

# Future risk framework: understanding tomorrow's risk and what we can do to reduce it

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Unless appropriate mitigation action is taken, disaster risk is likely to increase into the future due to factors such as climate change, population growth, economic development and an ageing population. Consequently, there is a pressing need to think about plausible future risks and how to best mitigate them. This paper presents the future risk framework, which provides a structured, stepwise approach for relevant agencies to explore future risk and what it means for their organisation. The framework consists of four main steps, progressively increasing in levels of insight into future risk, as well as increasing the level of quantification of risk. A key feature of the framework is the incorporation of sense-making and its implementation consists of a combination of participatory approaches and the use of data, information, modelling and analysis. Application of the framework is illustrated for the case study of Greater Adelaide, South Australia, highlighting the approaches used and the level of insight into future risk obtained at each of the four stages. A discussion on the challenges associated with using this insight to mitigate future risk is also provided, suggesting that a collaborative, multi-disciplinary, multi-agency approach is needed to effectively mitigate all aspects of future risk, especially those associated with increases in exposure and vulnerability.

## Introduction

Disaster risk is considered to be a function of three factors: hazard, exposure and vulnerability (Figure 1) (Crichton 1999). Hazard refers to the magnitude and extent of the event (e.g. the magnitude of an earthquake, the extent of a flood), exposure refers to how many people, assets and other things we care about are affected by the event (e.g. how many people are affected by floods, how many houses are exposed to wildfires) and vulnerability refers to the attributes of the

people and things exposed to the natural hazard event in relation to the degree of damage this event will cause (e.g. floor heights in relation to floods, ability of people to escape from wildfires). Consequently, risk only occurs if there is an intersection of hazard, exposure and vulnerability, where the people and things we value and care about are actually exposed to a hazard and the attributes of these exposed people and things are such that damage occurs. This is why hazards are natural, but disasters are not, as disasters only occur when we expose vulnerable people and assets to natural hazards.

As a result of drivers such as climate change, population growth, economic development and an ageing population, all of the factors contributing to risk are likely to increase in the future (Figure 1). However, many countries around the world, including Australia, are signatories to the Sendai agreement, in which it is stated that we will reduce global disaster mortality, reduce the number of people affected, reduce economic loss and reduce damage to critical infrastructure (UNISDR 2015). Consequently, there is an urgent need to think about future risk and what we can do to not only stop it from increasing, but to decrease it in order to meet our stated goals. The need to address future risk now is reinforced by the fact that it has been well established that investment in mitigation (i.e. prevention), as opposed to response and recovery (i.e. cure), is significantly more effective (Rose et al. 2007). In addition, there is a recognition that future risk is a function of decisions made today (Global Facility for Disaster Reduction and Recovery, 2016; Riddell et al. 2019). For example, allowing development in flood prone areas today will result in increased risk in the future.

However, understanding what specific future risks are and what can be done to reduce them is often difficult for organisations responsible for dealing with disaster risk

reduction. This is because there is generally a disconnect between the various factors affecting future risk (e.g. climate change, population growth, economic development) and their impact on local risks, as well as a lack of evidence to justify investment in specific mitigation options. In order to assist such organisations with obtaining a better understanding of the future risks, we present our future risk framework, which consists of four successive steps, each of which assists with obtaining a better and more quantitative understanding of future risk. In addition, thoughts are provided on the challenges associated with reducing future risk.

## Future risk framework

The proposed framework for exploring, understanding and quantifying future risk is shown in Figure 2. As can be seen, the framework consists of four main steps, where each stage builds on the outputs from the previous one. Each stage has specific outcomes that enable a more detailed and quantitative understanding of future risk. Consequently, users can decide how many stages of the framework they would like to implement, depending on the desired outcomes.

The first stage corresponds to the exploration of drivers of future risk, which enables users to develop an understanding of how factors such as climate change and population growth can impact future risk in their particular decision context. The second stage corresponds to the development of plausible future scenarios based on integrating drivers of risk explored in the first stage. These scenarios enable users to develop an understanding of how different future developments can combine and how they can create futures of particular

relevance to develop or test risk reduction strategies. As part of the third stage, the scenarios developed in the previous step are parameterised by determining the relative levels of common factors affecting future risk (e.g. population levels, community resilience, quality of housing stock) for each scenario. This enables users to develop an understanding of how different drivers of change can translate into different values of local risk factors affecting exposure and vulnerability, in particular. The final stage corresponds to the simulation of the impact of the different scenarios on future risk, which is achieved by quantifying the different parameters (risk factors) from the previous stage and quantifying their impact on hazard, exposure and vulnerability (and hence overall risk) over time using the Unified Natural Hazard Risk Mitigation Exploratory Decision support system (UNHaRMED). This enables quantitative information on the spatial and temporal distribution of risk under different plausible future scenarios to be obtained, increasing understanding of plausible future risk profiles and their contributing factors.

