazard risk in the planning and delivery of new housing. Effective risk assessment requires:

- access to relevant data and information
- coordination across actors and jurisdictions involved in decision-making processes
- implementation of collaborative, transparent and traceable processes within—and collaboration across—government agencies and other actors involved that underpin accountable decisions.

Improving future decision-making processes through better actors and data coordination requires an understanding of how current processes operate, their challenges, and the data needs of the actors involved. Therefore, this research has:

- mapped what data are available, including their accessibility
- charted how data are operationalised (or not) during decision-making by the key actors involved in housing planning and delivery
- identified actors' data needs while exploring opportunities for the delivery of efficient and effective data-sharing platforms and forecasting tools for risk assessment and disclosure.

This concluding chapter reflects on the impact of data in decision-making, provides an overview of the policy opinions discussed in this report, and, in conclusion, identifies where further research is needed.

5.1 The need for better data access, management and sharing

The availability of natural-disaster-related datasets and the use of effective sharing systems and platforms play a critical role in disaster risk prevention (Davlasheridze and Miao 2021; Sheldon and Zhan 2019; Sunarti, Gunawan et al. 2021). Natural-disaster-related datasets provide the necessary information to comprehend the risks and vulnerabilities associated with exposure to natural hazards. Effective sharing systems and platforms enable efficient distribution of this vital information among different actors involved in the process. This ensures that datasets can be collaboratively used to inform decisions around housing planning and development, and the implementation of adequate risk-reduction strategies.

This research has demonstrated the important role of data in assessing and managing risk when planning and delivering new housing. It has also demonstrated that better access, management, and data sharing need to be prioritised to support better disaster risk reduction throughout urban development processes.

For example, the lack of standardisation:

1. leads to inconsistency in data formats and classification methods, which
2. limits opportunities to compare and exchange datasets and analysis results, which
3. hinders collaboration across different sectors and diverse geographical regions, which results in fragmentation of information and decisions.

Across Australia, planning systems are struggling to harness data effectively to support decision-making. This is partly due to the lack of quality, accuracy and consistency in hazard data, and the misalignment between the fast pace of data improvement and the complexity of the planning-policy-development processes. Moreover, the capacity for the outputs of data analysis to shape decision-making is limited by the effectiveness of how information is communicated to (and between) actors.

Overall, the planners, housing providers and emergency management representatives who contributed to this research agreed that effectively addressing the risk posed by natural hazards in urban development depends on the coordination, aggregation, sharing and effective dissemination of information in the context of a clear legislative framework.

5.2 Improving the use of data and digital technologies in the planning and delivery of new housing

Three main areas of intervention need to be addressed to improve data-driven decision-making. These are:

- data governance
- risk management
- digital technology capacity and maturity.

Data governance

The first step in supporting data-driven decision-making is to ensure that the data are of high quality and accessible to all parties involved in the planning and development processes. The establishment of strong data governance is essential. To improve the condition of the Australian data landscape related to disaster-related data—which is currently characterised by data fragmentation and duplication—proposed policy interventions should aim at facilitating data integration, improving data quality and supporting data sharing. Achieving these objectives requires two different types of interventions: (1) addressing technical issues and (2) defining data users' and providers' responsibility and capacity. Both categories of interventions are underpinned by actions aimed at establishing new or improved governance structures.

We recognise that government agencies involved in disaster risk assessment for prevention—as well as those involved in other stages of the disaster management process—already have established data-governing protocols. What we recommend is that these protocols are revised through a collaborative process to facilitate the operability and interoperability of data in order to improve the decision-making process. Table 1 summarises the policy intervention proposed.

Table 1: Data governance: policy development options

Area of intervention — Data governance		
Aims	Objective	Proposed actions
Integration	*Reducing data fragmentation* *Eliminating duplication of information* *Strengthening individual agencies' data governance* *Improving the safety and security of digital environments*	• Establish an overarching governance system that is responsible for clearly mapping and quantifying data quality and availability. Support this by successfully establishing protocols for intervention, and setting parameters for data management to guarantee long-term management of the issues. • The Digital Transformation Agency (DTA) could be the leading agency in the establishment and implementation of this governance system. • Establish a working group comprising state and local-level representatives to support the work of the DTA, whose representatives are responsible for leading and facilitating the implementation of the framework within the government agencies in their state. • Provide financial and technical support to individual government agencies to revise and improve data management, security and privacy policies that address the requirement of established protocols for data, managing duplication and fragmentation and facilitating sharing protocols.
Quality	*Delivering better flood hazard data*	• Establish and enforce national protocols for flood data modelling. • Appoint a single state-based agency or department in charge of water management in Victoria and New South Wales that is also responsible for producing and managing catchment-level flood data. • Develop financial models aimed at providing ongoing funding to sustain ongoing flood hazard data review and maintenance. • Build and maintain technical skills within the state agency in charge of state water management to understand and produce 'in-house' data modelling.
Sharing	*Facilitating sharing and data use across government agencies, and with the private sector*	• Co-design of processes to enable the sharing and use of data across different government agencies and between government agencies and external players, based on a shared established vision and goal of the role of the data-sharing process in relation to DRR. • Strengthen individual agencies' data governance by addressing data management, security and privacy policies.

Source: Authors.

Risk assessment

According to the Australian Constitution, land-use planning falls under state responsibilities, with each state and territory having its legislative framework to govern and manage land. States and territories play a leading role in reducing natural disaster risk through decision-making within the regulatory planning environment. Each of the three states considered in this research has a different suite of policies addressing natural disaster risk assessment and management, with development control and operational policies guiding decision-making for land-use planning, including the delivery of new developments and assessing subdivisions and development approvals.

However, even if there are differences in planning systems and policies across the three states, the research exposed common issues related to risk assessment and land-use planning approvals. Policy options recommended to support planning systems and authorities in addressing their disaster risk assessment and management responsibilities are summarised in Table 2. The suggested action for intervention will need to be contextualised to the local regulatory system in their implementation.

Table 2: Risk assessment: policy development options

Area of intervention — Risk assessment		
Area	Objective	Proposed actions
Legislative reforms	*Increase the agility of planning tools*	• **Implement legal and regulatory reforms aimed at streamlining policy amendments and review processes** to increase the agility of planning tools. This would allow for quicker responses to changing circumstances (such as the availability of new or improved data) through simplifying procedural requirements for policy updates.
	Ensure consistency in risk-assessment approach	• **Amend development process approvals** to create specific and streamlined approval pathways for proposed developments located in areas identified as at-risk. Pathways could be based on the levels of risk the site is exposed to (such as low, medium and high). • **Establish uniform processes of risk assessment** across government agencies and between the government and the insurance industry, including standardised approaches to data used for risk assessment.

Source: Authors.

Digital technology capacity and maturity

For the successful implementation of new digital technologies aimed at facilitating the exchange and analysis of data for decision-making, it is imperative that all government agencies involved achieve comparable digital maturity. Intervention should aim at building capacity by reducing **structural barriers** as well as implementing **structural strategies** that support and facilitate the development and implementation of required new governance structures and protocols. Table 3 provides a summary of the policy interventions.

Table 3: Digital technology capacity and maturity: policy development options

Area of intervention — Digital technology capacity and maturity		
Aim	Objective	Proposed actions
Capacity building	*Improve digital capacity and maturity of government agencies and relevant professional organisations*	• Support the development of adequate and comparable data governance protocols, and establish protocols to underpin their interoperability and operability (refer to Section 2.4). • Provide funding for the acquisition of technological resources to guarantee that all parties involved have adequate hard and soft infrastructure to support the use of the new technology. • Plan for and invest in continued digital education. Provide adequate and ongoing allocation of funding to initiatives aimed at increasing and improving current staff digital skills (upskilling). Initiatives aimed at upskilling should prioritise peer base learning to strengthen collaboration. • Plan for talent acquisition and retention *(capacity building)*.
Facilitating implementation	*Support the transition to new processes triggered by the embedding of new digital technologies in the decision processes*	• Collaboratively set and implement necessary new protocols linked to changes in decision-making processes, and strengthen collaboration between and within the agencies involved. • Appoint a dedicated intra-agencies unit in charge of overseeing the transition. The main task of this operational unit is to support the setting of digital technologies and oversee their implementation.

Source: Authors.

5.3 Final remarks

The effectiveness of data platforms and decision-support tools in DRR is limited to the extent that they are integrated into the decision-making processes.

The use of digital tools to support urban development and policies is still an emerging field, and research aimed at supporting it is still largely concerned with addressing the technical aspects. This project contributes to widening the scope of research related to digital technologies to support decision-making by mapping current decision processes and identifying opportunities to improve digital capacity that responds to users' needs.

However, to help the advancement of data-driven decision-making, further research is needed to:

- evaluate the benefits and issues related to their implementation as part of decision-making in land-use planning and natural-hazard risk-assessment processes
- understand the cost and level of investment needed to develop and maintain a more efficient and comprehensive system for data sharing. Such a system should work within and across government agencies, and also reach out to external actors, including professional bodies and communities.

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Appendix 1: Research methodologies supporting information

Table A1: Summary of interview distribution across industry groups and relevant jurisdictions

		WA	VIC	NSW	AUS
Government planning agencies	*State government*	5	2	3	-
	Local governments	2	3	3	-
Social housing providers	*Government*	4	-	-	-
	Community housing	1	-	1	1
Developers and landowners	*Public*	1	-	1	-
	Private	1	-	-	-
Lenders and insurers	*Banks*	-	-	-	4
	Insurance companies	-	-	-	2
	Total 34				

Source: Authors.

Table A2: Questionnaire response rates by industry group

	n	%
Community housing	2	1.6%
Consultant	12	9.6%
Developer–government	2	1.6%
Developer–private	1	0.8%
Local government–planning	87	69.6%
Local government–sustainability	8	6.4%
Other	7	5.6%
State government–planning	6	4.8%
Total	**125**	**100%**

Source: Authors.

Table A3: Questionnaire response rates disaggregated by state and LGA

	Total		LGAs in the state	LGAs in sample	Proportion
	n	%	*n*	*n*	%
NSW	35	***28***	128	33	***25.8***
QLD	19	***15.2***	78	12	***15.4***
SA	9	***7.2***	68	8	***11.8***
TAS	4	***3.2***	29	4	***13.8***
VIC	24	***19.2***	79	22	***27.8***
WA	31	***24.8***	137	16	***11.7***
Multiple states	3	***2.4***		NA	
Total	125	***100***	519	95	***18.3***

Source: Authors.

Table A4: Workshop participants' expertise and industries by jurisdiction

	Expertise		
	WA	VIC	NSW
Stakeholder group			
State planning	Policy Land-use planning policy	Policy	Policy Land-use planning Housing
Local planning	Planning and policy	Strategic planning	-
Developers–state	Development Management	-	-
Developers–private	Sustainability	-	-
State housing	Data analyst Community engagement	Flood recovery program	-
Community housing	Asset management	Assets and development Strategic project management	-
State emergency	Strategy and policy (Recovery and resilience)	Housing recovery	Strategy and policy (Recovery and resilience)
Lenders and insurers	-	-	-

Source: Authors.

Questionnaire

Page 1

In which state or territory do you currently operate?

Tick all that apply.

- ☐ ACT
- ☐ NSW
- ☐ NT
- ☐ QLD
- ☐ SA
- ☐ TAS
- ☐ VIC
- ☐ WA

What best describes your area of work?

- ☐ Developer – Private
- ☐ Developer – Government agency
- ☐ Community housing
- ☐ Housing – Government agency
- ☐ Local government planning
- ☐ Local government sustainability
- ☐ State government planning
- ☐ State government sustainability
- ☐ Consultant – Planning
- ☐ Consultant – Risk management
- ☐ Other

How many years have you worked in this field?

- ☐ 1–5
- ☐ 6–10
- ☐ 11–20
- ☐ 20+

Page 2

Please note: In the following question, the term DATA refers to:

> *Base layers of locational information relevant to all hazards, including exposure data and fundamental geographic data. Used for a broad range of purposes, including but not limited to analysis of natural disasters;*
>
> *Hazard-specific information on the risks of different disaster types, providing contextual data about the history of events and the risk profile for Australian locations;*

Data on the potential and actual impacts associated with natural disasters, including information on historical costs and damage and the current and predicted future value at risk. (Deloitte 2014: 33)

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Is bushfire/flooding/cyclone risk relevant to the work that you do?

☐ Yes

☐ No

In your role, which of the following data related to bushfire/flooding/cyclone risk reduction and management do you consider when making decisions regarding housing planning and delivery? Choose all that apply, and organise them according to the level of importance in reducing bushfire risk.

Items

Housing mix (at-market, social and affordable)

Site condition and context

Hazard modelling

Scenario planning

Hazard mapping

Specialised technical reports

State government policy

Local government policy

Local government planning schemes

Building codes

Best practice/research evidence

Property developers' insurance

Home insurance

Asset management life-cycle costs

Site condition and context

Essential

Moderately important

Not relevant

Referring to your essential consideration, how well informed do you feel when making decisions relating to these items?

☐ Not well at all

☐ Slightly well

☐ Moderately well

☐ Very well

☐ Extremely well

Indicate your level of agreement with the following statements regarding making a well-informed decision relating to bushfire/flood/cyclone risk.

	Strongly disagree	Somewhat agree	Neither agree nor disagree	Somewhat agree	Strongly agree
I know how and where to access relevant and reliable data to inform my decision process to assess risk.	☐	☐	☐	☐	☐
Available data and information are sufficient for me to assess risk adequately.	☐	☐	☐	☐	☐
I am confident publicly available data and information are updated and of quality.	☐	☐	☐	☐	☐
There is adequate data and information, but these require specific technical knowledge and/or support for me to interpret.	☐	☐	☐	☐	☐
I understand how every stakeholder in the housing planning and delivery process assesses risk.	☐	☐	☐	☐	☐

Did we miss anything? Any further thoughts?

Appendix 2: Data mapping

Table A5: Foundational data: type, sources, custodianship maintenance and sharing platforms

Foundational Data (FD)

> *'Base layers of locational information relevant to all hazards, including exposure data and fundamental geographic data. Used for a broad range of purposes, including but not limited to analysis of natural disasters.' (Deloitte 2014: 33)*

AUS

Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Climate data online *(CDO)*	Provides access to a range of statistics, recent and historical weather observations and climate data.	Rainfall Temperature Weather summary Solar exposure Sea surface temperature	*Tables* *CSV* *PDF* *Graphs* *Maps*	Bureau of Meteorology	Weather stations Australian Data Archive for Meteorology (ADAM)	Varies	http://www.bom.gov.au/climate/data/
Tropical cyclone databases	The database covers all recorded tropical cyclone tracks over the region south of the equator between 90E and 160E.	Data includes: name, type location, pressure, radius wind speed, source	*CVS*	Bureau of Meteorology	Vary. Generally sourced from the region that performed the original best-track analysis.		http://www.bom.gov.au/clim_data/IDCKMSTM0S.csv
Water data online	Allows readers to view and download standardised data and reports.	• Watercourse level • Watercourse discharge • Storage level • Storage volume • Rainfall • Electrical conductivity @ 25°C • Turbidity • pH • Water temperature	*CSV* *Water data transfer Format (WDTF)* *Plain text* *TLM* *JSON*	Bureau of Meteorology	Lead water agencies from each state and territory (full list of data owners)	Most data is supplied daily. Water Data Online updates as soon as new data has been processed.	http://www.bom.gov.au/waterdata/

Table A5 (continued): Foundational data: type, sources, custodianship maintenance and sharing platforms