At the different stages, a combination of stakeholder input, data and modelling and analysis are used (Figure 2), although the degree of modelling and analysis increases in the latter stages. It should also be noted that although the four stages of the framework are sequential, there are feedback loops throughout the process via sense-making activities, where feedback is sought from stakeholders on whether the outputs from the previous stage make sense or need to be adjusted (Figure 2).

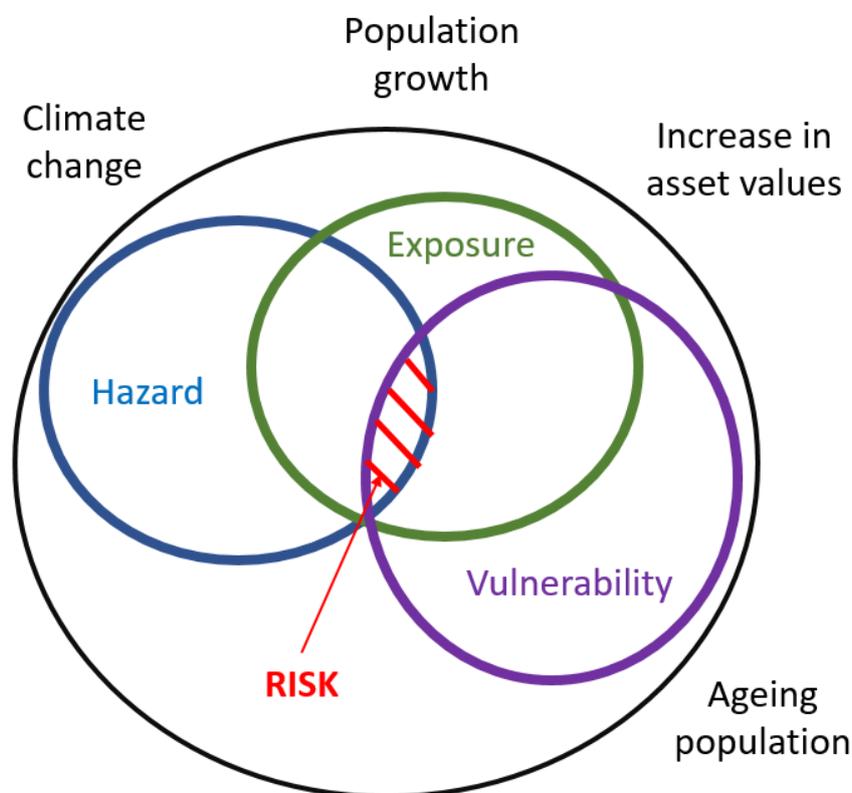
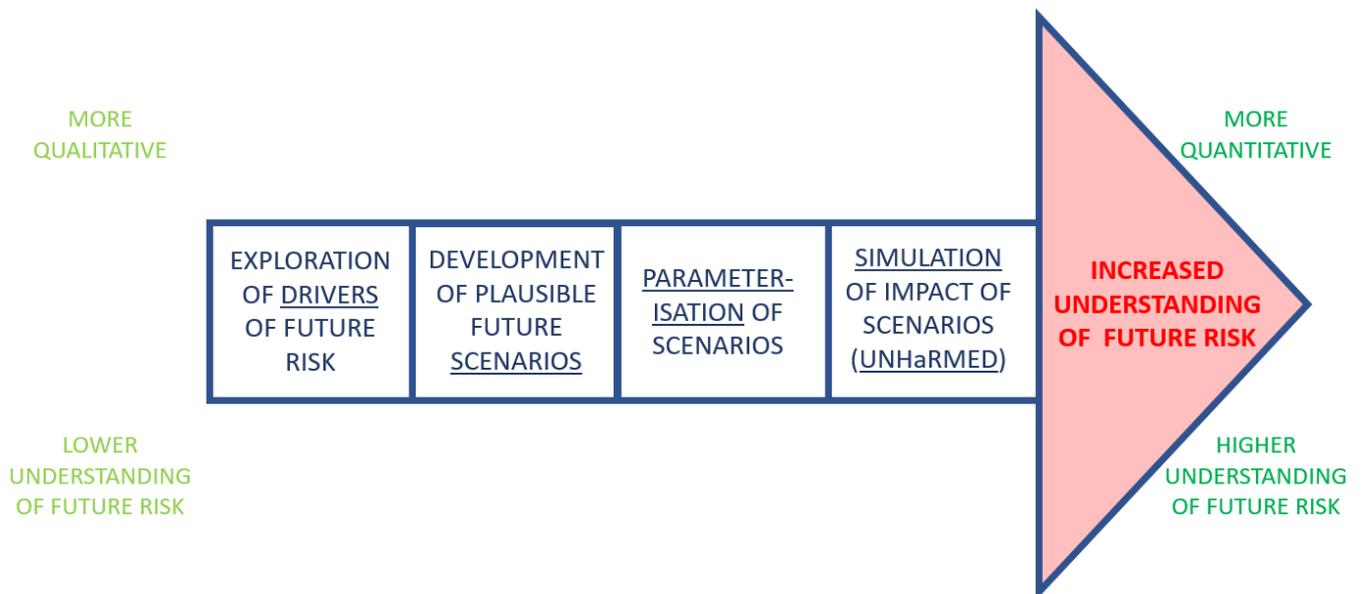