AUS							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Geofabric *Australian Hydrological Geospatial Fabric*	Registers spatial relationships between important hydrological features, such as rivers, water bodies, aquifers and monitoring points.	Six product datasets: • ***Geofabric Surface Cartography:*** *Surface hydrological features* • ***Geofabric Surface Network:*** *Hydrological features, including stream segments and gauging stations* • ***Geofabric Surface Catchments:*** *Catchment boundaries* • ***Geofabric Hydrology Reporting Catchments:*** *Contracted nodes, contracted catchments and node-link network, including gauging stations.* • ***Geofabric Hydrology Reporting Regions*** • ***Geofabric Groundwater Cartography:*** *Aquifer boundaries, salinity and rocks and sediments at different levels below the surface.*	Esri File *Geodatabase format*	Bureau of Meteorology, Geoscience Australia (GA), Australian National University Fenner School of Environment and Society (ANU), CSIRO, Land and Water	AusHydro V1.7.2 (AusHydro) surface hydrology Dataset Geoscience Australia (GA) ANUDEM streams	Irregular. The product is updated as deemed necessary to reflect changed attribution and new data sources.	https://portal.wsapi.cloud.bom.gov.au/arcgis/home/webmap/viewer.html?layers=ea9f7296abeb49c3a45430cd322400b1
Australian Groundwater Insight	GIS web-based application. Provides non-technical users access to broad-scale standardised national information on groundwater.	Includes information on: • hydrogeological information • licences & entitlements • bore density & ground-water management areas • groundwater levels over time • trends in and recent groundwater levels compared to the long-term average		BoM collates and manages groundwater information as part of its water information role and responsibilities under the *Water Act 2007.*	State and territory water agencies		http://www.bom.gov.au/water/groundwater/insight/

Table A5 (continued): Foundational data: type, sources, custodianship maintenance and sharing platforms

AUS							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Australian Groundwater Explorer	GIS web-based application. Allows visualisation, analysis and download of groundwater information within an area of interest.	Bore locations and data: • *construction logs* • *hydrostratigraphy logs* • *lithology logs* • *groundwater management areas* • *water levels* • *salinity.* Contextual layers: • *river regions* • *elevation* • *surface geology* • *sedimentary basins* • *land use* • *irrigation areas.*	*ESRI Geodatabase* *CSV* *ESRI Shapefile* *KML*	BoM collates and manages groundwater information as part of its water information role and responsibilities under the *Water Act 2007.*	State and territory water agencies		https://reg.bom.gov.au/water/groundwater/explorer/map.shtml
National Groundwater Information System	Spatial database for GIS specialists. Contains a range of groundwater information submitted by states and territories.	Bore sites' information including: • *monitoring* • *irrigation and commercial water use* • *lithology* • *construction and hydrostratigraphy logs* • *2D and 3D aquifer geometry.*	*ESRI file Geodatabase format*	BoM as part of its water information role and responsibilities under the Water Act 2007.	Lead water agency in each state and territory. Water Corporation also provides information for WA.	Annual basis each December following the delivery of updated data by lead water agencies.	Available by request: Australian Groundwater Explorer Some datasets are available as spatial APIs, and accessed from the Australian Water Data Service
Groundwater Dependent Ecosystems Atlas *(GDE Atlas)*	National dataset of Australian GDEs to inform groundwater planning and management. It is the first and only national inventory of GDEs in Australia.	• *Groundwater Dependent Ecosystems* • *Areas of update* • *Inflow Dependent Ecosystems* • *Water management* • *Hydrology* • *Hydrogeology* • *Environment*	*Shapefile* *KML* *File Geodatabase*	Bureau of Meteorology	National assessment. Regional studies; more detailed analysis undertaken by various state and regional agencies.	Regularly updated with regional-scale GDE mapping from state and regional agencies	http://www.bom.gov.au/water/groundwater/gde/map.shtml

Table A5 (continued): Foundational data: type, sources, custodianship maintenance and sharing platforms

AUS							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Water observations *(Landsat)*	Surface water observations derived from Landsat satellite imagery for all of Australia from 1986 to present.	Gridded dataset indicating areas where surface water has been observed using the Geoscience Australia (GA) Earth observation satellite data holdings. *measure: Water Observation Feature Layers (WOFLs).*	*Image*	Geoscience Australia	Derived	Daily	Digital Earth Australia - Public Data NCI - THREDDS
DEA Waterbodies *(Landsat)*	Monitor critical lakes and dams, including hard-to-reach waterbodies in remote areas and on large properties.	*Time series of wet surface area for waterbodies that are present more than 10% of the time and are larger than 2,700m²*	*Image*	Geoscience Australia	Derived	Monthly	Download the shapefile via eCat Digital Earth Australia - Public Data
DEA Water Observations Statistics *(Landsat)*	Gives the information on where water is usually and where it is rarely based on a combination of data from satellite images.	*Multiyear water observation:* *Clear count* *Wet count* *Water summary.*	*Image*	Geoscience Australia	Derived	Periodic	Digital Earth Australia - Public Data
DEA Land Cover	Appropriate to use at the national scale where other, more detailed land cover information is unavailable.	• ***Level 3 and 4 land cover classification*** • ***Lifeform:*** *Detail of vegetated classes, separating woody from herbaceous* • ***Vegetation cover:*** *Measured cover of vegetated areas* • ***Water seasonality:*** *Length of time an aquatic vegetated area was measured as being inundated* • ***Water state:*** *form of the detected water (swam, ice or liquid)* • ***Intertidal*** • ***Water persistence:*** *Number of months a water body contains water* • ***Bare gradation:*** *the percentage of bare soil in naturally bare areas.* Full description Where DEA land cover shows conflicting information to state or local datasets, those datasets should be considered authoritative.	*Image* *Land cover class structure*	Geoscience Australia	Satellite data from Landsat	Annually	Digital Earth Australia - Public Data

Table A5 (continued): Foundational data: type, sources, custodianship maintenance and sharing platforms

AUS							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
DEA Fractional Cover	Landscape observation data enabling measurement of green, brown and bare ground in any area of Australia at any time since 1987.	Four data layers: • *The fractional cover of green vegetation* • *The fractional cover of non-green vegetation* • *The fractional cover of bare soil* • *The fractional cover unmixing error*	*Image*	Geoscience Australia	Satellite data from Landsat	Weekly Product lifespan 1978–2030	NCI - THREDDS Digital Earth Australia - Public Data
DEA Mangrove Canopy Cover	Tracking changes in the extent and canopy density of mangroves.	Canopy cover classes are: • *20–50% (pale green)* • *50–80% (mid green)* • *80–100% (dark green)*	*Image*	Geoscience Australia	Satellite data from Landsat	Annually	Digital Earth Australia - Public Data NCI - THREDDS
DEA Surface Reflectance	Archive of images captured by the US Geological Survey (USGS) Landsat and European Space Agency (ESA) Sentinel-2 satellite programs, validated, calibrated, and adjusted for Australian conditions	Different data packages from different satellites: • *DEA Surface Reflectance* • *DEA Surface Reflectance NBAR* • *DEA Surface Reflectance OA*	*Image*	Geoscience Australia	Satellite data from Landsat and Sentinel-2	As needed	DEA Public Data on AWS NCI THREDDS
Digital Elevation Data	Describes Australia's landforms and seabed	Data packages: Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid GEODATA 9 Second DEM and D8 Flow Direction Grid 2008 Version 3.0 3 second SRTM Derived Digital Elevation Model (DEM) Version 1.0 SRTM-derived 1 Second Digital Elevation Models Version 1.0 SRTMGL1v003-DSM	*Image*	Geoscience Australia	Vary: Federal, state and local government agencies and private industry. Data contributors	Varies	Elvis - Elevation and Depth - Foundation Spatial Data

Table A5 (continued): Foundational data: type, sources, custodianship maintenance and sharing platforms

AUS							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Cadastre	Graphical index of digital cadastre or registered land parcels can be used to reference other geographic and land administrative data available from specific jurisdictions.	Spatial representation of every current parcel of land	*Esri* *Geometry* *Polygon*	DCCEEW	Vary: Federal, state and local government agencies		Layer: CADASTRE_AUS (ID: 12)
Terrestrial ecosystem data	Ecosystem and biophysical data via the TERN Data Discovery Portal	• *Continental-scale gridded remote sensing, soil and landscape products* • *Plot-based soil and vegetation surveillance monitoring data* • *Aggregated state government survey data* • *Calibration and validation data for remote sensing* • *Time-series flux tower, phenocam and acoustic monitoring sensor data*	*Vary: Image datasets*	Australia's Terrestrial Ecosystem Research Network (TERN)	Sensor and federal, state and local government agencies, researchers and private industry.	Varies	CoESRA Cloud-based virtual desktop to run and share experiments SHaRED Data submission, harmonisation and retrieval of ecological data Data Visualiser Discovery, mapping and analysis of landscape-scale ecosystem datasets
Population demographic data and Housing Census	Counts every person and home in Australia. The only source of information about small geographic areas & small population groups across the whole country.	Topics: • *Aboriginal and Torres Strait Islander peoples* • *Cultural diversity* • *Disability and carers* • *Education and training* • *Health* • *Household and families* • *Housing* • *Income and work* • *Location* • *Population* • *Service with the Australian Defence Force* • *Transport* • *Unpaid work and care* • *National reporting indicators.*	*CVS* *EXC*	Australian Bureau of Statistics (ABS)	Collected	5 years	ABS website TableBuilder

Table A5 (continued): Foundational data: type, sources, custodianship maintenance and sharing platforms

Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
AUS							
National location data	GIS information data server combining data derived from satellite and aerial imagery with data from private and public sources, including federal, state and LGAs.	• *Building* • *Solar* • *Surface features* • *Transport* • *Land parcels* • *Postcode boundaries* • *Administrative boundaries* • *Geocoded addresses G-NAF* • *G-NAF core.*	*ESRI Shapefile* *MapInfo TAB* *ESRI Geodatabase* *GeoJSON* *JSON*	Geoscape	Various, including federal, state & local governments	Quarterly	https://geoscape.com.au/data/
NSW							
Water Information Hub	View of river systems, including river flows, dam storages, water availability and weather outlook.	• *Surface water level and flow* • *Groundwater levels* • *Storage level and volumes* • *Surface and groundwater water quality and biological conditions.*	*CVS*	WaterNSW	Monitor and sensors	Real-time data	https://waterinsights.waternsw.com.au/
NSW Foundation Spatial Data Framework	Provides a common reference for the base and spatial FD essential for contextualisation Information.	Categories: • *Administrative boundaries* • *Land parcel and property* • *Geocoded address* • *Transport* • *Positioning* • *Place names* • *Elevation and depth* • *Imagery* • *Water* • *Land cover.*	*Shapefile* *Map* *geocoded information*	NSW Spatial Services (NSWSS)	Vary	As required	https://portal.spatial.nsw.gov.au/portal/apps/sites/#/homepage/pages/nsw-data-themes

Table A5 (continued): Foundational data: type, sources, custodianship maintenance and sharing platforms

VIC							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Water monitoring	Search, discover and download surface water and groundwater (monitoring data).	Site details: • *Water level data* • *Water flow data* • *Rainfall data* • *Water quality (spot data)* • *Water quality (continuous data).*	*Vary*	Department of Transport and Planning (DTP)	Telemetered surface water gauges and groundwater bores	Data less than 1 hour old	**Water Measurement Information System** https://data.water.vic.gov.au/
Spatial datasets	A suite of individual datasets provides a foundation for VIC's primary mapping and spatial information.	Datasets include: • *Administrative boundaries* • *Address* • *Buildings* • *Elevations* • *Hydro* • *Index* • *Property* • *Transport* • *Basemaps* • *Crown land tenure* • *Imagery* • *Topographic mapping* • *Vegetation.*	*Vector* *Spatial tables* *Raster*	Department of Transport and Planning (DTP)	Vary	Varies	Datashare Data.vic.gov.au Digital Twin Victoria Vicmap as a Service Vicmap Topographic Maps online Vicmap Viewer Vicmap Basemaps Image Web Server (for government users only)

Table A5 (continued): Foundational data: type, sources, custodianship maintenance and sharing platforms

WA							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Water information reporting	Data on the quality and quantity of WA water resources.	• *Borehole information* • *Water quality measurements* • *Surface water levels and flow* • *Groundwater levels* • *Rainfall*	Web GIS tool	Dept of Water & Environmental Regulation	On-site collection	Refreshed on a nightly basis.	https://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx
Perth groundwater map	Estimates the depth to the base of the water table (superficial).	• *Depth to groundwater*	Digital map	Department of Water and Environmental Regulation			https://maps.water.wa.gov.au/Groundwater/
Geospatial data services and maps (SLIP)	Curated collections of datasets.	• Administrative boundaries • Topographic mapping • Cadastral • Crown land • Tenure • Address • Geology • Imagery and maps • Infrastructures • Soil • Transport • Terrain • Water	*Vector data (Geodatabases, Shapefiles, GeoPackages, etc.).* *Raster data (aerial and satellite imagery, drone and UAV data, 3D models).* *Point cloud data (LiDAR).*	Landgate	The dataset is created from the data catalogue for specific events, project teams, or particular data themes.	Varies	https://www.data.wa.gov.au/slip

Source: Authors, from references listed in the table.

Table A6: Overview of climate tools and the data available

Tool	Description	Variables	Application ready	View	Download
Regional Climate Change Explorer	View regional summary information about future climate and key messages.	• Mean temperature • Rainfall • Extreme temperature • Extreme rainfall • Drought • Marine and coastal		X	
Climate Analogues	Find locations whose current climate approximates the future climate at your location.	• Based on changes in temperature and rainfall		X	
Summary Data Explorer	View bar plots of multi-model regional-average seasonal changes in eight variables.	• Mean temperature • Maximum temperature • Minimum temperature • Rainfall • Solar radiation • Evapotranspiration • Wind speed • Relative humidity		X	X
Extremes Data Explorer	View bar plots of multi-model regional-average seasonal changes in six extreme measures.	• Coldest night • 1-in-20 yr coldest night • Hottest day • 1-in-20 yr hottest day • Wettest day • 1-in-20 yr wettest day		X	X
Marine Explorer	View gridded maps or tabulated multi-model regional-average changes for seven marine variables.	• Mean sea level • Sea level allowance • Sea surface temperature • Sea surface salinity • Ocean pH • Aragonite saturation		X	X

Table A6 (continued): Overview of climate tools and the data available

Tool	Description	Variables	Application ready	View	Download
Map Explorer	View maps and download gridded projected change and future climate (change applied to historical data) data from eight individual climate models.	• Mean temperature • Maximum temperature • Minimum temperature • Rainfall • Solar radiation • Evapotranspiration • Wind speed • Relative humidity	X	X	X
Time Series Explorer	Interactively view multi-model data as a continuous time series 1900–2100.	• Mean temperature • Rainfall		X	
Thresholds Calculator	View maps and download gridded projected threshold data (e.g. days above 35°C) from eight pre-selected climate models.	• Maximum temperature • Minimum temperature	X	X	X
Climate Futures: Explore Projections	Explore climate projections using a simple Climate Futures Matrix defined by two climate variables.			X	
Climate Futures: Projections Builder	A guided interface to generate application-specific projections data for an impact assessment.	• Mean temperature • Maximum temperature • Minimum temperature • Rainfall • Solar radiation • Evapotranspiration • Wind speed • Relative humidity		X	X

Table A6 (continued): Overview of climate tools and the data available

Tool	Description	Variables	Application ready	View	Download
Climate Futures: Compare Projections	Explore projected changes from multiple sources or emissions scenarios and time periods.	• Mean temperature • Maximum temperature • Minimum temperature • Rainfall • Solar radiation • Evapotranspiration • Wind speed • Relative humidity		X	X
Climate Futures: Detailed Projections	Develop tailored projections, identify representative models and export change data for use in impact assessments.	• Mean temperature • Maximum temperature • Minimum temperature • Rainfall • 1-in-20 yr rainfall • Wind speed • 1-in-20 yr wind speed • Relative humidity • Evapotranspiration[1] • Solar radiation		X	

Source: https://www.climatechangeinaustralia.gov.au/en/projections-tools/ accessed 20 April 2024.

Table A7: Hazard data: type, sources, custodianship maintenance and sharing platforms

Hazard data (HD)

"Hazard-specific information on the risks of different disaster types, providing contextual data about the history of events and the risk profile for Australian locations' (Deloitte 2014: 33).