Figure 1: Illustration of risk as the intersection between hazards, exposure and vulnerability and some of the factors that affect future values of these three components, and hence future risk.



**Figure 2: Proposed future risk framework, consisting of four consecutive steps designed to develop an increasing understanding of future risk.**

In the subsequent sections, further details are provided on each of the four stages in the context of a case study application of Greater Adelaide. Adelaide is the capital of South Australia and has a population of approximately 1.3 million. It is prone to a number of natural hazards, including coastal flooding, riverine flooding, wildfires, earthquake, heatwaves and storms.

### Stage 1: exploration of drivers of future risk

While the general drivers of disaster risk, such as climate change, population growth, economic development, changing demographics etc., are well understood, as mentioned above, there is often a disconnect between these generic drivers and how they affect the specific risks disaster risk management agencies have to manage. In order to address this, we have developed an approach that enables drivers of future risk to be explored in the context of the increased challenges to disaster risk reduction organisations could face as a result of the above drivers of change (Riddell et al. 2018) (Figure 3).

As shown in Figure 3, the main mechanisms for disaster risk reduction considered include top-down government intervention and bottom-up community resilience. Some of the factors enabling government intervention include access to adequate data and knowledge, appropriate governance structures, policies and culture and sufficient economic resources and some of the factors facilitating community resilience include access to sufficient resources, appropriate stakeholder knowledge and understanding of risk and sufficient levels of social cohesion.

For the Greater Adelaide case study, participatory processes were used to take stakeholders through a number of structured exercises exploring how various global drivers of change could challenge the factors enabling government intervention and community resilience over time (Figure 4)

This enabled stakeholders to develop a better understanding of how drivers of change could affect future risk in the context of the decisions they have to make.

### Stage 2: development of plausible future scenarios

The outputs from the participatory processes from Stage 1 can be used to develop narrative scenarios that represent coherent storylines of how various drivers of change and their impact on the effectiveness of government intervention and community resilience can combine to represent different plausible futures. For the Greater Adelaide case study, such narrative scenarios were developed to represent five different futures (Figure 5):

- One in which there are low challenges to both the effectiveness of government and community resilience (Silicon Hills)
- One in which there are low challenges to community resilience and high challenges to the effectiveness of Government (Cynical Villagers)
- One in which there are high challenges to community resilience and low challenges to the effectiveness of Government (Ignorance of the Lambs)
- One in which there are intermediate challenges to both the effectiveness of government and community resilience (Appetite for Change)
- One in which there are high challenges to both the effectiveness of government and community resilience (Internet of Risk).