Flooding

Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
AUS							
Australian Flood Risk Information Portal *(AFRIP)*	Central online location for flood risk information.	Australian Flood Studies Database—the main catalogue that makes up the portal. Flood study information details of the study and associated data.	Digital document *Written report*	Geoscience Australia	State authorities, local councils, consultants and authorised data custodians		https://afrip.ga.gov.au/flood-study-web/#/search
Australian Disaster Resilience Knowledge Hub	Central online location for disaster risk information.	Extensive range of data and research findings on significant historical disaster events.	Digital document *Written report* Images	Australian Institute for Disaster Resilience (AIDR)	State authorities, local councils, consultants and authorised data custodians		Open-source platform https://knowledge.aidr.org.au/
NSW							
NSW Flood Imagery	Provides a reference for flood risk mapping and flood data collection.	Flooding event data is available, including data restricted to NSW government-only users	Map digital	Spatial Services (DCS) (Owner)	Vary		NSW Flood Imagery Viewer
Flood Studies	Provides information on flood behaviour such as depth, velocity and extent across the floodplain. It includes using historical data from past flood events to calibrate a model to estimate flood risk from various rainfall events.	Catchment hydrology: • *flood frequency analysis and run-off routing models* • *Flood flows and volumes modelled at different scales and changes in catchment and climatic conditions.* Floodplain hydraulics: • *Flood behaviour* • *Flood function and hazard across the floodplain and between events at different scales, catchment changes, and climatic conditions.*	*Digital document* *Written report*	Local councils	Vary	Ad hoc	Local government's web pages. **NSW flood data portal** https://flooddata.ses.nsw.gov.au/ **NSW SEED** https://datasets.seed.nsw.gov.au/dataset/

Table A7 (continued): Hazard data: type, sources, custodianship maintenance and sharing platforms

Flooding

NSW							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Flood Risk Management Studies and map	Assess potential management approaches to reduce the impact of flooding.	• *Compiling background information, including flood impacts, emergency management planning, land-use and socio-economic matters, and developing or updating flood damage models* • *Can identify areas where improvements may be necessary to better understand and manage flood risk.*	Digital document *Written report and maps*	Local councils	Vary	Ad hoc	Local government's web pages. **NSW flood data portal** https://flooddata.ses.nsw.gov.au/ **NSW SEED** https://datasets.seed.nsw.gov.au/dataset/
Flood Planning maps		Vary, according to LGA. Data could include: • *1:100 years flood velocity and flow direction* • *1:100 years flood mapping* • *cadastral (property boundaries, rivers, roads)* • *digital elevation models (DEM)*	*Digital document*	Local councils	Vary	Plans should be reviewed at least every 5 years or after a major flood	Local government's web pages. **NSW flood data portal** https://flooddata.ses.nsw.gov.au/ **NSW SEED** https://datasets.seed.nsw.gov.au/dataset/
Environmental Planning Instrument—Flood *(EPI flood)*	Spatial datasets identify parcels of land where development implications exist due to the risk of flood as designated by the relevant NSW environmental planning instrument (EPI).	Exposed layers: • *Flood planning* • *Landslide risk land*	Map digital *ESRI* *OGC SLD* *JSON*	ED e-Planning Department of Planning and Environment	Local government or the NSW Department of Planning, Housing and Infrastructure produces original data inputs according to map and data standards developed.	Since 14 July 2021, councils have been responsible for flood mapping for their local area. So, this dataset may not be the latest version.	**NSW Planning Portal** *Spatial viewer* Or files downloadable via: https://www.planningportal.nsw.gov.au/opendata/dataset/808d0b83-180e-44ac-b6b2-da0cdfc70944

Table A7 (continued): Hazard data: type, sources, custodianship maintenance and sharing platforms

Flooding

VIC							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
FloodZoom	Weather forecast models, satellite observations, river gauges and hydrological modelling to improve flood warning, flood preparedness and flood response activities	Compiles: • flood forecasts • flood mapping • real-time river height gauges	*Web GIS tool* *Map* *digital document*	Department of Transport and Planning	Victoria Flood Database (VFD), flood study reports, Municipal Flood Emergency Plans (MFEPs) and flood intelligence cards. BoM, Melbourne Water and other providers/ services		https://www.floodzoom.vic.gov.au/FIP.Site/Identity/Login Authorised use only. The level of access to data varies according to user.
Flood-related overlay	Planning scheme controls appropriate conditions and buildings' floor levels to address any flood risk to developments in areas prone to flooding.	**Special Building Overlays (SBO)** *identify areas prone to overland flooding* **Land Subject to Inundation** Land affected by flooding associated with waterways and open drainage systems. Such areas are commonly known as floodplains. **Floodway Overlay** Identify land carrying active flood flows associated with waterways and open drainage systems. **Urban Floodway Zone** Land use is restricted to low-intensity uses such as recreation and agriculture.	Map	Councils	Planning schemes.	Council	https://mapshare.vic.gov.au/vicplan/

Table A7 (continued): Hazard data: type, sources, custodianship maintenance and sharing platforms

Flooding

WA							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Floodplain mapping	Flood events for land-use planning, in most cases, the 1 in 100 (or 1%) annual exceedance probability (AEP) flood event (previously referred to as the 100-year annual recurrence interval (ARI) event).	Floodplain Dataset Layers: • *FPM Flood Level Points (m AHD)* • *FPM Flood Level Contours (m AHD) FPM 1 in 100 (1%) AEP Floodway and Flood Fringe Line* • *FPM Extent of Flooding FPM* • *Levee Banks FPM Location of cross-sections FPM 1 in 100 (1%) AEP Floodplain Development Control Area FPM Map Index FPM Bridges* • *FPM Special Development Condition Area FPM 1 in 100 (1%) AEP Floodway and Flood Fringe Area* • *FPM Floodplain Area*	Map digital	Department of Water and Environmental Regulation (DWER)	Digitised hardcopy floodplain mapping, reports, and consultant-provided shapefiles and edited them based on raster models, spot heights, LiDAR contours, and advice from DWER floodplain management engineers.	As required, whenever there are updates (i.e., new and existing floodplain mapping needs to be loaded, amendments and changes, etc.),	https://espatial.dplh.wa.gov.au/PlanWA/Index.html?viewer=PlanWA https://dow.maps.arcgis.com/apps/webappviewer/indexhtml?id=9817b8d31c224846abb68a75478e9cf0 https://catalogue.data.wa.gov.au/dataset/fpm-floodplain-area

Table A7 (continued): Hazard data: type, sources, custodianship maintenance and sharing platforms

Bushfire

AUS							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Digital Earth Australia Hotspot	National bushfire monitoring system detecting high levels of infrared radiation to identify potential fire locations	Reported time, location, power (megawatts), temperature	Digital mapping	Geoscience Australia	Sensors of satellites, including Himawari-9 satellite	Update every 10 minutes	https://hotspots.dea.ga.gov.au/
Amicus	Computer application that enables calculation of expected fire behaviour from burning conditions	Predicted fuel moisture content (FMC), heading direction, rate of spread, fireline intensity	Multi-platform computer application	CSIRO	Key variables: precipitation, air temperature, relative humidity, 10-m open wind speed, fuel load		https://research.csiro.au/amicus/
Spark toolkit	Simulation and analysis of wildfires	Different wildfire spread models based on land cover, fire intensity and arrival time	Text, Image, EsRI raster, ESRI vector NetCDF GeoTiff, GDAL	CSIRO	By user		https://research.csiro.au/spark/about/
NSW							
Bushfire Prone Land *(BFPL)*	Land that has been identified by local council that can support a bushfire or is subject to bushfire attack.	Spatial dataset identifying 3 Vegetation Categories (Cat. 1, 2, and 3) and one buffer zone.	Map shapefile	Prepared by local councils & certified by the commissioner of NSW RFS	Guide for bushfire-prone land mapping	Before the end of the period of every five years after the certification date of the map (section 146 of the *EP&A Act).*	https://www.planningportal.nsw.gov.au/spatialviewer/#/find-a-property/address **NSW SEED** https://datasets.seed.nsw.gov.au/dataset/

Table A7 (continued): Hazard data: type, sources, custodianship maintenance and sharing platforms

Bushfire

VIC							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Bushfire Prone Area (BPA) Map	Maps areas that are subject to or likely to be subject to bushfires.	Inputs used to determine Bushfire hazard level (BHL) areas include vegetation type (fuel) • *Vegetation size* • *Ember protection buffer* • *System Response (BPA, BMO)*	Map shapefile DWG DXF GDB WMS WFS	Department of Energy, Environment and Climate Action	Landscape conditions based on Ecological Vegetation Classes and size, topography, hydrology and roads. Modelled fuels (at maximum fuel hazard/fuel load) for different vegetation types and sizes. Calculations used in AS3959:2018 but adjusted to a Fire Forest Danger Index (FFDI) of 120 and a flame temperature of 1200 kelvin.	The map is reviewed twice a year. The Department reviews sites as requested by developers and councils where development is about to commence.	Vic Plan Tool
Bushfire management overlay (BMO) mapping	Planning scheme provision used to guide the development of land in areas of very high to extreme bushfire hazard.	Protection measures: standard planning permit conditions	Annotated map	Department of Transport and Planning (DTP)			Vic Plan Tool

Table A7 (continued): Hazard data: type, sources, custodianship maintenance and sharing platforms

Bushfire

WA							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Bush Fire Prone Areas 2021 dataset *(OBRM-019)*	Identifies bushfire-prone areas of WA as designated by the Fire and Emergency Services (FES) Commissioner on 11 December 2021.	A bushfire-prone area, as identified by the presence of and proximity to bushfire-prone vegetation; includes both the area containing the bushfire-prone vegetation and a 100m buffer zone around it.	Shapefile GeoJSON Geopackage File Geodatabase	Office of Bushfire Risk Management (OBRM)			https://catalogue.data.wa.gov.au/dataset/bush-fire-prone-areas-2021-obrm-019#:~:text=The%20Bush%20Fire%20Prone%20Areas,015%20and%20OBRM%2D017). https://espatial.dplh.wa.gov.au/PlanWA/Index.html?viewer=PlanWA

Cyclones

AUS							
Cyclone Hazard in Australia *Recurrence Interval 25 Years/ 500 Years*	Evaluate the likelihood and intensity of tropical cyclone winds across the Australian region.	Tropical Cyclone Hazard Assessment 2018 (TCHA18), 10,000 simulated years of tropical cyclone activity in the Australian region, with over 160,000 tropical cyclone events (Arthur 2018).	Map digital	Geoscience Australia	Derived using the Tropical Cyclone Risk Model (TCHA)		https://portal.ga.gov.au/persona/hazards
Wind regions of Australia map	Categorisation of different areas of Australia based on the average wind that each area experiences.	The four regions are: **REGION A:** *'Normal': wind speeds up to 162 km/h* **REGION B:** *'Intermediate': wind speeds up to 205 km/h* **REGION C**: *'Cyclonic': wind speeds up to 238 km/h* **REGION D:** *'Severe cyclonic': wind speeds up to 288 km/h.*	Map	Standards Australia	Derived from the Australian Standards AS/ NZS 1170:2:2002.	Infrequent	NCC 2016 Volume Two Part 3.10.1 High Wind Areas

Table A7 (continued): Hazard data: type, sources, custodianship maintenance and sharing platforms

Cyclones

AUS							
Dataset/tool	Description	Data/Information	Format	Custodian	Data sources	Maintenance	Dataset accessibility
Southern Hemisphere Tropical Cyclone Data Portal	Tropical cyclone tracks in the Australian region dating back to the 1969/70 cyclone season	**Cyclone track points (details)** Pressure (hPa)	Interactive map	Bureau of Meteorology	Based on a 48-year period from the 1969/70 to 2017/18 tropical cyclone season	Infrequent	http://www.bom.gov.au/cyclone/tropical-cyclone-knowledge-centre/history/tracks
Tropical cyclone climatology maps	Maps useful for identifying the regions where tropical cyclones are more likely to occur during El Niño years, La Niña years and neutral years.	Average number of tropical cyclones through the Australian region and surrounding waters in El Niño years, La Niña years, neutral years and using all years of data.	2D array data Gridded ASCII row major, NetCDF	Bureau of Meteorology	Based on a 48-year period from the 1969/70 to 2017/18 tropical cyclone season	Infrequent	http://www.bom.gov.au/climate/maps/averages/tropical-cyclones/

Appendix 3: Survey data

Table A8: Items considered in risk reduction and management in decisions around housing planning and delivery (%)

	Bushfire				Flooding				Cyclone			
%	**Essential**	**Moderately important**	**Not important/ not relevant**	**Not included in list**	**Essential**	**Moderately important**	**Not important/ not relevant**	**Not included in list**	**Essential**	**Moderately important**	**Not important/ not relevant**	**Not included in list**
Site condition and context	77	16	-	7	71	16	-	13	71	24		6
Housing mix	6	36	39	20	7	34	33	27	6	24	59	12
State government policy	72	20	2	7	72	17	1	10	59	29	6	6
Local government policy	49	31	7	14	53	26	5	16	47	29	12	12
Local government planning schemes	64	21	3	11	69	15	6	10	41	24	24	12
Building codes	52	29	6	13	27	43	9	22	77	18	-	6
Hazard modelling	49	32	6	14	69	16	-	15	47	35	12	6
Scenario planning	20	49	12	20	28	44	8	21	24	71	-	6
Hazard mapping	81	9	1	9	84	5	-	11	53	29	12	6
Specialised technical reports	73	15	2	10	73	12	-	15	53	35	6	6
Best practice/research evidence	33	49	3	15	34	41	4	22	35	53	6	6
Home insurance	6	8	65	21	6	11	55	28	24	12	59	6
Property developers' insurance	5	7	65	23	2	10	62	27	12	12	71	6
Asset management lifecycle costs	6	33	38	23	10	24	39	28	24	29	35	12

Source: Authors.

Table A9: Respondents' confidence in data quality, accessibility and decision-making processes (%)

	%	Extremely well	Very well	Slightly well	Not well at all
Referring to your essential consideration, how well-informed do you feel when making decisions relating to these items?	Flooding	5	33	15	2
	Bushfire	8	36	11	1
	Cyclone	12	24	6	12

		Strongly agree	Somewhat agree	Somewhat disagree	Strongly disagree
I know how and where to access relevant and reliable data to inform my decision process to assess risk.	Flooding	24	62	6	2
	Bushfire	40	51	5	1
	Cyclone	18	41	24	6
Available data and information are sufficient for me to assess risk adequately.	Flooding	10	50	21	1
	Bushfire	12	59	10	2
	Cyclone	0	59	12	12
I am confident publicly available data and information are updated and of quality.	Flooding	11	37	23	5
	Bushfire	10	48	17	2
	Cyclone	0	41	29	12
There is adequate information, but requires specific technical knowledge and/or support for me to interpret.	Flooding	19	41	14	5
	Bushfire	18	46	14	3
	Cyclone	12	18	29	12
I understand how every stakeholder in the housing planning and delivery process assesses risk.	Flooding	5	23	32	7
	Bushfire	5	21	39	6
	Cyclone	0	18	35	18

Source: Authors

Table A10: Ranking of items considered in risk reduction and management in decisions around housing planning and delivery (All, LGA officers, and all others)

a. All respondents (unweighted responses)

	Flooding	Bushfire	Cyclone
1	Hazard mapping	Hazard mapping	Building codes
2	State government policy	State government policy	Site conditions & context
3	Site condition & context	Site condition & context	State government policy
4	Hazard modelling	Specialised tech. reports	Hazard mapping
5	Specialised tech. reports	LG planning schemes	Hazard modelling

b. LGA (planners and sustainability officers)

	Flooding	Bushfire	Cyclone
1	Hazard mapping	Hazard mapping	Building codes
2	State government policy	State government policy	Hazard mapping
3	Specialised tech. reports	LG planning schemes	State government policy
4	Site condition & context	Site condition & context	LG planning schemes
5	Hazard modelling	Specialised tech. reports	Site conditions & context

c. All others

	Flooding	Bushfire	Cyclone
1	Hazard mapping	Site condition & context	Building codes
2	Hazard modelling	Specialised tech. reports	Site conditions & context
3	Site condition & context	Hazard mapping	State government policy
4	Specialised tech. reports	State government policy	Hazard modelling
5	State government policy	Building codes	Hazard mapping

Source: Authors.

Appendix 4: Further information

A4.1 Natural-hazards state-planning-policy overview

In general, planning state-based strategic and statutory policies guide development—including housing delivery—in areas at risk of disaster events. They provide a framework under which planning decisions are made at the local government (LG) level. These policies vary in approach according to the state, and also depending on the type of natural hazard considered.

Flooding

State policies addressing flooding across the three jurisdictions vary in approach to risk assessment and mitigation measures according to how the responsibilities of risk management are shared between state and LGAs. Requirements for development control relative to flooding are primarily addressed at the state level in all three states.