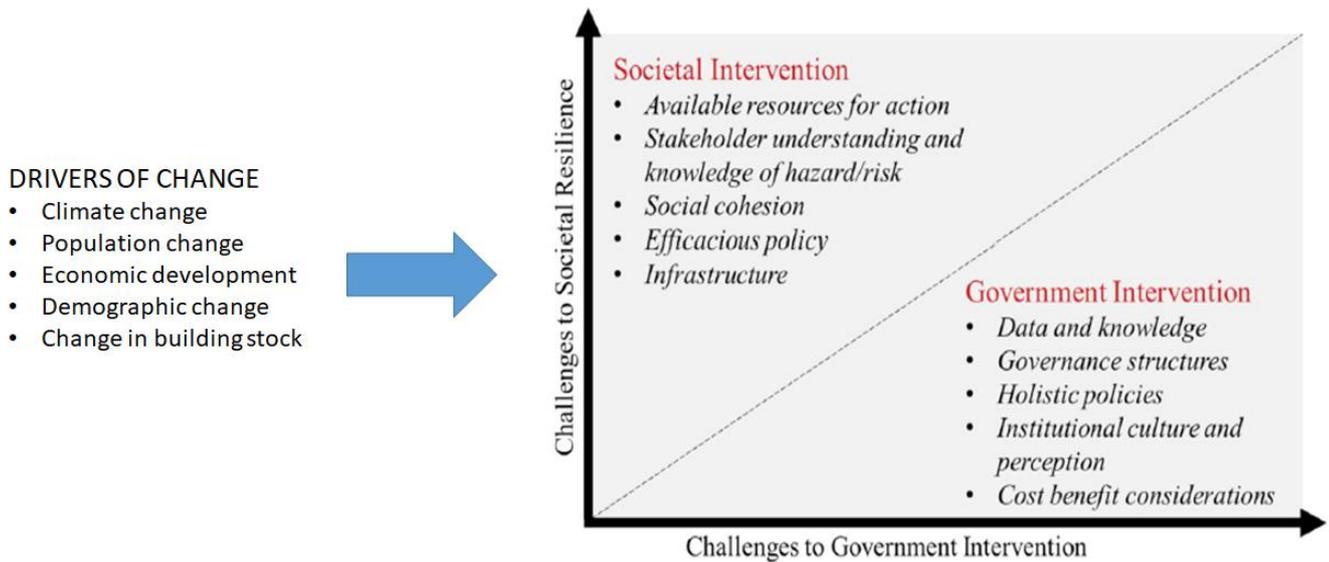


Figure 3: Approach to exploring drivers of future risk in the context of the increased challenges to disaster risk reduction (adapted from Riddell et al. 2018).



Figure 4: Example of output from participatory process exploring how drivers of change impact on future risk in their specific decision context.

By way of example, the coherent storyline associated with the Ignorance of the Lambs scenario is that there is significant population growth in Adelaide, underpinned by a large influx of refugees (e.g. from areas affected by sea level rise or from areas of unrest). Due to their relative poor economic circumstances, these refugees are likely to be settled on the outskirts of Adelaide in housing of relatively low quality and are reliant on government assistance. The resulting long commute times for work and differences in culture and language are likely to limit opportunities for the development of a strong sense of community. In addition, there is likely to be a lack of situational awareness of potential risk factors associated with natural hazards. Consequently, this scenario

corresponds to challenges to community resilience and low challenges to government action. A brief summary of the other four scenarios is given in Table 1, with full descriptions of these narratives given in (Riddell et. al. 2018).

It should be noted that the scenarios are not designed to represent the most likely futures, but plausible futures that stress-test our ability to cope with future risk. In this sense, it is extremely unlikely that any of these scenarios will actually occur. However, they enable relevant government agencies to develop an understanding of how different future developments can combine to challenge / stress their ability to reduce future risk.

Table 1: Summary of motivating factors underpinning each of the plausible future scenarios for the Greater Adelaide case study.

Scenario	Motivating Factor
<b>Silicon Hills</b> <i>Low challenges to resilience and mitigation</i>	Growing valuation of nature and stimulation of tech industries see increase in skills for technology, innovation and R&D.
<b>Cynical Villagers</b> <i>High challenges to mitigation</i>	Downturn in mining and ageing population, shift towards nature and high quality agricultural society.
<b>Ignorance of the Lambs</b> <i>High challenges to resilience</i>	Large immigration to SA from various global areas of unrest. Increasing reliance on Federal Government for funding.
<b>Appetite for Change</b> <i>Moderate challenges to resilience and mitigation</i>	Current projections hold steady, however mid-scenario a series of hazard events leads to increased community awareness.
<b>Internet of Risk</b> <i>High challenges to resilience and mitigation</i>	Increasing reliance on the internet for social and work-related activities decreases community connectedness and resilience.

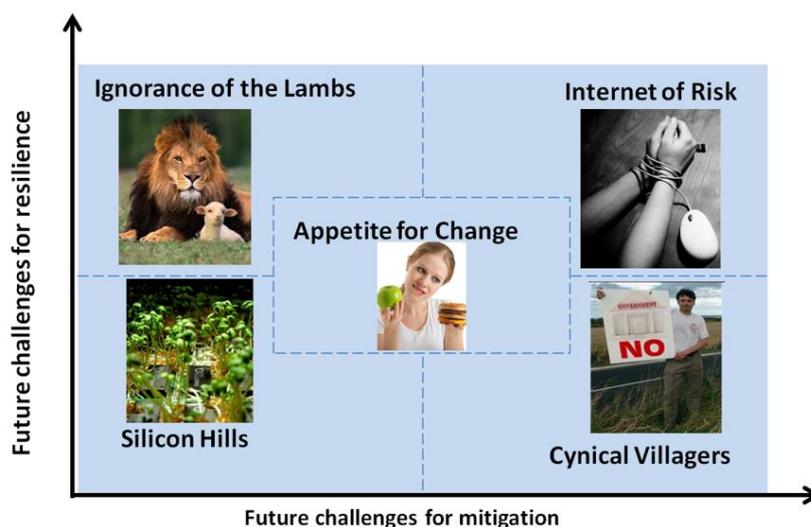


Figure 5: Illustration of the five narrative scenarios / storylines developed corresponding to different levels of future challenges for societal resilience and mitigation (government intervention).

	Silicon Hills	Cynical Villagers	Ignorance of the Lambs	Appetite for Change	Internet of Risk
Population in 2050	1.9 M	1.5 M	2.5 M	1.8 M	1.5 M
Economy					
Community resilience					
Building stock resilience					
Residential land use developments	<i>Gradual growth urban and rural areas</i>	<i>Large increase in rural residential, mixed with other land uses</i>	<i>Residential commuter communities in the hills</i>	<i>Infill, some sprawl on the fringe and rural residential development</i>	<i>Large increase in rural residential</i>
Land use planning					
Education & awareness					
Structural mitigation					

Figure 6: Relative changes in parameters / factors affecting future exposure and vulnerability for the five scenarios developed for the Greater Adelaide case study.

### Stage 3: parameterisation of scenarios

In this stage, the narrative storylines associated with each of the scenarios can be examined to extract the key parameters / factors that change in the different scenarios and the relative degree of change of each. The results of this analysis for the Greater Adelaide case study are shown in Figure 6, which shows the relative changes in population, the state of the economy, community and building stock resilience, the characteristics of residential land use developments, the effectiveness of land use planning, the level of education and awareness and the degree of structural mitigation for each of the five scenarios. This enables agencies responsible for disaster risk reduction to develop an understanding of how different drivers of change can translate into different values of local risk factors, especially those related to exposure and vulnerability.

### Stage 4: simulation of impact of scenarios (UNHaRMED)

In this final stage, the relative changes in parameters are converted to numerical values based on policy documents and other relevant information, and the resulting spatial and temporal impact is modelled using the Unified Natural Hazard Risk Mitigation Exploratory Decision support system (UNHaRMED) (<https://lnkd.in/fhmcpgS>). This will provide a range of quantitative dynamic risk outputs at a spatial resolution of 100mx100m and a temporal resolution of 1 year. For example, the change in residential land use, which is a

component of exposure, between 2013 and 2050, is shown in Figure 7 for three of the five scenarios. The associated average annual loss from bushfires for building stock in 2050 is shown in Figure 8, and the associated change in social impact of bushfires from 2013 to 2050 is shown in Figure 9.

An understanding of the spatial and temporal distribution of different facets of risk under different plausible future pathways provides the first step towards developing appropriate mitigation strategies. It also provides much needed evidence for investment in long-term disaster risk reduction strategies.

### Sense-making

Sense-making is an important component of the overall process to ensure that the information provided on future risk is consistent with prior knowledge. For example, for the Greater Adelaide case study, stakeholders were asked whether the narrative scenarios developed (Stage 2) based on Stakeholder input in Stage 1 were (i) too extreme, (ii) not extreme enough, (iii) internally consistent storylines and (iv) representative of the input provided by stakeholders to ensure these narratives make sense and therefore provide useful insights into plausible future risks (Figure 10). In addition, stakeholders were asked to comment on the realism of the risk maps produced by using UNHaRMED (Stage 4) (Figure 11).