New South Wales: The main policy document addressing flooding in land-use planning is the *Flood Risk Management Manual* (FRM manual)[21] (NSW Government 2023). The FRM manual establishes that *'FRM in New South Wales is a partnership across all levels of government […] with local councils being primarily responsible for FRM in their LGAs'* (NSW Government 2023: 6)—aligning with EP&A Act (1979). [22] The FRM manual tasks LGAs with developing and implementing floodplain risk management plans. The FRM Manual works in conjunction with:

- *Ministerial Directions - 4.1 Flooding* established under Section 9.1 Environmental Planning and Assessment Act 1979 (EP&A Act), which articulates where development is not permitted in flood-prone areas;

and

- *Considering Flooding in Land Use Planning guideline* (2021), identifying areas where development control should be implemented (Department of Planning, Housing and Infrastructure [DPHI] 2024).

Victoria: The roles and responsibilities of government agencies and authorities in flood management are set out by the *Victorian Floodplain Management Strategy* (DELWP 2016). Flooding is directly addressed in the Planning Policy Framework under *Sect. 13. Environmental risks and amenity,* in clause *13.03 Floodplains and Sect. 44, Land Management Overlays.*[23] Clause 13.03 establishes objectives and overarching strategies for floodplain management. The overlays identify development controls aimed at minimising flood risks and impacts through the overlay system. These measures are then embedded in local government policies, providing a unified approach to risk management in development.

21 The Manual incorporates the New South Wales Flood Prone Land Policy.
22 The EP&A Act establishes that LGAs are primarily responsible for land-use planning.
23 Several overlays apply to flooding. These are Special Building Overlays (SBO), Land Subject to Inundation Overlays (LSIO), Floodway Overlays (FO), and Urban Floodway Zone (UFZ).

Western Australia: There are two main policies addressing development in flood-prone areas. The first is the *State Planning Policy (SPP) 3.4 Natural Hazards and Disasters*. Sect. 5.2 Hazard Considerations (Flood) of SPP3.4 establishes parameters for when development is acceptable in floodplains, and identifies the 100-year flood data as the standard for defining flood events. The second policy is SPP 2.9 *Planning for Water,* which in Schedule 1 provides the minimum recommended requirement for development in flood-risk areas.

Bushfire

State planning policies addressing bushfire risk identify development controls and requirements that apply to bushfire-prone land. Building requirements are nested within the planning consideration and then layered over.[24]

New South Wales: *Planning for Bush Fire Protection* (NSW RFS 2019) delivers the framework for development assessment provisions and control for bushfire-prone land (BFPL). Section 9.1 of the Ministerial Direction extends the provision included in the *Planning for Bush Fire Protection* document to all planning proposals affecting or located near BPAs, and mandates consent authorities to consult with the NSW Rural Fire Service when assessing such proposals.

Victoria: *Clause 13.02-1S bushfire planning* of the Victoria Planning Provisions (VPP) identifies overarching strategies to guide decision-making to reduce and mitigate bushfire risk in settlement planning. This policy applies in identified BPAs and in areas where the bushfire management overlay (BMO) applies. BMO identifies areas where bushfire hazard is rated high or extreme (DELWP 2019). Hazard data related to bushfires underpinning the rating is developed by DELWP. So, while a BMO provides a unified approach to the planning requirement for areas identified as at-risk—which is similar to flooding overlays—the data underpinning the BMO is state-based.

Mandatory conditions that affect areas where a BMO applies are set in Clause 44.05 of the VPP planning schemes. This clause is completed by Clause 53.02, which specifies design and construction requirements for single dwellings to ensure bushfire risk is reduced to an acceptable level. Such requirements are based on the site assessment approach of the Australian Standard AS 3959-2009 (Groenhart, March et al. 2012).

Western Australia: Bushfire management is addressed in State Planning Policy 3.7—*Planning in Bushfire-prone Areas.* The policy is designed to guide decisions relative to land-use planning and development assessment in BPAs. It is accompanied by guidelines identifying actions to address the objectives and measures for intervention articulated in the policy.

A4.2 Legislative requirements of hazard disclosure in selling properties

State regulations govern the duties and responsibilities of real estate agents. For example, in Victoria, the Real *Estate Agents Act 1980* is consumer-protection legislation that prescribes standards of conduct, protection of users of real estate services, and frameworks for resolution of disputes (Engstrom, Hurst et al. 2023). Each state has its own Real Estate Institute and set of codes of practice and penalties. In Victoria, Consumer Affairs Victoria (CAV) oversees consumer legislation and industry codes of practice, including the real estate industry. The Victorian Civil and Administrative Tribunal (VCAT) has the power to fine, issue penalties, and revoke licences. In addition, real estate agents must comply with other consumer laws. For example, under the Australian Competition and Consumer Commission (ACCC) act, an agent cannot make a false or misleading representation about the sale of an interest in land.

24 Building permits and requirements are discussed in more depth in Section 4.4 'Building approvals and construction'.

A sale and purchase agreement may contain conditions of the contract such as builders' or engineers' reports, pest damage checks, verification that the property is insurable, title checks, and valuation reports. The purchaser must confirm whether the conditions have been met prior to the conditional date expiring. If not, the purchaser may try to renegotiate the price or conditions, or cancel the agreement altogether. An auction process requires that the purchaser has already completed their due diligence prior to the auction and is, therefore, effectively an unconditional contract.

Disclosure statements are also required by the vendor when marketing their house or land for sale. These vary between states and territories and, in most cases, do not compel the owner to reveal all known risks, such as flooding potential. For example, in Victoria, when buying or selling property, section 32C (b) of the *Sale of Land Act 1962* requires a vendor statement to state whether the land is in a designated bushfire-prone area but not whether it is exposed to flooding. In addition, disclosure statements are completed by the vendor, whose motivation is to sell their house, rather than an independent entity such as a council that is likely to have better information about exposure to disaster events that impact property risk. This means that despite the significant economic impact of disaster risk exposure, sellers of residential property may not generally be required to disclose these risks to buyers. Thus, any investigation to ascertain the frequency and severity of the risk is at the discretion of the buyer (Brown, Christensen et al. 2023). There is no requirement for purchasers to elicit natural hazard risk information from state or local government, nor to seek out a consultant to conduct this part of due diligence.

Statutory seller disclosure rules for land operate in most states and territories:

- NSW: *Conveyancing Act 1919* (NSW) s52 A(2)
- Victoria: *Sale of Land Act 1962* (Vic) s32(1)
- South Australia: *Land and Business (Sale and Conveyancing) Act 1994* (SA) s7
- ACT: *Civil Law (Sale of Residential Property) Act 2003* (ACT)

Laws in Queensland and Western Australia also cover disclosure for strata title units. However, all these laws only go some way to requiring sellers to disclose adverse information affecting a property (Brown, Christensen et al. 2023).

Most disclosure rules do not require disclosure of natural hazard risks; where disclosure is required, the information and consequences of non-disclosure vary. In Victoria, a seller is required to disclose the risk of a material fact, including floods or bushfires: *Sale of Land Act 1962* (Vic) 12(1)(d), 12 A and the Material Fact Guidelines issued by the Director of Consumer Affairs Victoria. In New South Wales, this obligation is confined to a five-year period: *Property and Stock Agents Act 2002* (NSW) s52 and *Property and Stock Agents Regulation 2022* (NSW), reg 60.

Eves (2002) states that homebuyers are advised of flooding risk upon conducting a title search on a property in New South Wales. Further, a Section 149 Disclosure certificate will also provide information about flood risk from local authority records. However, as Eves (2002) points out, purchasers must make their own requests to obtain the specific classification (severity) of flood risk that a property is exposed to. Since flooding is an uninsurable event in Australia, this last point is important—as it can mean the difference between a property that a lender is satisfied to issue a mortgage against and one they won't.

A4.3 Factors determining housing vulnerability

Defining vulnerability

Contemporary approaches to hazard risk assessment recognise the importance of vulnerability. However, it was not until the 1979 report of the United Nations Disaster Relief Organization (UNDRO 1979) that vulnerability was included as the third dimension of risk assessment, together with hazard and exposure (Birkmann 2016). What vulnerability entails has changed over time, reflecting a shift in focus from simply physical risk to recognising the complex interactions between social and economic factors and hazards (Limongi and Galderisi 2021; Perry 2018; Zhu, Holden et al. 2021). The first priority of the Sendai Framework for Disaster Risk Reduction (DRR) 2015¬2030 (UNDRR 1015a: 14) establishes a need for policies and actions aimed at DRR and management to be informed by an evidence-based consideration of all risk dimensions—including vulnerability.