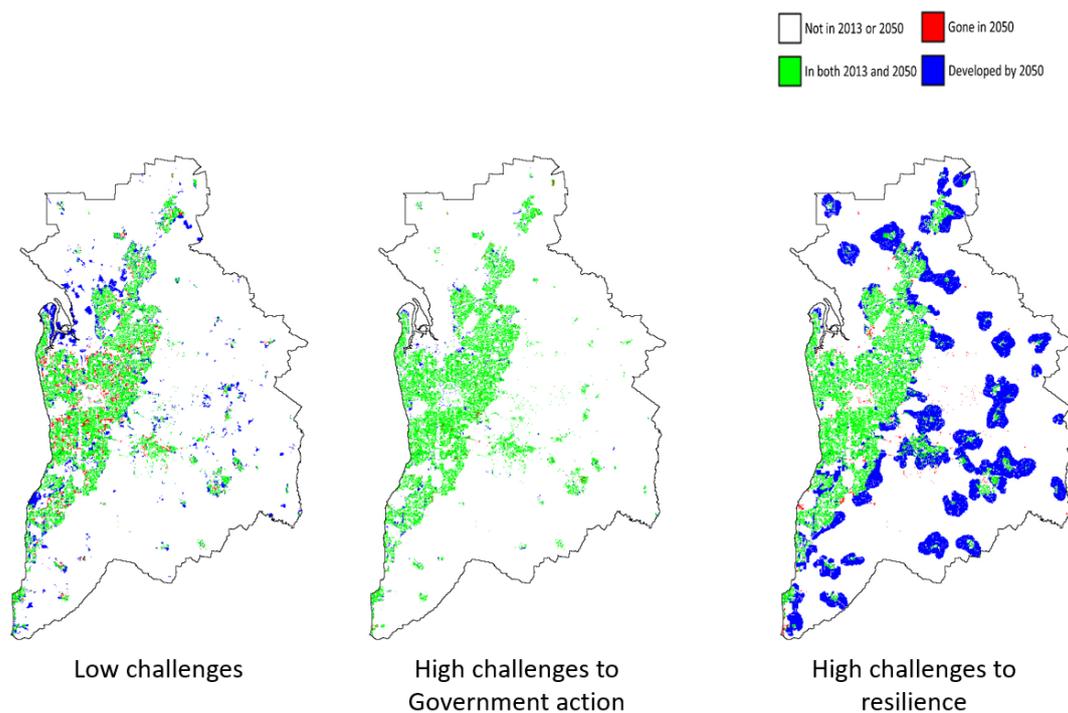


Figure 7: Change in residential land use from 2013 to 2050 under three of the five scenarios considered for the Greater Adelaide case study (Silicon Hills, Cynical Villagers, and Ignorance of the Lambs).

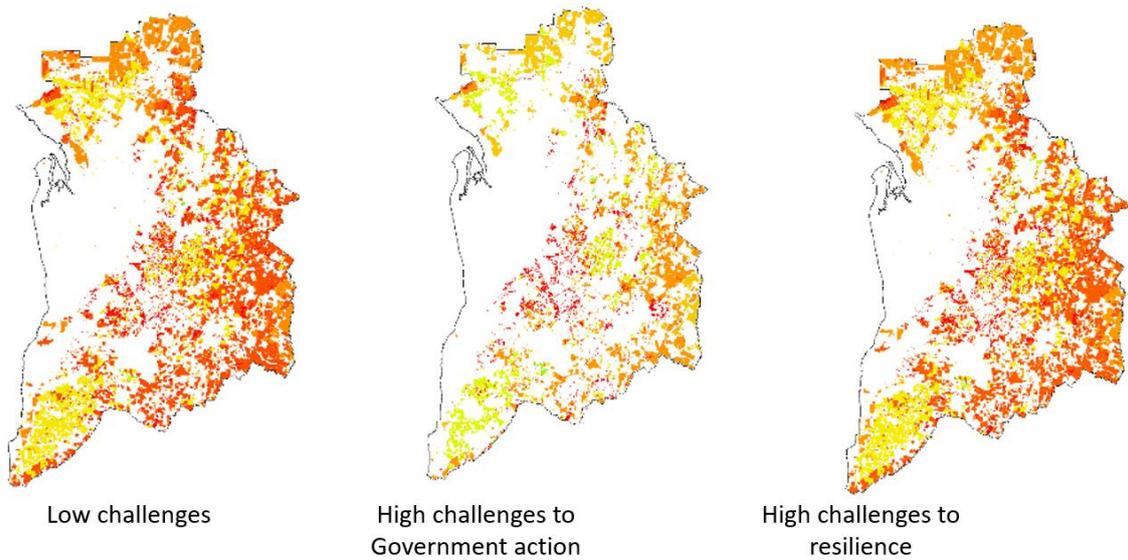


Figure 8: Average annual loss for building stock due to bushfire in 2050 under three of the five scenarios considered for the Greater Adelaide case study (Silicon Hills, Cynical Villagers, and Ignorance of the Lambs).

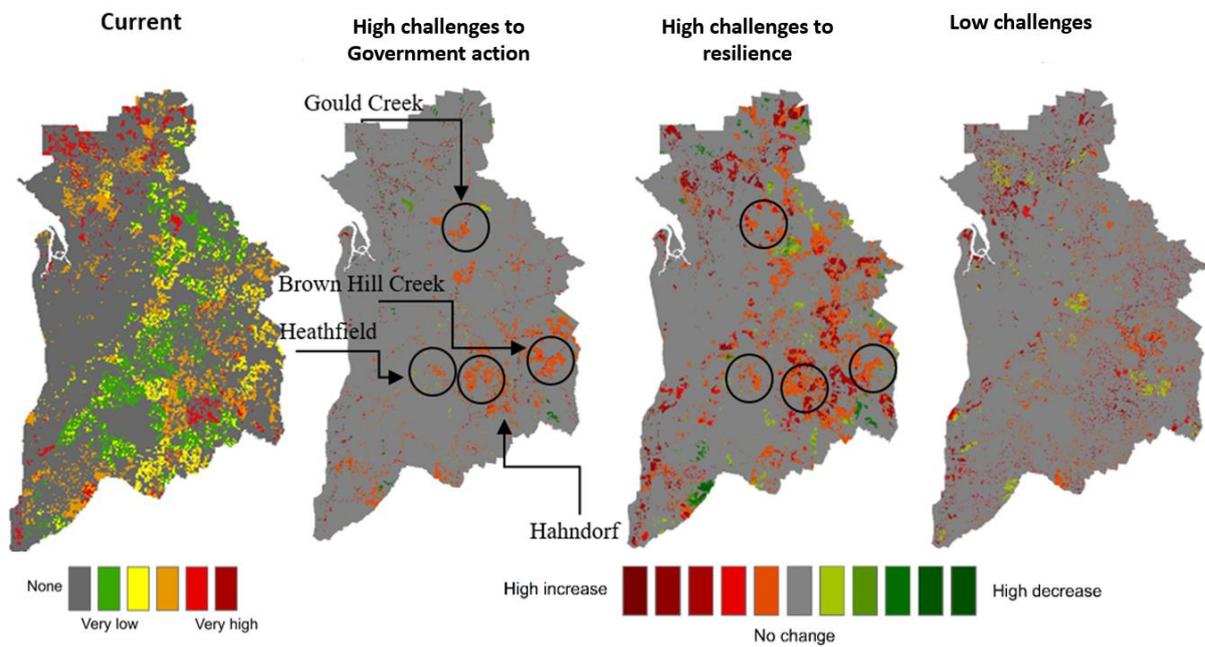


Figure 9: Change in social impact due to bushfire from 2013 to 2050 under three of the five scenarios considered for the Greater Adelaide case study (Silicon Hills, Cynical Villagers, and Ignorance of the Lambs).

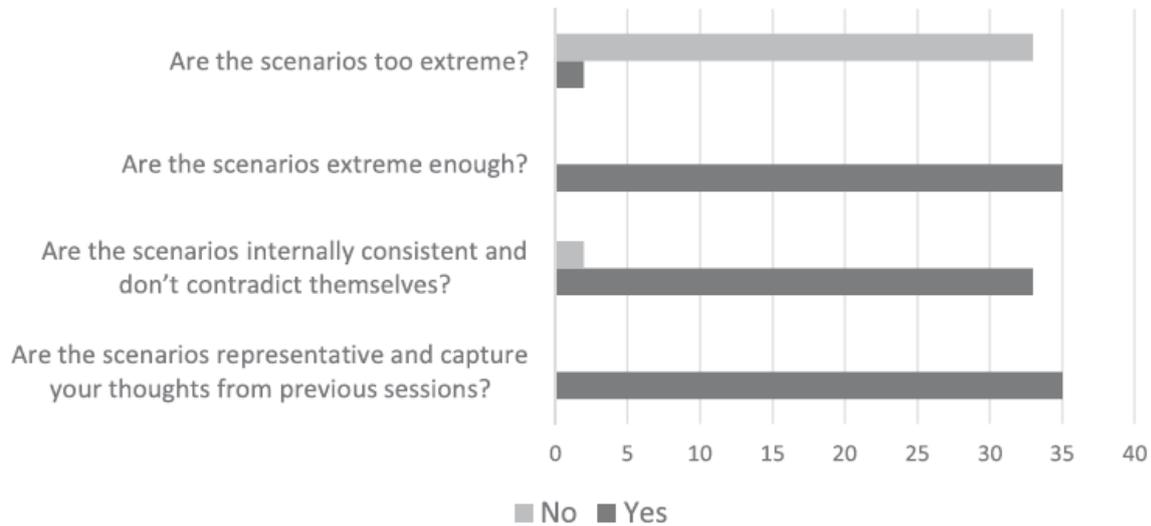


Figure 10: Stakeholder feedback on narrative scenarios developed for the Greater Adelaide case study



Figure 11: Stakeholder feedback on risk outputs from UNHaRMED for the Greater Adelaide case study

### Mitigating future risk

The biggest increases in future risk are likely to stem from increases in exposure and vulnerability, driven by population growth, urbanisation, urban sprawl, economic development and an ageing population. However, there is generally decreased awareness about the impact of these factors on disaster risk, compared with the influence of hazards (Figure 12). This is because these changes are driven by a range of community values, such as the desire for economic prosperity and living in locations with high amenity value (e.g. near the coast or in forested areas), rather than a desire to reduce disaster risk. Similarly, government organisations regulating such developments also have to accommodate this range of often competing objectives, where the desire to reduce future

disaster risk often has a lower priority than objectives likely to result in more immediate benefits (e.g. economic development). As a result, future risk increases almost by stealth, as the increase in exposure and vulnerability over time occurs “naturally” as a by-product of other activities.