In the context of this research, we have embraced the definition of vulnerability identified in the Sendai Framework:

> *Vulnerability is the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards. (UNDRR n.d.)*

The Intergovernmental Panel on Climate Change (IPCC 2014: 5) adds to the vulnerability elements defined in the Sendai Framework: *'a lack of capacity to cope and adapt'*. Moreover, they point out that vulnerability and exposure are not fixed factors, but evolve over time and according to the geographical scale considered. They are also determined by changes to *'economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors'* (IPCC 2014: 67). In summary, vulnerability as an overarching concept, when applied to disaster risk, is concerned with future and potential harm and captures the capacity of a system to respond to the possible impacts of disasters (Wisner 2004).

The concept of housing vulnerability is not uniquely defined. Zhu, Holden et al. (2024: 4) point out that changes in definitions depend on *'who is vulnerable, vulnerable to what (negative outcomes), what drives housing vulnerability (risk factors), and how housing vulnerabilities manifest (measurement)'*. Most often, when referring to housing vulnerability in the context of natural hazards, this is seen through the lens of the physical domain of housing, and described in relation to the capacity of the dwelling to endure the risk linked to hazard exposure (Zhu, Holden et al. 2021). Accordingly, housing provides *'material resources for households to buffer external risks, and those in substandard housing, therefore, are considered vulnerable'* (Zhu, Holden et al. 2021: 2). The social vulnerability component of housing related to disaster risk is mostly discussed in the literature in the context of post-disaster or resilience (Cutter, Barnes et al. 2008; Davies, Haugo et al. 2018; c; Wigtil, Hammer et al. 2016).

Factors

Table A11 presents a summary of the domains according to vulnerability categories. The vulnerability factors emerging from the LR are outlined below.

Structural characteristics

These include the physical features of the dwelling associated with the design and material choice of the building's:

- **structure elements**—foundation, structural frame, floor height, and roof shape and material
- **external envelope**—wall thickness and material, floor finishes.

For all three hazards considered, overall construction quality is identified as playing an important role in determining housing vulnerability.

Housing-type characteristics

Key factors relating to vulnerability include:

- **dwelling type**—including size, number of bedrooms and number of storeys
- **tenure** (Heley, Lloyd et al. 2022: 3).

The majority of literature about dwelling-type characteristics refers to flood hazard risk, while other studies consider housing tenure to be a vulnerability factor. In particular, renting is associated with a higher level of vulnerability. Renters endure acute residential instability as they move to safer areas, as people who were exposed to disaster-related home damage have a higher prevalence of forced moves (Li, Toll . 2023).

Holding a mortgage can also be a vulnerability factor. Homeowners whose homes were damaged by disasters related to natural hazard events—such as floods, bushfires or cyclones—experience increased housing affordability stress (Li, Toll et al. 2023). These households are required to pay their mortgage even when their dwelling has been damaged or destroyed—while also paying temporary accommodation costs (De Oliveira Mendes 2009).

Alternate tenure types, such as mobile home parks (MHPs)[25], are also vulnerable. In the MHP model, residents own their homes but rent the land where the dwellings are located. Rumbach, Sullivan et al. (2020) argue that this housing type is often overlooked. Using the 2013 Colorado flood as a case study, they find that MHPs were exposed to flooding events at a greater rate than housing in general. Moreover, regardless of land tenure, mobile home living also contributes to housing vulnerability to both flood and fire, as these dwellings are not designed to withstand these hazards.

Socio-economic characteristics

Socio-economic characteristics related to housing vulnerability are determined by the community's attributes. Social capital, housing vulnerability and disaster resilience are deeply interconnected. These can broadly be grouped into **socio-economic disadvantage** dimensions such as household composition, minority status, language, disabilities and health indicators. Fraser, Aldrich et al. (2021) point out that literature on vulnerability has stressed that minorities—defined in terms of race, class, gender, health and disability—are disproportionately represented when identifying social groups affected by disasters. Extreme weather events heightened homelessness risks for vulnerably housed individuals, particularly those from low socio-economic backgrounds (Bezgrebelna, McKenzie et al. 2021) and older people, who are disproportionately affected—particularly when it comes to accessing affordable housing.

Moreover, most of the literature in the LR identifies indicators related to social connection, as measured by the strength of social networks. 'Social connection' is included in most of the literature concerning natural hazards, especially the role it plays in post-disaster recovery. Research shows that residents' social capital facilitates collective action, reciprocity and civic engagement independent of social vulnerability (Fraser, Aldrich et al. 2021). The LR also identified **housing financial security** (determined by insurance and mortgage) and **dwelling adequacy** (overcrowding) as determining factors of housing vulnerability to natural hazards.

25 The Australian equivalent of American mobile home parks (MHPs) are manufactured housing estates (MHEs).

Contextual factors

Risk caused by exposure to natural events depends on the interactions between several factors. Context is a multilayered category, with spatial and temporal elements determining unique conditions that contribute to the occurrence of natural events. From the LR, the link between housing vulnerability and context is determined by three main factors:

1. **natural characteristics**
2. **built environment** (human intervention)
3. **meteorological conditions.**

Natural characteristics include the geophysical conditions of the area where housing is located and how its surroundings contribute to determining the impact of natural events. Across the three natural events considered in this report, *topography,* the presence and characteristics of vegetation, and soil condition are shared factors that influence hazards and the level of risk.

Built environment refers to human interventions and decisions. The human-produced contextual factors increasing vulnerabilities are the proximity of the dwelling to the areas at risk, the characteristics of the built environment (including density and spatial arrangement), and the road network.

Meteorological conditions refer to the main environmental conditions related to weather. These include precipitation, wind speed and direction, and temperatures. Climate change increases the frequency, duration, and intensity of weather events (such as droughts, floods, and hurricanes). Such changes in weather conditions increase the vulnerability of individuals, communities, and assets.

Table A11: Housing vulnerability factors

Housing vulnerability factors				
		Flood	Bushfire	Cyclone
	factors	dimension		
Structural	**Structural elements**	Foundation type Plinth level Floor height Floor material	Foundation type Structure material Building materials	Foundation type Structural frame Roof shape Roof cover
	external envelope	Floor and wall construction Wall thickness Windows Doors	Roof shape Windows Doors	Case of the building Walls Windows Doors Joints
	Services	Drainage		
	Quality	Maintenance condition Year of construction	Construction quality	
Type	**Dwelling type**	Building size Number of storeys Mobile homes	Detached vs attached buildings	Number of storeys
	Tenure	Renting Ownership-Mortgage	Renting Ownership-Mortgage	Renting Ownership-Mortgage
Socio-economic	**Socio-economic disadvantage**	Age Gender Employment Population density Cultural heritage Health Income Education	Age Gender Employment Population density Cultural heritage Health Income Education	Age Gender Employment Population density Cultural heritage Health Income Education
	Housing financial security	Insurance Mortgage		
	Social connection	Social networks Engagement Service activities Resource availability	Social networks Engagement Service activities Resource availability	Social networks Engagement Service activities Resource availability
	Dwelling adequacy	Overcrowding	Overcrowding	Overcrowding

Table A11 (continued): Housing vulnerability factors

		Flood	Bushfire	Cyclone
Contextual	**Natural characteristics**	Land cover Green spaces and trees Elevation and topography Slope Geology Soil type Seasonal changes in surrounding water bodies Flood plain area Watershed area	Vegetation condition Vegetation type & characteristics Topography Slope Soil moisture Regional wildfire	Land cover Surrounding condition (trees) Elevation and onshore topography Slope of continental shelf Rate of shoreline changes Coastal geomorphology Relative sea-level change Mean wave height
	Built environment	Planning policy and regulation Residential/areas density Drainage systems/urban water management Distance to rivers Road network	Spatial Arrangement Prescribed Fire Closeness to the Vegetated Areas / Wildland	Built environment density Distribution of build-up Road network Drainage Distance to sea and river
	Meteorological conditions	Flood frequency and duration Flood occurrence frequency Precipitation	Wind speed Wind direction Precipitation Temperature Climate change	Wind speed & direction Precipitation Storm track Temperature Storm surge of sea Combined effects of storm surge and inundation

Source: Authors.

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