As exposure and vulnerability are likely to be the largest contributors to disaster risk, it follows that mitigating these risks by strategies such as land use planning is likely to result in the largest reduction in future risk. However, given that such strategies are not directly controlled by disaster risk reduction agencies (Figure 12), there is a need for a collaborative, multi-disciplinary, multi-agency approach to reducing future disaster risk. The first step in such an approach is the development of a shared understanding of future risk, which can be achieved via the future risk framework introduced in this paper.

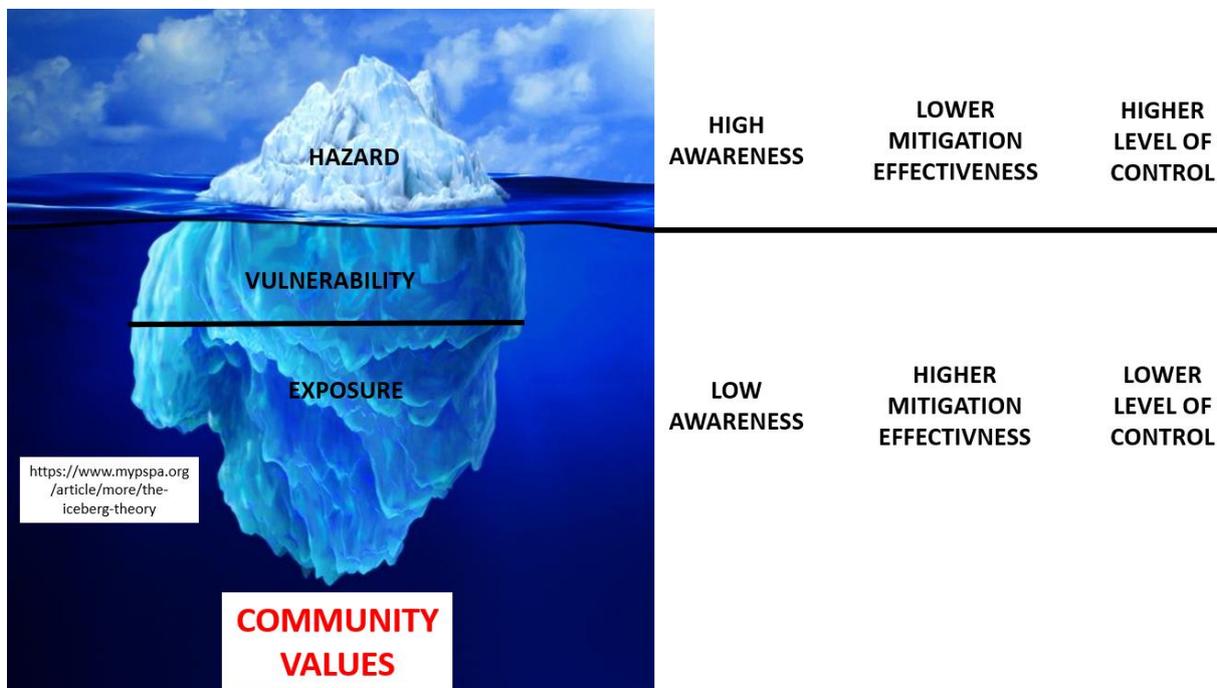


Figure 12: The “risk iceberg”, indicating that there is generally high awareness of the hazard aspect of disaster risk, while awareness of the influence of vulnerability and exposure on disaster risk is generally significantly less, although they are likely to have the biggest influence on future risk.

## Conclusions

Future risk is a function of decisions made today, so we need to understand future risk now. The Future Risk Framework presented here provides a series of steps to achieve this, each increasing the level of insight into future risk, as well as the degree of its quantification. As much of our future risk is related to increases in exposure and vulnerability, which are driven by factors such as population growth, economic development and an ageing population, a collaborative, multi-disciplinary, multi-agency approach is needed to mitigate future risk. The framework presented here provides a means for facilitating this by enabling different stakeholder groups to achieve a shared understanding of future risk and its drivers, which is the first step in enabling such a collaborative approach to be successful.

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